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Michał Suchanek *Editor*

Sustainable Transport Development, Innovation and Technology

Proceedings of the 2016 TranSopot Conference

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Editor
Michał Suchanek
Department of Economics and Management
of Transportation Companies, Faculty of
Economics
University of Gdańsk
Sopot
Poland

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Preface

The TranSopot 2016 conference is a continuation of a long series of conferences devoted to the topic of the transport sector development. The goal of the conference is to exchange views on the current trends in the transport growth and to spread the results of conducted research. The main purpose of the conference is to integrate researchers and practitioners in the field of transport, shipping and logistics. With that point in mind, "TranSopot 2016 Conference: Transport Development Challenges in the 21st century" has been held from 23 May 2016 to 25 May 2016 at the University of Gdańsk, Faculty of Economics. The proceedings of the conference are presented in this book.

The book is divided into three parts, each focusing on different transport aspects: green transport, transport innovations and metropolitan transport. All of these fields are dependent on one another, but they also constitute important separate areas for research. These are the areas on which the research presented in this book is focused.

The area of green transport deals with the strategies for the sustainable growth of transport, both in the urban and rural areas. Different instruments for the internalisation of external costs are presented, and proecological behaviour in transport is promoted along with the increase in the energetic efficiency in transport.

Transport innovations can be dealt with both from the market and technology point of view, and this is also the way in which the researchers cover the topic while focusing on areas such as infrastructure innovations, intelligent transport systems, transport processes and new concepts of transport organisation and management.

Lastly, the metropolitan transport is an important research subject both from the point of view of safe and clean commuting as well as specialised transport areas such as emergency services.

All of those fields are an interesting subject from the theoretical and practical standpoints, and therefore these proceedings may be interesting both for the transport researcher who can find new and interesting aspects of transport research, as well as for the transport practitioners who might get to know new methods useful in planning and managing their enterprises can provide added value. These proceedings can be seen as a review of the transport development challenges in the twenty-first century.

Sopot, Poland Michał Suchanek

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HGV and Maritime Transport Costs—Comparative Study Related to Efficiency and Environmental Issues

Eugen Ferdinand Spangenberg

Abstract Heavy goods vehicle (HGV) is accounted for approximately 20% CO_2 of total GHG emission in the transport sector. The allegedly inexpensive goods transport does not take increasing external environmental cost into account. The latter development undermines European climate targets. Generally, the efficiency of a transport system should take into account all aspects, economic criteria, and also the resource consumption (resource extraction) for the construction of the vehicle and associated carbon emissions (life cycle cost and emissions). The aforementioned points are the objects of investigation. The goals are a transparency of the influencing factors and develop sustainable and equitable transport indicators for goods transport. Optionally it is possible, e.g., to take into account the emission trading scheme (ETS). Maritime transport by feeder or short sea shipping is a main issue of the study comparison with truck transport on the road.

Keywords Sustainable transport · Goods transport · Transport quality index · TQI · Maritime transport mode · Carbon savings

Introduction

Today's goods transport sector is characterized by high share of "heavy goods vehicle" (HGV). Goods transport on road is less expensive and time-consuming than compared to an intermodal rail transport. Growing carbon emissions from transport is the consequence of the increasing truck transport (74% of goods); goods transport by HGV is accounted for approximately 20% CO_2 of total GHG emission in the transport sector. Road transport causes more than 350% CO_2 emissions relative to the maritime transport performance (intermodal). Moreover, the announced relocation (shift) process from road to rail is not yet addressed in a

E.F. Spangenberg (✉)
University of Gdansk, ul. Armii Krajowej 119/121 PL 81-824, Sopot, Poland
e-mail: spangenberg-uni.gda@directbox.com

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comprehensive manner (Marco Polo). Maritime transport by feeder or short sea shipping could be a way out to more sustainability and less GHG emissions in the transport sector.

Nowadays allegedly inexpensive goods transport does not take increasing external environmental cost into account. The latter development undermines European climate targets. Generally, the efficiency of a transport system should take into account all aspects, economic criteria, and also the resource consumption (resource extraction) for the construction of the vehicle and associated carbon emissions (life cycle cost and emissions).

The introduction of an “Emission Trading Scheme” (ETS) system in the transport sector would improve sustainably overall conditions.

Maritime transport by feeder or short sea ships could be an alternative transport mode to more intermodal freight transport and more sustainability and energy efficiency, in regard to certain freight connections in the member states of the Baltic sea region (BSR).

The following detailed investigation includes a full comprehensive survey of current situation on the North Sea–Baltic corridor route (TEN-T project) and illustrates how this can be extended by an alternative maritime transport mode on the future freight market (Fig. 4).

Sustainable Material Consumption Over Time

Consumption of goods and correlated transport services means resource extraction and an equivalent emission footprint. On the one hand, it contributes to the human well-being, and on the other hand it damages the environment overall. Goods transport is a necessary component of the global economy. Transport vehicle itself and the associated construction and the usage later on leads to resource destruction and additional pollution to the environment. Electronic goods, for instance, requires relative much energy for the construction and uses valuable materials, in contrast to simple metal structures which can be recycled. “The solution to a natural resource dynamic optimization problem would be a schedule or time path indicating the optimal amount to be harvested (extracted) in each period (depends on the size of the resource stock)” [1]. The aforesaid implies that an unrestrained mining of resources is not legitimate. Resource stocks in the broadest sense, such as air, water, and minerals, are actually the property of the world community. The amount used today does have implications for future availability and environment condition. Resource stocks can be defined by following formula:

$$\Delta S = S(t) – S(t-1) = G(t) - E(t) \qquad (1)$$

where E (extraction), G (growth), t (time unit); $E(t) > G(t)$, then it is an unsustainable harvest level, means extraction rate cannot be maintained for a long [2] time.

The problem is where should lie the limit level of resource extraction for the present generation, even with unlimited resources, and not to forget emission impact, it is, for example, not advisable to use all known resources in the next centuries, because of the harmful environmental impact. The manufacture of products should be as far as possible sustainable, such as the energy for the production should come from renewable energy sources. The principles of ecodesign should be used, which means optimizing resource and material efficiency. The design should also take into account the following: design criteria, durability, and recyclability of the product (resource efficiency of products throughout their life cycle). The product carbon footprint will be in the future the most important issue, at the latest in the next centuries. Many materials have become scarce, but still these materials' use is not restricted. The task is to analyze the entire product life cycle and product chain; the principles can be extended to all areas, and every action is to investigate in terms of energy and material consumption. The global annual extraction of material resources is constantly increasing, and an overview of the remaining reserves remains unknown. Resource scarcity and climate change increase the risk of violent conflict in the world (IPCC report). The scenario is that prices of rare resources will rise strongly, depending on the depletion time of the resource and the cost of a substitute material. The fact can be expressed by the following relation:

$$\mathrm{sr} \sim b_\mathrm{s}/R_\mathrm{er} \cdot 1/t_\mathrm{r} \tag{2}$$

where sr = scarcity rent,[1] b_s = backstop substitute, relative cost, t_r = relative time of depletion, R_er = extraction rate of resource. Source: own elaboration based on N. Khanna.

The price[2] increase could be exponential over the time, products could not be established as the materials are too expensive and correspond to the today's gold price, exploration requires an immense effort with high energy levels, which is contraproductive in context with the carbon emission target, and the purchase of CO_2 certificates will be very expensive. The scarcity triggers a spiral of cost and leads to a stop of certain products. The goal is to find the optimum allocation of rare resources over time; priority should be given to used recycled material; in each case, the specific energy consumption and associated carbon footprint should be taken into account. First and foremost, we need to conserve resources and should not to consume it to 100%; this should be the commitment toward future generations. For instance, the supply with chromium (stainless steel requires chromium) is very critical. Europe and the USA are import-dependent for chromium. Exploration countries are South Africa, India, and Kazakhstan. Substitutes for chromium do not exist so far. World chromium reserves are about 200 Mt (mill. tons) of contained

[1]Scarcity rent is the cost of "using up" a finite resource marginal opportunity cost.

[2]$P* = P \times \mathrm{sr} = P \times \mathrm{e}^{(r \times t)}$.

chromium compared with consumption of about 5.8 Mt of chromium per year. World reserves are more than 30 times the current rate of world production [3]. In contrast to Dennis Meadow's value of 775 Mt (US Bureau of Mines dated 1970) chromium reserves, means approximately 3 times higher resource stock in 2007. Assuming the reserves of 200 Mt, the following calculation can be stated:

$$u := 0.01 \qquad a := 30$$
$$U1 = 5.8 \times 10^6 \qquad U0 = 2 \times 10^8 \qquad U_a : U1 \cdot e^{U \cdot a} = 7.83 \times 10^6$$
$$\text{Resource} := U0 - \left(\int_0^a U1 e^{u \cdot t} dt \right) = -2.934 \times 10^6$$

where u (growth rate %), a (years, time of extraction), and $U0$ (resource stock tons). Resource exhaustion of chromium. Source: own elaboration and Mathcad calculation.

This means a maximum projected growth rate of 1% per year, which is relative low for this crucial resource. The above calculation shows very impressive that all reserves are exhausted after 30 years at the latest. The recycling of chromium from waste material is very important and could help to extend the date of depletion.

A much more sustainable resource extraction would be a growth rate of −3%, which increases the availability of chromium resource for a longer period, in the above case for 35 years and 74 mill. tons (37%) left reserves in the year 2050.[3] Prices should rise and also the incentive to recycle material, what is necessary to close the inevitable demand gap. Below the corresponding calculation results:

$$u := -0.03 \quad a := 35 \quad U1 = 5.8 \times 10^6 \quad U0 = 2 \times 10^8 \quad U_a = 2.03 \times 10^6$$
$$\text{Resource} = 7.431 \times 10^7$$

Above resource conservation of Chromium for a longer period.

Source: own calculations by using Program Mathcad.

The recycling of the material is less energy-intensive[4] than in comparison with starting further intensive exploration with the intention to discover new mines. Latter activity leads to corresponding high carbon emissions (6.5 kg CO_2/kg chromium) and not at least to environment destruction of the earth's crust.

The movement "Cradle to Cradle"[5] and their ideas change the way to make things. Product innovation is the challenge for the coming industry, to set new design principles. More and more product designers and manufacturers use the

[3](5.8 Mt (2015) and (2050) 2 Mt p.a).

[4](0.15 kg CO_2/kg (carbon emission/kg), Ref.: Environment Agency).

[5]C2C, Products should be sustainable-sourced and suitable for reuse and recycling at the end of the life span.

criteria of the C2C philosophy. The message is "conserving resources through continuous product cycles, increasing use of renewable energy, and to use improved energy and water efficiency, which has a positive impact on ecosystem" [5].

The current economy system hardly supports these principles and material resources with regard to the C2C criteria, in most cases are not assessed. The product development chain and their effect is disputed, in particular manufactured products in undeveloped countries generally does not meet C2C criteria. Companies and consumers should receive full reliable information (labeled) about the products they purchase. Each person in Europe has a carbon footprint of around 15 tons per annum and a material consumption nearly of 10 tons p.a., such as 50 DIN A4 pages emits 1.0 kg carbon [6]. A tour by a middle-class petrol car is equivalent to 400 g carbon emission per kilometer, including fuel supply chains and manufacture of the car [7]. Following vehicles cause an environment CO_2 footprint at different levels:

- Middle-class car 17 (t)
- Heavy SUV 35 (t)
- Heavy duty truck 135 (t)
- Container ship (1000 TEU) 10.000 (t).

Figure 1 shows the dependency of product grading and corresponding equivalent carbon emissions (CO_2e kg/kg). The highest value with 14 kg CO_2 per kg vehicle weight for a Land Rover Discovery type 3L V8 340PS, the smallest for Citroen C1 with 6 kg CO_2/kg car weight. The specific truck footprint is between high technical vehicles (SUV) and standard cars such as the car C1 (Citroen). Ships are in the main "steel box" with relative small section for the engine part. Vessels have in principle a high share steel and can be well recycled at the end of the life span.

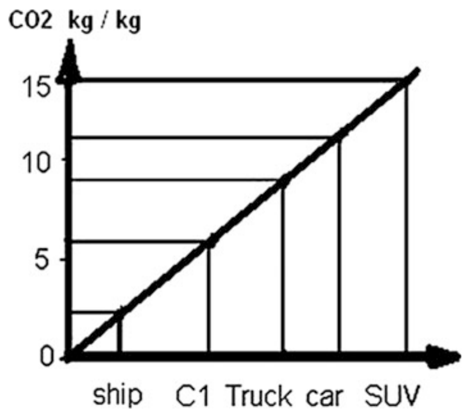

Fig. 1 Different vehicle construction footprints CO_2e kg/kg resource material (by own estimations based on The Guardian 23.09.10 own estimation for c-d based on material approach and Environment Agency database). *Source* Own elaboration

Transport Quality Index (TQI)

In relation to a sustainable transport, in addition to the economic cost, the indirect costs due to environmental stresses should be taken into account. The problem is the costs for environmental destruction; on this, there is no international agreement. In the EU, transgressions by CO_2 emissions are punished with penalties; in reality, this issue is discussed very carelessly. In the future, this topic can and must enter in foreground. A first step has been made already, such as the intention to shift traffic from road to rail; however, nowadays the implementation is not very ambitious. The option to more ship transport was not so far considered. There is probably a deficit in knowledge about this subject. The advantages and disadvantages to relocate transport from road to the rail were already discussed in many ways. In the following, the focus is therefore the shift of freight from road to maritime (open sea ship) transport mode.

It is an economic and an environmental concern to seek for an alternative transport solution which is less harmful. The great challenge is to identify a better solution[6]; the result should be a normative analysis, which is useful in many aspects and can be used by different institutions in the transport sector for comparative studies.

The problem is to operationalize through the creation of relevant indicators; it is possible to evaluate at the level of social well-being or with market-based instruments, where the latter is preferred in the following solution.

It can be defined a "Transport Quality Index" (TQI) on the basis of a particular transport performance and associated environmental "valued cost" and usual economical cost. The new TQI value can be expressed as according the following equation:

$$\mathrm{TQI} = \frac{(\text{Transport Performance})}{(\text{Economic} + \text{Environm Costs})} \tag{3}$$

where Transport Quality Index (tkm/Euro), Transport Performance (tkm/dt), Environmental Cost (Euro/dt), Economical Cost (Euro/dt) dt = time.

Source: TQI value is elaborated and defined by the author.

Using the above equation, different transport modes can be compared with regard to economic and environmental aspects. Intermodal container transport can be calculated for each mode and summarized.

Proportional infrastructure costs, social costs, such as the loss of land, were not included (noise, habitat loss). Also material extraction costs were not taken into account, and there is still no secured database for this. But, it can be assumed that the specific material extraction for the transport by road is minimum threefold

[6]Baltic Transport Journal Clean Shipping Index is already introduced and compares ships in a database Partners: Maritime BTJ 3/2013 www.cleanshippingindex.com.

higher than that for the ship transport, which means that the benefits would be even greater for the maritime transport sector.

Future additional mandatory internalization of external costs can be taken into account, e.g., noise, pollution, etc. as weighted evaluation, if desired.

In the following is a TQI assessment performed (Table 1).

The new building price for a containership is less than 20 million Euro (USD 21–22 mill.). The daily capital cost is about 4834 Euro (0.09 cent per tkm), and the equivalent costs for a truck (0.2 mill. Euro) is about 0.30 cent/tkm. Also, the specific operating costs for trucks are much higher (1.12 cent against 0.16 cent/tkm). Specific carbon emissions (g/tkm) for trucks are 3.6-fold higher than those for comparable containership transportation; in the estimation are taken into account all emissions for construction and production such as provision of fuels (Table 2).

Table 1 Calculation transport quality index (TQI) 1 part

	SHIP		TRUCK
1 USD~1,1 Euro	mill USD		mill Euro
	Build-Cost		Purchase
			Price
Cont-ship 1000TEU	20	Heavy Truck	0,2
Emission CO2 g /tkm TTW	12,75	Emission CO2 g/tkm TTW	45
payload tons	12000	payload tons	20
	0		0
Emission CO2 tons p.day	66,1		
Fuel consumption tons/day	21,0	Fuel consumption liter p.day	420
Fuel price MGO LS 0,1	500	Fuel price Road Diesel	1,25
Fuel costs p.d. Euro	11577,3	Fuel costs p.d. Euro	577,5
Fuel costs cent p.tkm	0,2233	Fuel costs cent p.tkm	2,41
Euro p.d.		Euro p.d.	
Capital-Cost p.d.	4834	Capital-Cost p.d.	71
5% 20 years		5% 10 years	
Capital costs cent p.tkm	0,0932	Capital costs cent /tkm	0,30
Operating cost p.d.	8219	Operating cost p.d. Euro	268,49
		(Serv+Wage+Hotel+Insur)	
Operating costs cent p.tkm	0,1585	Operating costs cent p.tkm	1,12
Ship Construction footprint		Truck Construction footprint	
Containership 1000TEU		40 t MAN D38 640PS	
Lightweight tons	4000	Lightweight tons	15

Source Own development

Table 2 Calculation transport quality index (TQI) 2 part

Transport by containership		Transport by HGV	
Ship construction footprint		**Truck constr. footprint**	
factor CO2 steel plate material	1,66	factor CO2 steel plate	1,66
weight steel tons	3000	weight steel tons	8
CO2 tons	4980	CO2 tons	13,28
engine tons	200	engine tons	1,5
factor CO2	12,5	factor CO2	75
CO2 tons	2500	CO2 tons	112,5
Fitting tons	30	Fitting tons	0,5
factor CO2	6,5	factor CO2	6,5
CO2 tons	195	CO2 tons	3,25
GRP tons	10	GRP tons	1
factor CO2	3	factor CO2	3
CO2 tons	30	CO2 tons	3
Summation CO2	7705	Summation CO2	132,03
Add %	30	Add %	5
CO2 tons footprint	10016,5	CO2 tons footprint	138,6
		Usage factor	0,5
Ship in operation years	15	Truck in operation years	10
Distance km	2000000	Distance km	2190000
Constr. footprint CO2 g/tkm	0,42	Constr. footprint CO2 g/tkm	3,17
Resource Extraction	nn	Resource Extraction	nn
WTT		WTT	
Fuel footprint g/tkm	2,805	Fuel footprint g/tkm	9,9
Habitat Loss / Noise Pollution	nn	Road Tax	nn
Kiel Canal charge	nn	Habitat Loss / Noise Pollution	nn
Port charge	nn	Road Infrastructure	nn

Sustainability Criteria	15,97	g/tkm	Sustainability Criteria	58,07	g/tkm
Economic Criteria	0,48	cent p.tkm	Economic Criteria	3,82	cent p.tkm
Freight capital cost Euro /t/d	0,55	Euro /t /d	Freight capital cost Euro /t/d	0,55	Euro /t /d
Trip (day) km	432		**Trip (day) km**	1200	
Average speed km/h	18,00		Average speed km/h	50,00	
Detour Factor	1		Detour Factor	1	
Number of (ships)	1		Number of Trips/vehicles	216	
payload / Trip	12000		payload / Trip	20	
Transport Performance tkm/d	5,184E+06		Transport Performance tkm/d	5,184E+06	
	tons/d CO2	**82,80**		**tons/d CO2**	**301,01**
	Euro p.d	**31230**		**Euro p.d**	**200438**
TQI-Solution			**TQI-Solution**		
	tons/d CO2	**82,80**		**tons/d CO2**	**301,01**
ETS Euro /t CO2		**70**	ETS Euro /t CO2		**70**
ETS Costs p.d. Euro		**5796**	ETS Costs p.d. Euro		**21071**
	TQI =	**140** tkm p.Euro		**TQI =**	**23** tkm p.Euro

Transport by containership | Transport by HGV

Source Own calculation

In summary, the analysis has shown clear advantages for the transport by sea ship. The shipping is with regard to the cost-effectiveness and sustainability, the better solution.

The calculation for the TQI has following results, taking into account the carbon certificate cost of Euro 70 per tons:

(1) For the containership transport 140 tkm/Euro.
(2) The corresponding value for road transport is 23 tkm/Euro.
(3) The transport cost by road is more than sixfold higher than that for a ship transport.
(4) Carbon emissions of truck transport is 3.7 higher compared to ship alternate.
(5) Freight capital costs are three times higher for ship transport.
(6) Increase in CO_2 tax leads to less economic benefit of ship transport (Fig. 2).

The last point describes the functional dependency of economic and environmental relation. The functional relation between maritime and road transport starts with 6.4 (ETS = 0) and ended above the value of 3.7 (ETS > Euro 1000).

The values arise under the prerequisite that carbon certificates cost much less than 1000 Euro per tons in the maximum. The carbon cost for transport by road is relative small, in contrast to the cost ratio in shipping.

The future level of the certificate costs is not known so far, but it is most likely that the ETS system or a comparable tax system (polluter pay principle) will be most likely introduced in the next years. The calculation shows also that a containership (1000 TEU capacity) replaces more than 200 trucks based on the transport performance. The total carbon load is approximately 3.7 times higher than that for a ship. The costs are even more than sixfold higher (without certificate or

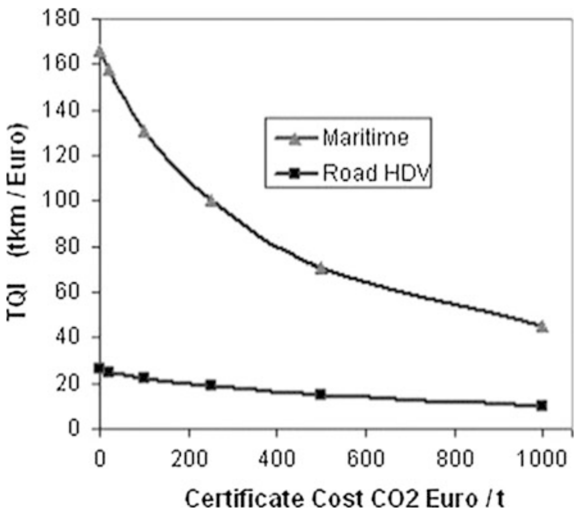

Fig. 2 TQI dependency to carbon costs. *Source* Own calculation

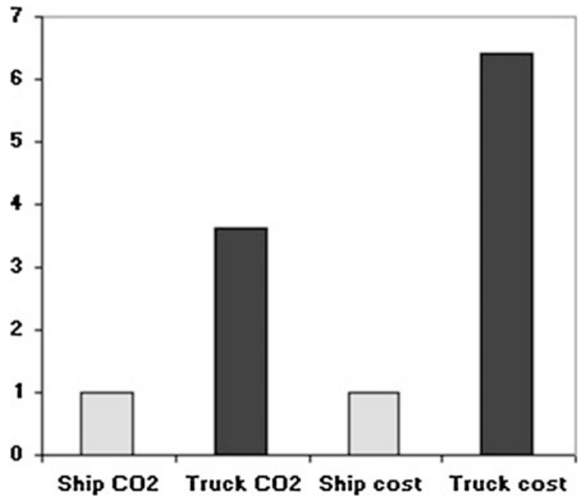

Fig. 3 Relative comparison of carbon emissions and costs. *Source* Own calculation

tax costs) for transport by road. The minimum daily fixed cost (cost increases at lower loading condition and consideration of environmental costs) for a 20′ container on a ship (1.000 TEU) is about Euro 32.00.[7]

The latter numbers are expressed in detail, i.e.,

Daily fixed costs 20′ Cont. = 1/TQI × distance × payload = 1/140 × 432 × 12 = 37 Euro,

where 20′ Cont. capital costs approx. 7 Euro; ETS charges approx. 6 Euro.

Note: Freight times are usually not explicitly taken into account in the transport costs (Fig. 3).

It should be noted that in the above comparison, additional loading and unloading costs were not taken into account, and it creates additional costs compared to road transport by USD 300 (lift cost of USD 100–200 each). The transshipment procedure is not necessary for direct delivery at destination, which is usually daily practice by price conscious road transport (even for distances over 800 km); the latter means that intermodal transport will be disadvantaged all the time, because they cannot save the additional cost. Furthermore, ships are unable to sail directly to the destination, so an intermodal transport is needed through sea ports and rail or road terminals such as in Gdynia or Gdansk.

These circumstances make sense to simulate a concrete transport and representative freight situation such as (Fig. 4):

(a) Container freight 40′ (20 t) transport by road from Wilhelmshaven to Warsaw (distance 1021 km)
(b) Container freight 40′ (20 t) transport by ship from Wilhelmshaven to Gdansk (893 km)

[7]With: ETS(70) Euro 37.00 and fuel price of 500 USD/tons.

(c) Container freight 40′ (20 t) transport by road from Gdansk to Warsaw (387 km)
(d) Intermodal transport by ship and truck (Fig. 5 and Table 3).

The calculations result shows significant changes, because the intermodal transport by ship and truck has led to additional cost. The additional lift costs weigh heavily and are relatively high.

Fig. 4 Main transport routes Poland and West European-Ports/Industrial centers. *Source* Own illustration

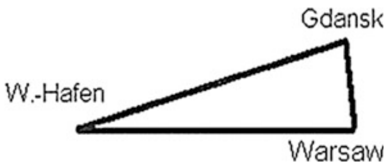

Fig. 5 Routes of 2 different transport options Wilhelmshaven to Warsaw. *Source* Own graphic

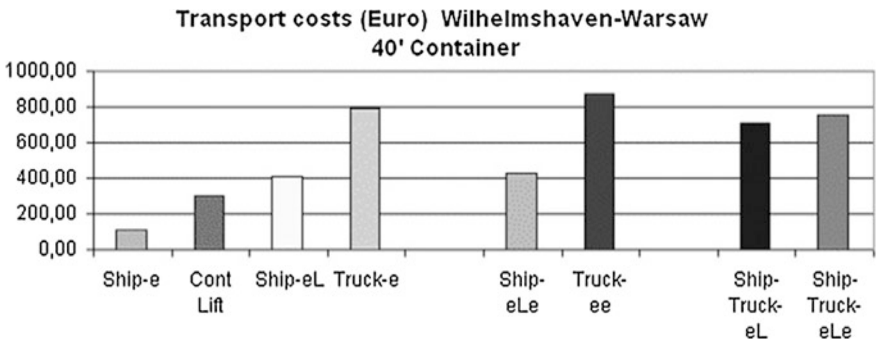

Fig. 6 Costs comparison of transport by road and intermodal transport by ship and road. *Source* Own calculation

Table 3 Cost overview (Euro) of Fig. 6

Ship-e (ship economical cost Wilhelmshaven—Gdansk 893 km)	107.60
Cont Lift (un-uploading costs)	300.00
Ship-eL (Ship-e + Cont Lift)	407.60
Truck-e (truck economical cost Wilhelmshaven—Warsaw 1021 km)	789.53
Ship.eLe (Ship-eL + environmental cost)	427.56
Truck-ee (Truck-e + environmental cost)	872.53
Ship-Truck-eL [Ship-eL + Truck-e(Wilhelmsh—Warsaw 1280 km)]	706.86
Ship-Truck-eLe (Ship-Truck-eL + environmental cost 1280 km)	758.29

Source Own calculation

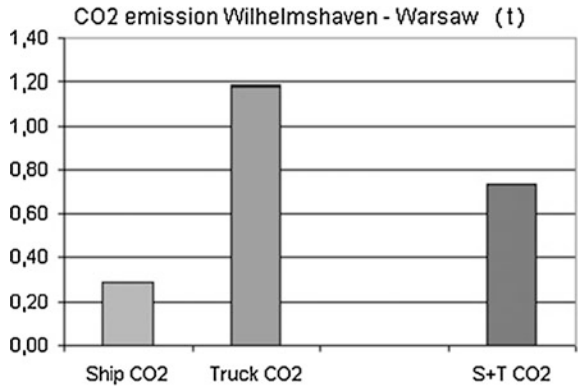

Fig. 7 40′ Container transport and related CO_2 (tons) emissions. *Source* Own calculation

Nevertheless, the cost of the truck transport is very high (789 Euro). For the entire route to Warsaw, the costs are 706 by ship and truck, which is 83 Euro or 11% less than by truck alone (without taking into account any highway fees). If environmental costs (70 Euro/tons CO_2) are taken into account, the difference is 114 Euro (Fig. 7).

The most important issue is the reduction in the carbon impact. The calculation result shows very clear that the ship transport has the potential for an improvement. A saving of over 35% is possible. Further savings are possible if the subsequent transport by rail takes place; here the transport from Gdansk to Warsaw is by rail, in particular if the power comes from renewable energy.

Bypassing the main transport through populous areas is an important measure—via the Baltic Sea, also to counteract the increasing traffic in the coming years. But the ultimate aim of all efforts should be to limit the steady increasing carbon emission to the environment; the Paris summit 2015 has called for progress.[8]

[8]Paris 2015 Climate Change Conference Nov. 2015 UNFCCC COP21 CMP11.

Future Outlook

The presented "Transport Quality Index" should be helpful for decision makers in the transport industry. Freight transport must meet stronger environmental standards in the future in addition to the economy necessities. First progress has already been made in particular in the maritime sector with the introduction of EEDI (Energy Efficiency Design Index, carbon emission reduction program for new ships IMO) and the stronger sulfur regulations, e.g., in the Baltic region (SECA Sulphur Emission Control Area). Previous measures have unfortunately not led to more and environmental friendly transport at sea. Many authors have criticized additional costs associated with the new sulfur regulations. But in fact the ship is quite competitive as before and has many advantages compared to the dominant road transport. Today's relative low oil price (the oil price is falling since more than a year) could lead to more transport activities in the future and probably more traffic on the road, and at the same time the motorway infrastructure becomes increasingly worse (road performance is increasing, speed reduction increase congestion). Transport times can no longer be kept; as a result, the cost increases. Additional motorway lanes need to be built, and European TEN-V project promotes the expansion of motorways and railways; however, citizens start protests and want no additional environmental destruction. The already long-announced relocation process, shifting from road to rail and maritime transport modes, has not yet been implemented (EU Commission/White Paper 2011 mandatory shift process of road transport for distances > 300 km). Pricing of the external effects of road transport would help to achieve a modal shift to rail and water-borne goods transport, a high share of freight trips in the EU over 800 km do not proceed intermodal (e.g., West Europe to Poland). A main step forward would be to reinforce efficient connections to the hinterland, e.g., from Gdynia/Gdansk ports to industrial centers of Poland, and then more container transport could be shifted to feeder and short sea shipping where there are still more than enough spare capacity.

Assessment of intermodal opportunities in the transport sector is one import aspect and a key ingredient of future policy development; in addition to the economic aspects, sustainable criteria should be applied and rewarded. Political leadership, bold decisions, and determined implementation are needed to transform the EU transport economy into a genuine environmental friendly transport community.

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The Impact and Role of Transportation on the Construction and Operations of the Green Supply Chain

Blanka Tundys

Abstract The supply chain management strategy evolves increasingly and includes new areas and issues. The requirements of the sustainable development and its principles are also present in this field. The practical reflection of these ideas in the supply chain is the creation of sustainable and green supply chains. This task includes many activities at both the operational and strategic level. Also in the coordination and implementation of ideas on the level of the whole chain and in participating units which determine a challenge for the managers. The legal, organizational, social, environmental, and economic requirements in the field of sustainability have a huge impact on the supply chains. One of the fundamental processes in the chain is the transportation. It is therefore important to research the role of transport, above all, because of the cost of the construction and operation of the green supply chains. The attention was focused primarily on aspects of cost and organizational activities in the field of the transportation in the green supply chain.

Keywords Transport · Green supply chain

Introduction

Changes on the international markets of the exchange of goods, especially mass consumption and market development of client, economies of scale of production, specialization of labor, and the increasing importance and the use of outsourcing make the place of manufacture of products not coincide with places where is reported the demand. Therefore, the organization of the supply chain requires additional action. This situation is particularly seen in transport processes, which are beginning to play a significant role and function in the supply chain management. Transport is necessary to eliminate the gap between the buyer and the seller,

B. Tundys (✉)
Department of Logistics, Faculty of Management and Economics of Services,
University of Szczecin, Szczecin, Poland
e-mail: blanka.tundys@usz.edu.pl

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and lengthening the supply chain means that suppliers and customers can share large distances. This situation causes a significant increase in transport costs, as well as other elements of the global logistics costs (including the costs of storage and a higher level of inventory). In addition, a growing interest in the new direction of development of the supply chain strategy, which is green and sustainable supply chains, entails redesigning and adapted to the new requirements, in the context of the particularly negative impact on the environment transport processes.

From a scientific point of view, it is interesting to see an indication of how transport processes affect the creation of green supply chains. Are there adequate determinants of the procedures of implementation of sustainable transport solutions for supply chain strategy?

It is also important to indicate who the initiator of the change is, and what level (operational and strategic) are introduced, and how they have the character (organizational, economic, legal, and administrative).

The considerations have to give an answer to the question to what extent, and what elements have an influence of the changes in transport processes taking place in the green supply chains. Are they a determinant, and may spur the development of new business concepts, or are they only a part of the whole, which is necessary and imposed by the leader of the chain. The requirements of the sustainable development, including in particular, economic aspects and cost have an influence of the changes in the organization and execution of transport processes, so that they are more environmentally friendly. The change is accompanied by the legal and organizational regulations.

The increasingly important role is played by the social aspects, and it is also affected by the creation of the green supply chains.

The article has an epistemological, as well as an empirical character. In the theoretical part will be aspects of the structure and requirements for green supply chain addressed, particularly focusing on a process approach in the management of the transport. It will be the role of selection of the sector and the mode of transportation in shaping of the effective and ecological supply chains explained.

In the empirical part will be the results of the research carried out on a sample of more than 500 companies operating in Poland and representing the three branches of the economy. The research was concentrated on the role of transport costs in the creation and operation of green supply chain.

Relevant Literature

Supply Chain—Sustainable Supply Chain—Green Supply Chain

An efficient supply chain is in many cases a guarantee of the success. Synchronized flow streams between cooperators allow adapting to a specific, required market demand. Such an understanding of the issue points out the crucial role of transport in the supply chain.

In addition, a new trend and direction of the development of the supply chain strategy, which is the balance and closing the loop, contributes to the redesign of the activities related to transport (including optimization) in order to introduce the most efficient and environmentally friendly transport throughout the chain.

Transport is an essential and integral part of the chain, which means that the green supply chain will require a green and sustainable transport process. As a part of creating a sustainable and green supply chain, it is necessary to meet three requirements, economic: relating not only to optimize the cost, but also fair conditions of contracts, timely adjustment of receivables, not to use the economic advantage to negotiate the inadequate conditions of contracts, transparency in establishing business contacts, prevention corruption; social: pertaining to fair labor practices, and practices aimed at cooperation with the local communities; environment: related to the impact on the environment, relating to the whole life cycle of the product design, material handling, use of raw materials for production and disposal.

The most important from the point of view of considerations definitions can be presented as: the strategic, transparent integration, and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains [1].

Carter and Rogers identify four supporting facets, or facilitations of the sustainable supply chain management (SSCM) (Fig. 1),

- strategy—holistically and purposefully identifying individual SSCM initiatives which align with and support the organization's overall sustainability strategy;
- risk management, including contingency planning for both the upstream and the downstream supply chain;
- an organizational culture which is deeply ingrained and encompasses organizational citizenship, and which includes high ethical standards and expectations

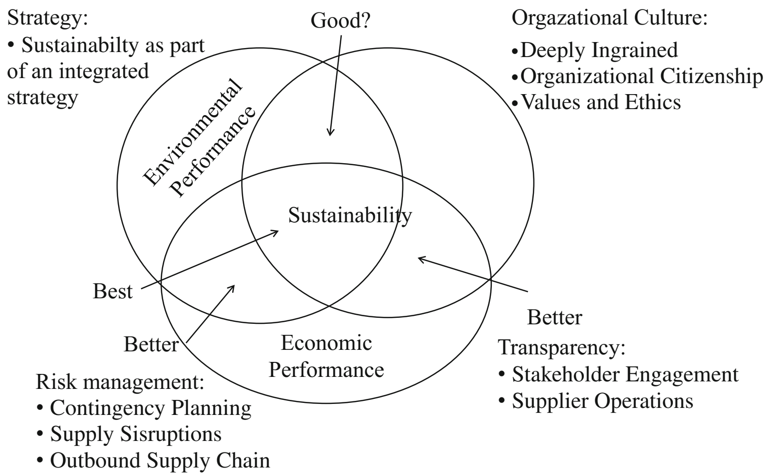

Fig. 1 Sustainable supply chain management. *Source* 1

(a building block for SSCM) along with a respect for society (both within and outside of the organization) and the natural environment; and
- transparency in terms of proactively engaging and communicating with key stakeholders and having traceability and visibility into upstream and downstream supply chain operations.

The problems they have to face to implement the sustainable supply chain refer to the first in 3 areas:

- economic—supporting SMEs, local producer, reducing barriers to entry, job creation, achieving value, fair supplier agreements, and business viability;
- social—base of competitive suppliers, fair employment practices, promoting workforce welfare, supporting skilling and development, community benefits, fair trade, and ethical sourcing practices;
- environment—reducing emission to air, releases to water and land, water and energy management, sustainable use of resources, using of renewable energy, minimization of waste and environmental impact

The tasks, problems, and objectives of sustainable supply chain can be related to the theoretical basis of the creation of green supply chain. In this case, attention and concentration is focused not only on aspects of sustainable development, but also more in terms of operational and also at this level, referring to the various phases and processes taking place within the chain. Theoretical basis can be found in the following publications covering various aspects of the green supply chain management [2–7]. Green supply chain management recognizes the disproportionate environmental impact of supply chain processes in an organization.

The analysis of the case studies related to the implementation of the green supply chain and indicate that business results must be directed to: combining the objectives of the green chain with the objectives of the individual and of the whole chain, analysis of the GSC can become a catalyst for the innovation, focus on reducing the use of natural resources and production of waste, and assessment of the supply chain as a single system life cycle. The implementation of the green chain allows reviewing processes, materials, and operational concepts. A very large role in implementing the concept of systems is played in the processes of ordering, negotiating, and vendor selection, also in the field of transport.

One of the elements of the strategic tools used in the construction of the GSCM is pollution prevention hierarchy (Fig. 2). These elements show the value of environmental programs.

GSCM must be linked to the life cycle thinking, combining the processes in the supply chain from strategy (green) flow of materials, manufacturing, transportation, retail/use, disposal, recycling, and re-return at least as a spare parts for the recycling. Green supply chains cover green thinking in the implementation of all processes taking place in the chains and which are needed for several reasons: the environment (global warming), the need to apply the principles of CSR, the benefits for participating organizations (including economic, e.g., by reducing costs) eco-friendly, increasing environmental awareness in stakeholders, evolving consumer demand, and response to increasing fuel prices.

In the context of the consideration about green supply chain the framework should be indicated on the 3 major components forming a unified system: elements, contents, and key factors (Fig. 3).

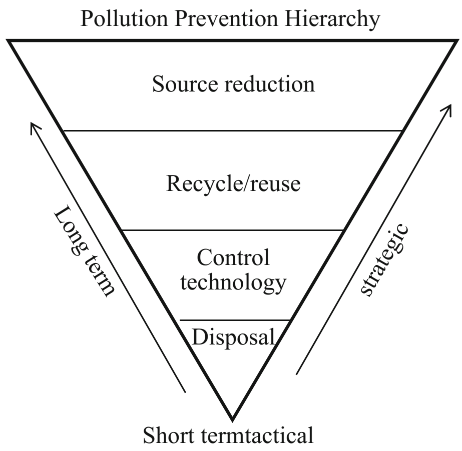

Fig. 2 Pollution prevention hierarchy. *Source* 1

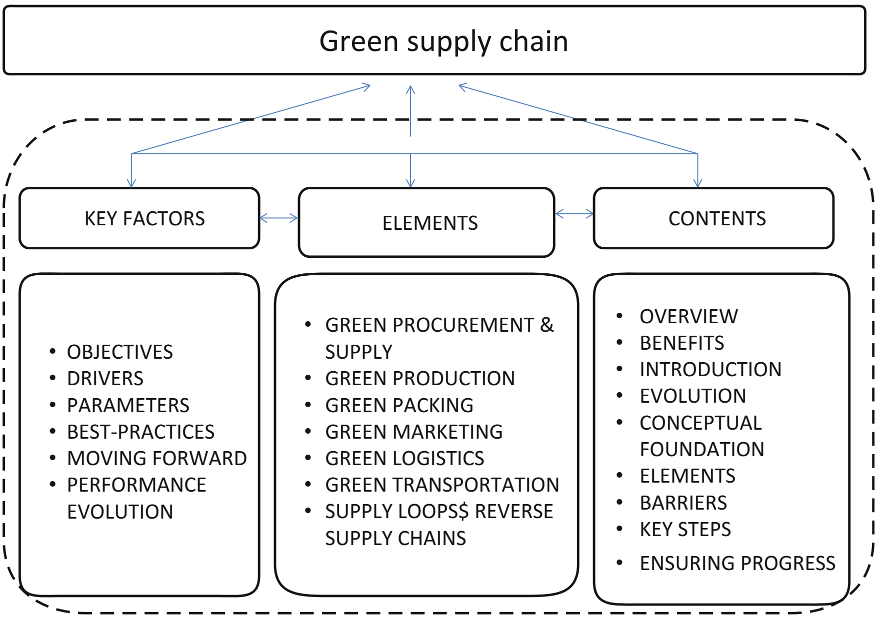

Fig. 3 Elements of the Green supply chain. *Source* Own elaboration on the basis on Ref. [8] [11.02.2016]

Sustainable and Green Transportation

The changes in the development of the supply chain strategy (in the direction of green supply chain) are uniquely associated with the changes in the implementation of the transport processes. The movement of goods must take place smoothly, without interference, and high efficiency of a well-organized transport ensures the smooth functioning of the supply chain as a whole depending on the business.

An efficient and effective processes related to handling transport provide delivery of goods to the customers on time and in good condition. In broad terms, the process has also to rationalize the cost of supplies or precise linking of the supply the needs of the recipient. The more complex the relationship between individual recipients, the greater the importance of the transport processes.

In the context of the considerations, it is important to indicate the nature and characteristics of the sustainable transport. Most often they talk about a sustainable transport system that is efficient, meets the expectations of society, economic, and above all minimize the harmful effects of transport on the environment. Generalizing these are the implemented solutions that have a positive impact on all areas of the sustainable development: society (enabling the fulfillment of basic needs access to the transport system by individuals and society in a safe manner and consistent with the needs of human health and ecosystems), the economy (affordable, efficient, supporting developing economies) and ecological (reduces emissions and waste, minimizes consumption of non-renewable resources in the long term will be based on the use of vehicles to supply renewable energy, reducing the scale of the destruction, and reduces the noise level) (own elaboration based on Ref. [9]). As the main features of the development in these areas should be considered [10]:

- social features: availability, liquidity, security, social cohesion, and the integrity of the transport system;
- the economic characteristics: competitiveness, working conditions in the sector, intensity, infrastructure (development, modernization, investing, capacity, quantity, and quality of the transport network) modality, and development of the market of transport services;
- environmental features: environmental friendliness of transport, minimizing environmental impacts, and prevention and liquidation of the consequences of the transport of environmental hazards.

The sustainable transport must reflect a steady disparate aims: economic, social, and environmental. This means that the construction of relations and links in the sustainable and green supply chain should definitely be taken into account. It is not without significance that the relationship with the clients and the measurement chain takes sustainability and green transport into account.

Transport as a Part of the Green Supply Chain

The success of the processes in the chain decided to shorten the time flow of goods and information, cost reduction, higher levels of customer service, and increased environmental processes. Modern business strategies are aimed at managing the entire supply chain and the primary role of time, as well as increasing the role of sustainable development.

The transport processes play an extremely important role in the supply chain. On the way to their realization, they affect both the logistics strategy and organizational solutions occurring in the individual chain links, and they are related to the elimination of ineffective solutions and the desire to reduce the cost of their own business. The actions taken within the supply chain and related to the implementation of the transport processes include the following:

- support of various types and forms of cargo,
- optimization of the using of means of transport,
- optimization of the unit load,
- optimization of routes,
- provide timely delivery,
- locations transshipment points,
- organizational, functional, and technical specifications in the movement, handling, and storage,
- the legal and financial, and
- rotation packaging and recycling.

It is also important that actions taken in the process of transport and modern application are often held at the legal level (e.g., by the need for appropriate standards for emissions), organizational (by optimizing and modeling of routes), economic (economic benefits achieved through the use of modern technology, including new contracts, have the ability to reduce operating costs). Definition of the green transportation in the framework of the green chain requires a statement of its most important features desired. It should start from the means of transport, which should meet the requirements of the low-carbon transport. Another element is the proper integration and optimization of the transport, and it is also related to its cost-effectiveness and efficiency. Another element is the implementation of IT systems, the use of which will allow for eliminating the negative impact of transport on the environment. They allow, inter alia, for the monitoring of the vehicles, and pollution.

These elements are a part of the green supply chain. In practical solutions, its essence and objectives are hidden under the concept of green logistics, which also includes the green storage processes. The elements that define green transport are as follows: electric vehicles, fuel cells, and bio-diesel efficiency, use hybrid vehicles for distribution and delivery, proper planning of shipment.

An important factor is the use of monitoring and evaluation of the activities of transport, including the efficiency and environmental performance, sustainable measurement of sustainability in transport, both in terms of macro and micro area. Referring both to the level of the whole economy and the assessment processes in individual companies. In this regard, it is about the growing importance of sustainable transport [more: 10].

The transportation is one of the most cost-intensive elements of the supply chain, while being one of the most negatively influencing on the environment. Therefore, process approach indicates the need to link with the objectives of the green supply chain. Firstly, using appropriate planning tools to optimize its use, and secondly using appropriate (environmentally neutral) means of transport, and thirdly using and applying appropriate indicators and gauges measuring of the sustainable transport as part of the assessment and measurement of the green supply chain.

Research and Questionnaire Design

As a part of the research on the green supply chain, there were choosing companies representing the three sectors of the economy, they are functioning in Poland. In this research, it was referred to the transport issues. The issues referred were considering to the aspect of cost and environmental aspects in general using to choose a supplier (including whether one of the criteria is "clean" transport). The samples were subjected to the food industry (manufacturers and dealers), clothing (manufacturers and sales network) as well as manufacturers and distributors of household appliances. The study involved 549 enterprises, drawn on the basis of the specific research sample, determined in proportion to the number of economic entities operating on Polish territory. Selected test results and their interpretation are the following figures.

The first important question referred to the role of transport costs (general) in the functioning of the green supply chain. Of 549 respondents answered the question 540. Detailed data are presented in Fig. 4.

When interpreting the presented data, it should be pointed out that more than the half of the respondent's transport costs play a very important or important role. Surprisingly, despite everything, it seems that managers of the supply chains,

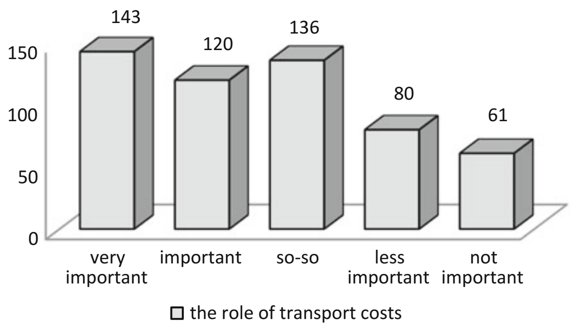

Fig. 4 What role in the functioning of the green supply chain plays a transportation costs

who were responsive to the questions, in 141 cases responded that transportation costs do not actually play a significant role in the functioning of the green supply chain. The term "so-so" means that managers are aware of the existence of such costs, but there are other elements that play a more important role than transportation. This means that the Polish enterprises, in terms of the need to build a green supply chain, including the use of green transport, have less knowledge of the subject.

Another question was concerning the determination of the overall "greening" their supply chain, in the context of greening of the transport processes (Fig. 5). The sample was 549 respondents, of whom it is interesting that 64 replied that they had no knowledge on the subject. Unfortunately, as other answers indicate awareness of the need for greening, including the balancing of transport processes, it is small, because the 207 respondents were in favor of rather small involvement in this type of processes and an indication that the degree of greening of these processes is small and very small. In addition, taking into account even those who have no knowledge about, it should be noted that the level of awareness and implementation of sustainable transport in these chains is small.

In the context of questions about the sustainability criteria for the suppliers selection, relating to the selection of suppliers using "clean" transportation the answers were not clear. The question answered 494 respondents (Fig. 6), which accounted for 90% of all respondents. Of which only 121 answered that this criterion is used very often or often. "Sometimes" indicated 136 respondents, which accounted for 27.5% of the responses. And in this case, it should be noted the fact that making a vendor selection takes these aspects into account. This is important in the context of the whole green supply chain management, since it indicates that at one of the most important decisions concerning the selection criteria on the supplier associated with a pure transport are starting to be taken into account, although unfortunately in Polish realities do not play a significant role.

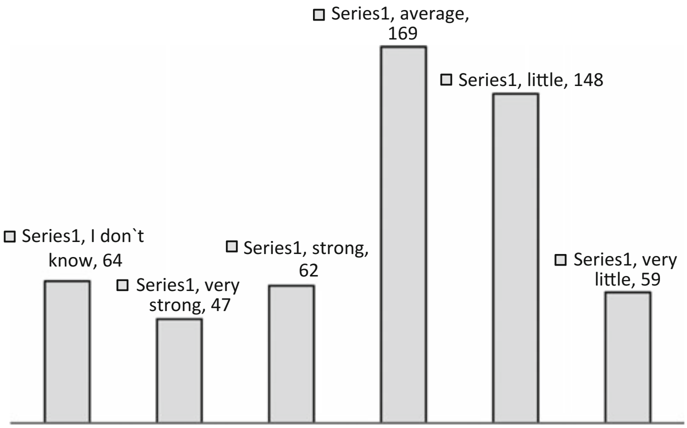

Fig. 5 How would you evaluate the general "greening" yours supply chain (in the context of transport processes)

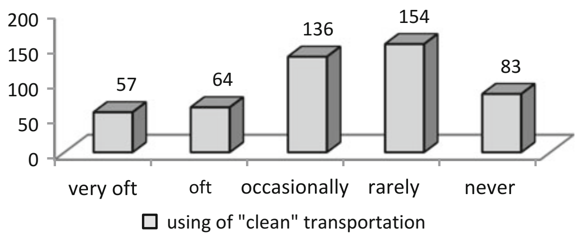

Fig. 6 Elements which are taken into account by sustainable selecting criteria of suppliers

Another question is related to the role of ecological transport in the functioning of the green supply chain answered 537 respondents. In this regard, it should be noted a large variety of answers. In fact, almost the same number of questions played a large and a small role (Fig. 7).

The responders were also asked about the evaluation of "greening" supply chain processes and/or use the meters and indicators of the sustainable transportation. In this regard, there is more "no" answer in the area of the companies. Regarding the assessment of the whole supply chain, it is a difference occurred in only one answer (1 affirmative answer more). Lack of the dominant response and hesitancy of respondents (managers) points to the lack of knowledge or skills to using it to evaluate the enterprise or an entire of the supply chain (Fig. 8).

Interpreting the test results, it should be noted that in the polish reality (at least in the range tested and surveyed industries) subject, the use of "clean" transport is generally unknown but to a small extent used.

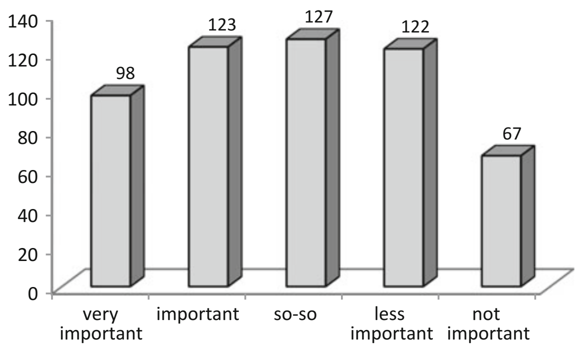

Fig. 7 What role in the functioning of the green supply chain plays environmentally friendly transport

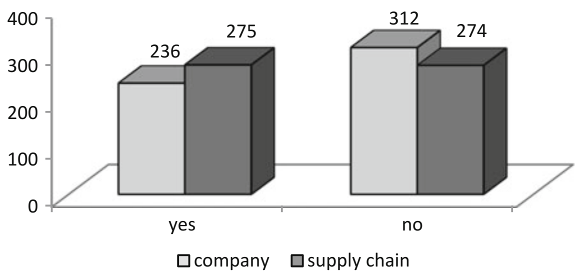

Fig. 8 To the evaluation of "greening" supply, chain processes are used the meters and indicators of the sustainable transportation

Discussion and Limitation of This Study

Elements of the discussion should be referred to the significance of transport costs in the creation and operation of the green supply chain and their role in the supply and generally using of "green" transport in the supply chains. The cited study did not refer to the significance of transport and their optimization. They were designed to identify, or during the implementation of the transport processes in the framework of the green supply chain, companies have pay attention to the need to use a green transportation.

The limit element of this development and the data is the fact; there were no studies closely related to the role of the transportation. Transport in this study is only a part of the functioning of the green supply chain. Another element is the limitation of industries. It seems reasonable to take a further extension of the research spectrum and scope associated with the areas of transport and its importance in the green supply chain. Importance in future studies is the expansion of the role of transport as one of the most important elements of the green supply chain.

Summary

Summing up the considerations, it should be noted that the subject matter is extremely important and present in the literature. Theoretical considerations indicate what elements should have a sustainable and green transportation, as well as a part of the process of green supply chains. Unfortunately, the practical reflection indicates that in the Polish reality, it is not yet subject raised and implemented in the supply chain. It reveals a lack of knowledge and awareness, and probably also the knowing of the specific elements and practical solutions which are already implemented in other organizations and supply chains. It can be concluded that in the current situation, only the elements required by law are implemented. Perceived are also those elements that bring economic benefits, but less attention is paid to those that are related to the social element.

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An Overview of the Progress Towards Sustainable Transport Development by Using TERM Indicators

Barbara Pawlowska

Abstract A sustainable transport system is one of the greatest challenges in the pursuit of sustainable development. A wide range of environmental problems has to be solved in ways that are compatible with social and economic goals. The transport sector has already taken a lot of measures to reduce the burden on the environment. In order to achieve an environmentally and socially sustainable transport system, more action is needed. The integration of environmental concerns into policies and decision-making has to be extended and deepened. There is no doubt that if something can be measured, it can be managed, so the success of current and future integrated policies can only be judged by identifying key indicators that can be tracked and compared with concrete policy objectives (benchmarking). A TERM is a proposed reporting tool on transport and environment, which has been developed by the European Commission and European Environmental Agency. Under the TERM, annual indicator-based reports are produced as a tool to assist policy makers with the assessment of the effectiveness of strategies. The proposed indicators can help in the assessment of policy-level strategies and the level of goal achievements. The aim of this article is to review the effect of sustainable policy implementation based on the TERM indicators in the latest report and draw some conclusions and recommendations how to go ahead to reach the goals assumed in the long-term perspective by 2050.

Keywords Sustainable transport · Policy integration · TERM · Transport policy

Introduction

The relationship between transport and environmental issues is one of the most crucial elements in progress towards sustainable development. It has been recognised for many years that transport contributes significantly to several environ-

B. Pawlowska (✉)
University of Gdansk, Gdansk, Poland
e-mail: bpawlowska@ug.edu.pl

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mental problems, in particular to climate change, air pollution, acidification, acoustic climate, land take and fragmentation and disruption of nature habitats. These problems could be mitigated by better integration of environmental concerns into transport policies and decision-making. According to the International Energy Agency (IEA), as appears from their recent analysis, transport is the greatest consumer of energy in the developed world, consuming more than industry. The structure of the OECD total final consumption (TFC) shows that transport was the largest energy consuming sector in 2013 with the growth rate of 2% compared to 2012, accounting for a third (33%) of the final energy consumption, followed by industry with 31% and residential use with 20%. These shares have reversed since 1971, when industry accounted for 41% of total final consumption and transport for 24% [1]. In the OECD European countries, industry is still the biggest consumer, but transport is closing the gap.[1] Oil still makes up around 95% of all transport fuels in the EU, while industry has a roughly equal mix of coal, oil, gas, electricity and other sources, which include biofuels and waste [2].

Taking all these facts mentioned above into consideration, it is very important to combine the environmental elements into sector or branch development. The integration of environmental aspects into the sector policy as a concept in the environmental policy has been known at least since the first UN conference on the environment in Stockholm in 1972. However, the importance of the principle of integration really first seemed to receive attention in transport sector more than a decade later. The EC Expert Group on Transport and Environment described the concept of integration in relation to transport as [3]:

> … environmental issues are taken into account on an equal basis to other concerns such as economic and social aspects. All stakeholders would include the relevant environmental aspects in the framework of their responsibilities and these would be reflected in their actions

> [integration] must lead to concrete actions by the authorities responsible for transport, and ultimately, by all actors having an influence on the design and the use of the transport system.

Strategies for the integration of environmental and sectoral policies were strongly outlined in the EU's 5th Environmental Action Programme (5EAP) [4]. Better integration of environmental concerns into other policy areas, such as regional policy, agriculture, fisheries, energy and transport, ensures better decision-making and coherent policy approaches that deliver multiple benefits. The

[1]There are big variations across the regions. The share of transport in 2013 was the largest in very large countries, such as the USA, Mexico and Australia, all with values around 40%, as well as in Luxembourg (57%), in this case due to price-driven fuel tourism. It was much lower in smaller countries with a strong industrial sector (e.g., Korea, Iceland, Finland, Belgium and the Netherlands).The effect is that in the European OECD countries, transport is still behind the industry sector.

7th Environment Action Programme (7EAP) continues this approach. It guides the European environment policy up to 2020. It also expands this long-term direction by setting out a vision beyond that of where the Union should be by 2050. Three key objectives are identified [5]:

- to protect, conserve and enhance the Union's natural capital;
- to turn the Union into a resource-efficient, green and competitive low-carbon economy; and
- to safeguard the Union's citizens from environment-related pressures and risks to health and well-being.

Three so-called action areas will help Europe to deliver these goals:

- better implementation of legislation;
- better information by improving the knowledge base more and wiser investment for environment and climate policy; and
- full integration of environmental requirements and considerations into other policies.

Integration has been given a higher political priority following the Treaty of Amsterdam, which underlines its importance and defines it as a way to achieve sustainable development. The following elements of environmental integration in the transport sector should be distinguished [6]:

- Institutional Integration: this means greater coordination between land-use and transport planning and economic policy; greater coordination and synergies between transport planning and other human activities; and increased responsibility for the promotion of sustainable development at the sectoral level;
- Market Integration: this means greater cost responsibility for all modes (environmentally related charges, etc.) and differential taxation of vehicles and fuels to encourage the use of environmentally friendly alternatives;
- Management Integration—relating to the environmental consequences of transport: this means greater use of environmental and sustainability objectives and targets; increased application of environmental impact assessment procedures at the strategic and project levels; support for research, development and modelling; and creation of the conditions for greater coordination and interoperability between modes of transport; and
- Monitoring/Reporting Integration: this means increased monitoring of the environmental implications of decisions and use objectives, targets and indicators to report on progress and effective integration.

Policy Framework for Sustainable Development in the EU Transport Sector

Nowadays, the EU transport system cannot be classified as sustainable, and in many respects, it is moving away from sustainability rather than towards it. The European Environment Agency (EEA) highlights in particular the sector's growing CO_2 emissions. With growing freight and passenger transport, the risk of pollution and congestion is increasing. The European Commission (EC) is working towards a form of mobility that is sustainable, energy-efficient and respectful of the environment. The Europe's general policy framework for reducing the environmental impacts of transport has evolved substantially since the early 1990s. These trends have strongly reinforced the need for fully developing and consistently implementing a policy response, which has had sustainability at its core, as set out in the Green Paper on Transport and the Environment (1992) [7], and taken up by the White Paper on the future development of the common transport policy (1992) [8]. The last one was dedicated to market opening, in line with the priorities at the time.

In July 1995, the EC issued a communication on the transport policy action plan 1995–2000 [9], setting out in more details the timetable for implementing the actions announced in the White Paper (1992). Among the announced measures, the forthcoming Green Papers on the internalisation of external costs (1995) [10] and the Citizens Network (1995) [11], the environmental assessment work on the Trans-European Networks (1995–1996), the environmental framework on road freight transport (1996) and action on air transport and airports (1997 and beyond) were of particular importance for the integration of transport and environment policies.

In 2001 [12], the EC presented the White Paper proposing 60 measures to overhaul the EU's transport policy in order to make it more sustainable and avoid enormous economic losses due to congestion, pollution and accidents. One of the main messages of the White Paper (2001) was that in addition to facilitating the growing demand for transport, a modern transport system must be sustainable from the economic, social and environmental viewpoints. Although it stressed the need to control the growth of air transport and promote the use of non-road transport modes, no specific overall environmental targets were included at the time. Only the need for these to be developed and quantified in the future was highlighted.

The 2006 midterm review updated attempts to rebalance the policy towards economic objectives. The review of the White Paper (2001) stated that the objectives are still relevant, but the context defining European transport policy has changed over the last five years due to the enlargement and globalisation [13].

The integration of the environmental considerations within the transport sector was significantly extended with the publication of the new transport policy in 2011. Now, the 2011 White Paper *a Roadmap to a Single European Transport Area—Towards a competitive and resource efficient transport system* takes a global look at developments in the transport sector, at its future challenges and at the policy initiatives that need to be considered [14]. It takes on the challenge of seeking a deep transformation of the transport system, promoting independence from oil, creation of modern infrastructure and multimodal mobility assisted by smart management and information systems. The aim of the established seven initiatives is to ensure the more competitive and integrated transport system providing increased mobility and lowering emissions by 2050. The initiatives cover 40 different areas necessary for the transformation of the European transport system and address challenges, such as reducing dependence on oil, tackling congestion and improving infrastructure and cut carbon emissions in transport by 60% by 2050. For the next 40 years, the EC has set forward a range of impressive policy goals in the White Paper (2011) that will require a true transition in the mobility system.

Transport is a complex system that depends on multiple factors [15], including the pattern of human settlements and consumption, organisation of production and availability of infrastructure. Adding to this complexity, any intervention in the transport sector must be based on the long-term vision for the sustainable mobility of people and goods and must be planned well in advance. Figure1 presents the factors influencing decarbonisation of the transport sector.

As statistics and analysis suggest, road transport plays a vital role in the European society, not only as the main mode for people and goods to move from one place to another, but also as an important economic sector. At the same time, it is responsible for about a quarter of the EU's energy consumption and about a

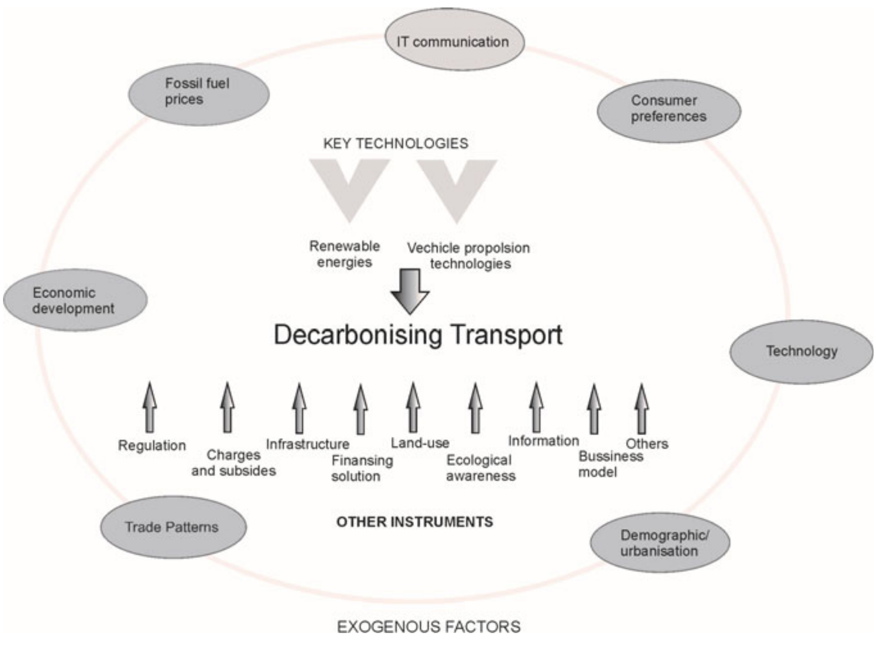

Fig. 1 The factors influencing decarbonisation of transport sector. *Source* Own elaboration

one-fifth of its CO_2 emissions. It is important that while these emissions fell by 3.3% in 2012, they are still 20.5% higher than in 1990. Transport is the only major sector in the EU where greenhouse gas emissions are still rising [16].

Review of the TERM Indicators Towards Achieving Transport Policy Targets

Sustainable transport is a key challenge of the EU Sustainable Development Strategy (EU SDS) [17]. The objective of this strategy is to ensure that the member states' transport systems meet the public's economic, social and environmental needs, without causing any negative effects that may affect meeting these needs The environmental pressures from the transport sector depend on the following factors: the number and length of trips, the modes of transport used, where some are more environmentally friendly than others, and the technology that each mode uses.

There is no doubt that if something can be measured, it can be easily managed, so the success of current and future integrated policies can only be judged by identifying key indicators that can be tracked and compared with concrete policy objectives (benchmarking). A Transport and Environment Reporting Mechanism (TERM) has been set up specifically for this purpose. As part of this process, the concept of an indicator-based system for the EU was initiated in early 1998. It has been designed to help the EU and member states to monitor the progress of their transport integration strategies, and to identify changes in the key leverage points for the policy intervention (such as investments, economic instruments, spatial planning and infrastructure supply). Seven questions are addressed, which policy makers in the EU regard as key to understand whether the current policy measures and instruments are pushing the transport/environment interactions towards the sustainable direction [18]:

1. Is the environmental performance of the transport sector improving?
2. Are we getting better at managing transport demand and at improving the modal split?
3. Are spatial and transport planning becoming better coordinated so as to match transport demand to the needs of access?
4. Are we optimising the use of existing transport infrastructure capacity and moving towards a better-balanced intermodal transport system?
5. Are we moving towards a fairer and more efficient pricing system, which ensures that external costs are recovered?
6. How rapidly are improved technologies being implemented and how efficiently are vehicles being used?
7. How effectively are environmental management and monitoring tools being used to support policy and decision-making?

Initially, in order to answer these questions, a selection of 31 indicators was made to deal with the various aspects of the transport and environment system. Today, after 15 years, the set of indicators is wider but is still developing. It consists of 40 indicators used for tracking the environmental performance of the transport sector and measuring the progress in meeting the key transport-related policy targets. The European Environment Agency (EEA) uses the DPSIR approach (Driving forces, Pressures, State, Impact and Responses) as a generic tool to support the understanding of these complex relationships and reporting them across the whole range of environmental issues [19]. The DPSIR model shows the connections between the causes of environmental problems, their impacts and the society's responses to them in an integrated way [20].

The TERM indicators cover the most important aspects of the transport and environment system. They represent a long-term vision of the indicators that are ideally needed to answer the above-mentioned aspects. The TERM addresses seven issues [21]: (1) freight transport and the modal split; (2) passenger transport and the modal split; (3) need for demand management; (4) greenhouse gas emissions from the transport sector; (5) transport fuel developments; (6) transport noise; and (7) local emissions and air quality. Table 1 presents qualitative evaluation of key indicator trends.

As the article length constraints do not allow for an in-depth analysis of observed trends and description of indicators, only brief comments will be provided to selected indicators for the above 7 groups.

The Freight and Passenger Transport Demand, Modal Split and Need for Demand Management

Minimising the negative social and economic impacts of the transport sector is a central theme in the EU transport policy. The objective of decoupling the freight transport demand from GDP was first mentioned in the transport and environment integration strategy, which was adopted by the Council of Ministers in Helsinki [22]. The expected growth in the transport demand was named as the area where urgent action was needed. In the sustainable development strategy adopted in Gothenburg, the objective of decoupling is set in order to reduce congestion and other negative side effects of transport [23].

The White Paper 2011 states that freight shipments over short and medium distances (below some 300 km) will mostly remain on trucks. For longer distances, the options for road decarbonisation are limited and efficient options for freight multimodality are needed. Based on the EUROSTAT data, road freight (over 300 km) represents 11% of tonnes lifted and 56% tkm. The major groups of goods carried in road transport exceeding 300 km are food products (17% tkm), agricultural products (10% tkm), mixed goods (10% tkm), chemical products (9% tkm), metal products (9% tkm) and wood, paper and pulp (8% tkm) [24].

Table 1 Qualitative evaluation of key indicator trends

TERM no.	Key indicators	Integration question	Target	Evaluation of indicator trends
TERM 01	Transport final energy consumption by fuel	5	70% reduction of transport oil consumption from 2008 to 2050	☹
TERM 02	Transport emissions of greenhouse gases	4	Transport GHGs (including international aviation, excluding international maritime shipping): 20% ↓ (vs. 2008) 2030 60% ↓ (vs. 1990) 2050 EU CO_2 emissions of maritime bunker fuels 40% ↓ (vs. 2005) 2050	☹
TERM 03	Transport emissions of air pollutants	7	EU limit values on concentrations of individual pollutants in ambient air	😐
TERM 04	Exceedances of air quality objectives due to traffic	7	Good quality of air	☹
TERM 05	Exposure to and annoyance by traffic noise	6	Good quality of acoustic climate	😐
TERM 12	Passenger transport volume and modal split	1	The majority of medium distance passenger transport should go by rail	☹
TERM 13	Freight transport volume and modal split	1	Road freight over 300 km shift to rail/waterborne transport: 30% shift 2030 50% shift 2050	☹
TERM 20	Real change in transport prices by mode	3	Internalisation of external costs	😐
TERM 21	Fuel tax rates	3	Internalisation of external costs	
TERM 27	Energy efficiency and specific CO_2 emissions	5	Target average type-approval emissions for new passenger cars: 130 g CO_2/km 2012–2015; 95 g CO_2/km 2020	☺

(continued)

Table 1 (continued)

TERM no.	Key indicators	Integration question	Target	Evaluation of indicator trends
			Target average type-approval emissions for new light vans: 175 g CO_2/km 2014–2017 147 g CO_2/km 2020	
TERM 28	Specific air pollutant emissions	7	The reduction of specific emissions from road transport (VOC, CO, NO_x, PM per paskm, tkm)	☺
TERM 31	Proportion of renewable energy in the transport sector	5	40% proportion of low carbon sustainable fuels in aviation—2050 10% proportion of renewable energy in the transport sector's final energy consumption for each member state Fuel suppliers to reduce life cycle GHGs of road transport fuel 6–10% ↓ (vs. 2010 fossil fuels) 2020	☹ ☹
TERM 33	Average age of the vehicle fleet	1/2	Improving the environmental performance of the fleet	☺
TERM 34	Proportion of vehicle fleet by alternative fuel type	5	Use of conventionally fuelled cars in urban transport: 50% ↓ 2030; 100% ↓ 2050 Target average type-approval emissions for new light vans: 175 g CO_2/km 2014–2017; 147 g CO_2/km 2020	☹

☺ positive trend (moving towards objective)
😐 some positive development (but insufficient to meet objective)
☹ unfavourable trend (large distance from objective)

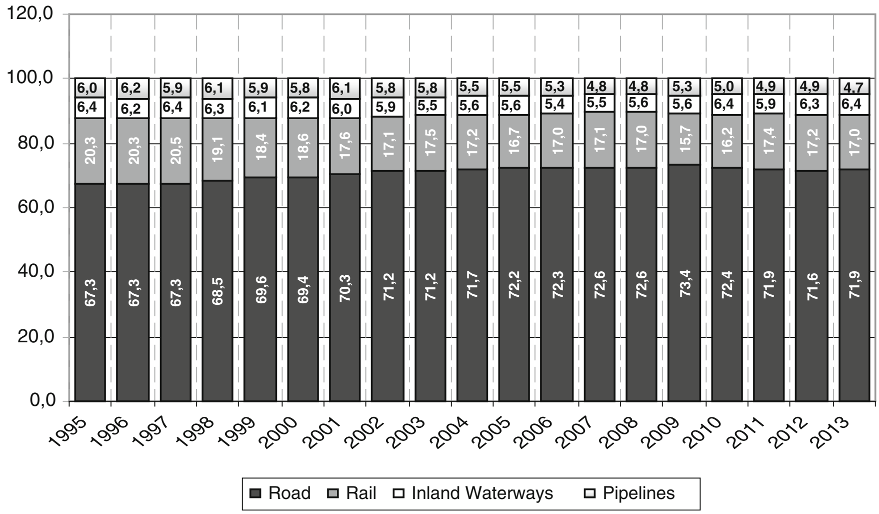

Fig. 2 The modal split of freight transport (1995–2013). *Source* [32]

The trends analysis revealed that the modal split for inland freight transport has not changed substantially since 2000. Freight is generally transported by road, rail, inland waterways and pipelines. In 2013, road transport constituted almost 72% of all tkm performed in the EU-28, followed by rail (17%), inland waterways (6.4%) and pipelines (4.7%). The analysis of trends in road transport distinguished two clear developments. First, the share of road transport increased steadily between 2000 and 2009. Second, road transport lost more than 1.5% in the aftermath of the economic crisis between 2009 and 2013 as other transport modes started gaining ground. In this context, the support to shift freight from road to water and rail is an important strategic element in the EU transport policy. Figure 2 presents the modal split in freight transport.

Looking at individual countries in the context of the modal split in the long term, countries that joined the EU in 2004 and 2007 recorded the largest increases in the share of road transport in the total inland transport performance. One reason is that the extension and integration of the common market are heavily interlinked with the transport demand. The resulting additional demand for transport will overflow onto roads, as this form of transport is the easiest to interconnect and cheaper compared to other modes.

Additionally, the projection developed in “EU Energy, Transport and Greenhouse Gas (GHG) Emissions Trends to 2050 Reference Scenario 2013” [25] shows an increase in the total freight transport activity by about 57% (1.1% per year) between 2010 and 2050. Road freight is projected to grow by 55% during the same period, while rail freight is projected to grow by 79% and inland waterway by 41%. This means that road freight is projected to amount 2721 billion tkm by 2050. This projection proves that additional measures will be needed to obtain the objectives defined in White Papers.

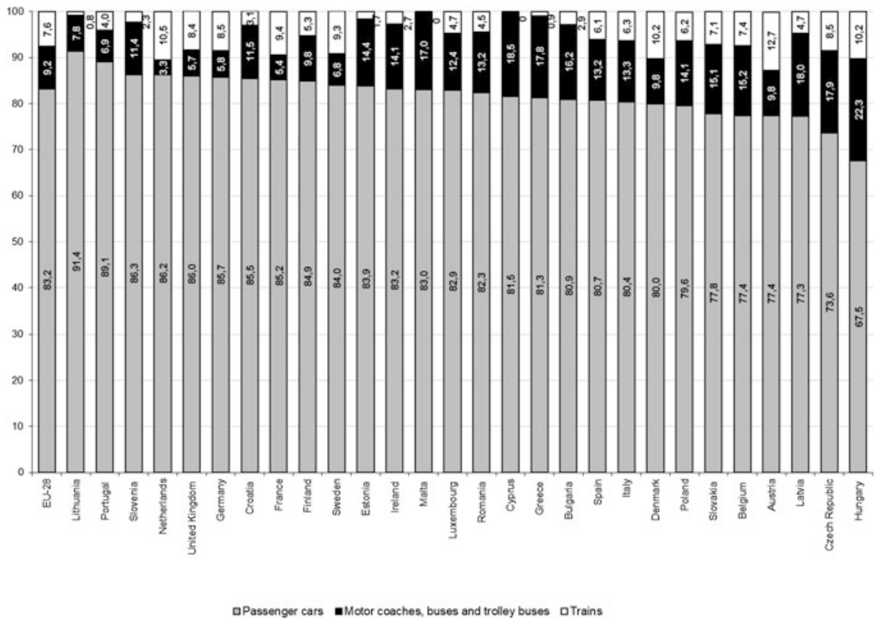

Fig. 3 The modal split of inland passenger transport, 2013. *Source* [32]

The total demand for passenger transport in 2013 was 8.4% higher than in 2000. Passenger cars accounted for 83.2% of inland passenger transport in the EU-28 in 2013, with coaches, buses and trolley buses (9.2%) and trains (7.6%). Among the EU Member States, the relative importance of passenger cars was the highest in 2013 in Lithuania, where it accounted for 91.4% of passenger transport in 2013. In most countries, the passenger car share was between 80.0% and 90.0%, although there were seven countries where this share was lower, most notably in Hungary (67.5%). In 2013, trains accounted for more than the one-tenth of all inland passenger transport in Austria, the Netherlands, Denmark and Hungary, while their share fell below 2.0% in Estonia, Greece and Lithuania (Fig. 3).

The differences in trends are easily noticed between EU-15 and EU-13. The average pkm in the research period fell slightly in the first group, while grew significantly in the EU-13. There is, however, considerable variation across the individual states. The decreasing average distance travelled by a car was also observed. Looking at air transport is also very important because of the very dynamic rate of growth in this mode reaching 27% since 2000. It grew rapidly between 2000 and 2007, but then the economic crisis caused the sudden decrease by 6.9% in 2009. The crisis hit especially traditional airliners, while low-cost operators have grown steadily since 2008.

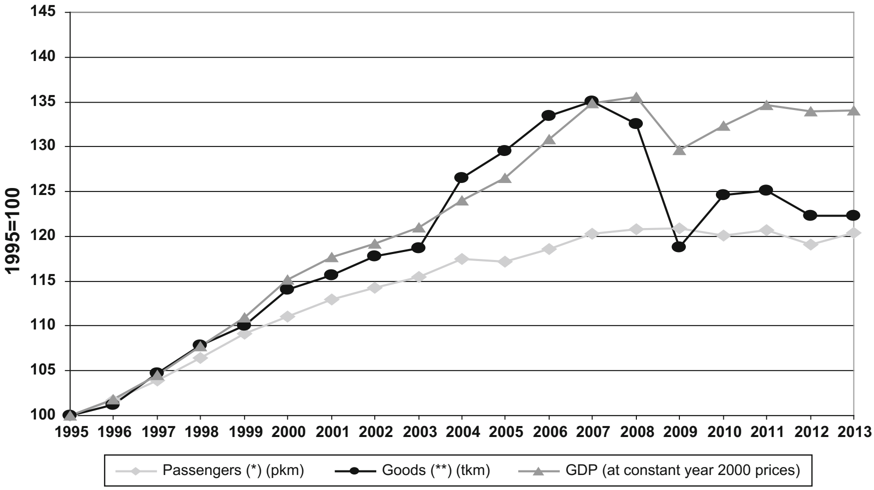

Fig. 4 Transport performance and the relation to GDP (1995–2013). *Source* [32]. (*): passenger cars, powered two wheelers, buses and coaches, tram and metro, railways, intra-EU air, intra-EU sea. (**): road, rail, inland waterways, oil pipelines, intra-EU air, intra-EU sea

The analysis of statistics presented in the TERM revealed that freight transport grew considerably in the EU 28 between 2000 and 2008. Passenger transport increased until 2008, but it then remained broadly stable after being hit by the economic recession. One of the operational objectives of the EU Sustainable Development Strategy has been “decoupling economic growth and the demand for transport”. So far, this has only been observed during the economic crisis. In the period of positive economic growth, before 2007, the freight transport volume increased at much greater pace than GDP. Figure 4 presents the extent to which the freight and passenger transport volume is coupled with a slowdown in economic growth between 2000 and 2013. Thus, the transport demand intensity (the transport volume associated with one Euro of GDP) was lower in 2013 than in 2000. Over the long-term period, between 2000 and 2013, both GDP and transport volumes increased: GDP grew by 16.1% and transport volumes by 11.5%. As a result, relative decoupling between transport volumes, both passenger and freight, and economic growth took place.

Greenhouse Gas (GHG) and Local Emissions from the Transport Sector

The total GHG emissions in the EU-28 have decreased by 1203 million tonnes since 1990 (or 21.2%), reaching their lowest level during this period in 2013. Such a commitment is included in the EEA report concerning GHG emissions

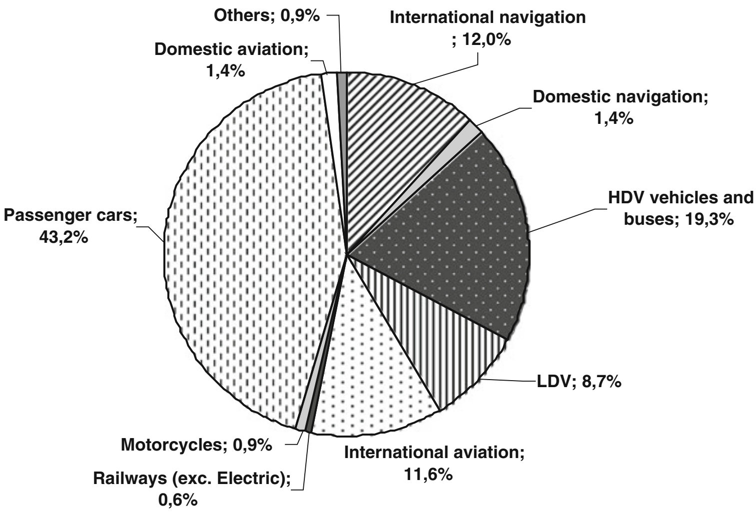

Fig. 5 The contribution of different modes of transport to the EU's transport GHG emissions in 2013. *Source* [26]

monitoring. It means absolute decoupling of GDP and GHG emission compared to 1990, with an increase in GDP of about 45% alongside a decrease in emissions of over 21% over the 23-year period [26]. GHG emissions decreased in the majority of sectors, with the notable exception of transport, including international transport, and refrigeration and air conditioning.

According to the TERM 2015 report, GHG emissions from transport have increased by 19.4% since 1990. In 2013, transport accounted for almost a one-quarter (24.4%) of the EU's total GHG emissions (one-fifth excluding international aviation and maritime emissions). Passenger cars contribute almost 45% and heavy-duty vehicles a further 20% of the transport sector's emissions [21]. Transport urgently needs to find a pathway towards providing carbon neutral mobility. The technological progress is important but not enough to obtain assumed targets. Figure 5 presents the contribution of different modes of transport to the EU's transport GHG emissions in 2013.

As it is shown in Fig. 5, road transport is responsible for about 73% of all GHG emissions. The passenger cars' share is 60% of all road transport emissions, while HDVs' share is 27%. Emissions from LDV are accounted for 8.7% of the total transport GHGs. Domestic and international aviation is responsible for about 13%, and the same share belongs to international and domestic navigation.

The COP21 Paris Agreement from December 2015 created a political pathway for the global CO_2 mitigation efforts by setting up a five-year review cycle for national decarbonisation commitments, starting in 2020 [27]. The Paris commitments and their milestones are vitally important and represent an exceptional opportunity for the transport sector to develop a road map towards carbon neutrality. While advances in the renewable power generation and propulsion technology will deliver significant progress, this will not suffice [28]. Changes in behaviour and novel approaches to organise mobility and land use will be necessary. At the same time, the transport demand is rising, and changing demographics, rapid urbanisation, new trade patterns, digital connectivity and future infrastructure need to be considered.

Transport Fuel Development and Improving Energy Efficiency

The annual transport energy consumption grew significantly between 1990 and 2013. However, the impacts of the economic crisis caused a decline in transport demand, and hence, energy consumption also decreased by 10.5% between 2007 and 2013. Overall, between 1990 and 2013, the net growth of the EU-28 transport energy consumption is estimated at 22.3%. Road transport accounted for 8.6% of the transport energy consumption in the EU in 2013, followed by international aviation with 12.7% [16]. The energy consumption growth analysis indicated that factors, such as high oil prices in the past, the economic recession, higher efficiency of vehicles and slower growth in mobility, as well as other specific causes contributing to changes in energy consumption over the past decades, should be taken into consideration.

The target of 60% reduction of CO_2 emissions from transport by 2050 set out in the White Paper (2011) is a very ambitious goal. One way of bringing the transport sector closer towards reaching this goal is alternative fuels. At present, the market development of alternative fuels is still held back by the technological and commercial shortcomings, the lack of consumer acceptance and missing adequate infrastructure. The current high cost of innovative alternative fuel applications is largely a consequence of these shortcomings.

The use of fossil fuels across the EU economy continues to decline, in part, due to increased consumption of renewable energy sources, such as wind, solar and biomass [29]. The transport sector is very important concerning its share in energy consumption. The amount of transport energy used to produce one unit of GDP has declined since 2000. In 2013, about 33 g of oil equivalent for each EUR of GDP was used to satisfy the total transport demand in the EU, compared with some 37 g in 2000 [16]. This ongoing reduction indicates relative decoupling of energy consumption in transport from economic growth over the long term. It means that GDP grew at greater pace than energy consumption from the transport sector. This target was set out in the previous White Paper 2001. It should be also noted that although energy consumption of transport per unit of GDP declined, the long-term trend is unfavourable because energy use was still slightly higher in 2013 than in previous years.

Table 2 Renewable energy final consumption in transport (biofuels) in the EU-28

Technology	Final energy (ktoe)					Growth rate (%)		
	2005	2012	2013	Proxy 2014	NREAP 2020	2005–2013	2012–2013	2013–2020
Biodiesels (all)	2,565	11,492	10,293	11,076	20,920	19	−10	11
Biogasoline (all)	560	2858	2717	2700	7324	22	−5	15
Other biofuels (all)	155	117	126	357	746	−3	7	29
Compliant biofuels	3,240	11,595	11,932	12,841	28,989	18	3	14
Total	3,276	14,467	13,135	14,133	28,989	19	−9	12

Source [29]

According to the TERM, the proportion of renewable energy used by the transport sector is growing, but is still considerably small. The share of renewable fuels in transport in the EU-28 was 5.4% in 2013. Table 2 shows the development of the use of biofuels in this sector up to 2013, approximated estimates for 2014 and their expected development based on the National Renewable Energy Action Plans (NREAPs).

The gross final consumption of compliant biofuels was 11.9 Mtoe in 2013, which corresponds to an increase of about 0.3 Mtoe compared to 2012. It can be noticed that over the period 2005–2013, the annual growth rate was 19% per year. It is worth mentioning that in order to realise the NREAPs target for 2020, the growth rate should be about 14% per year over the remaining period. The trends in biofuels consumption emphasise that since 2005, the gross final consumption of biofuels has increased strongly, but it has slowed down and more or less stalled since 2010. Year 2013 was the first year when the total consumption of biofuels decreased compared with the previous year. Most countries are below the expected realisations in their NREAPs.

The renewable transport sector has a separate RES target for 2020, which is equal to 10% for each member state. Of all EU countries, Sweden consumes the largest amount of renewable energy in transport, with a figure of more than 16% in 2013, and therefore has already reached the Directive's 2020 target. Finland showed a considerable increase in the use of renewable energy sources in transport compared to previous years, with a share reaching almost 10% in 2013. Finland is very close to reach this level. The 7% share is observed in such member states as France and Austria. If an average of 5.4% is assumed, 19 countries are below this average and 5 countries (Bulgaria—5.6%, Denmark—5.7%, Germany—6.3%, Poland—6%, Czech Republic—5.7%) are above 5.4%. The lowest share occurred in Spain (0.4%), Portugal (0.7%), Estonia (0.2%), Cyprus and Greece (1.1%).

In summary, the proportion of renewable energy used by the transport sector is growing but remains small. Several reasons lie behind the slow uptake of renewable fuels across the EU, including the market uncertainty caused by delays in finalising the legislation limiting the risk of greenhouse gas emissions due to indirect land-use change, relatively high abatement costs related to biofuels and slow progress in the deployment of second generation biofuels.

Alternative fuels are also urgently needed to reduce the overdependence of European transport on oil. Transport in Europe is 94% dependent on oil, 84% of it being imported. As it is stated in the White Paper (2011), the challenge is to break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility. In line with the flagship initiative "Resource efficient Europe" set up in the Europe 2020 Strategy and the new Energy Efficiency Plan 2011, the paramount goal of the European transport policy is to help establish a system that underpins the European economic progress, enhances competitiveness as well as offers high-quality mobility services in line with the efficient use of resources.

The supply of oil, and thus the mobility, depends to a large extent on politically unstable regions, which raises concerns about the security of supply. According to the EC, the EU strategy for the transport sector to gradually replace oil with alternative fuels and build up the necessary infrastructure could bring the annual savings on the oil import bill of 4.2 billion in 2020 [30]. More importantly, this support to the market development of alternative fuels as well as investments in their infrastructure will generate growth and employment in Europe.

In addition to influencing the demand for transport and the energy consumption, improved efficiencies and technological factors have also greatly affected the environmental performance of transport. However, these improvements in energy efficiency alone are often insufficient to reduce the environmental pressures, especially that energy efficiency can make products or services cheaper, which in turn may lead to the increased demand, and this phenomenon is knows as a "rebound effect" [21].

The technological development of the "Euro" emission standards plays an important part in reducing emissions of air pollutants from passenger cars, LDVs and HDVs. Over time, the standards have been progressively tightened, therefore necessitating improvements in the exhaust control technologies. Unfortunately, although the vehicle emission standards can be effective in reducing exhaust emissions per vehicle, the real reduction in emissions was not always significant. However, this approach is also important in other transport modes (i.e. maritime and aviation in particular). These modes face the substantial time lags before the introduction of new technologies.

Conclusions

As it was stated in the introduction, the sustainable transport system is one of the greatest challenges in the pursuit of sustainable development. A wide range of environmental problems has to be solved in ways that are compatible with social and economic goals. The EU itself has set the ambitious targets for the decarbonisation of the transport sector. However, according to the European Commission's own projections, the White Paper's (2011) decarbonisation targets will not be met unless further ambitious measures are taken. It is clearly stated that curbing mobility is not an option. New transport patterns must emerge, according to which a larger volumes of freight and greater numbers of travellers are carried jointly to their destination by the most efficient transport. Individual transport is preferably used for the final miles of the journey and performed with clean vehicles.

'Growing out of oil' will not be possible if relies on a single technological solution. It requires a new concept of mobility, supported by a cluster of new technologies as well as more sustainable behaviour. Such tools as land-use planning, the support of intermodality and integration between modes, pricing of infrastructure or building public acceptance should be included in the active transport policy instruments [31].

Land-use planning is an essential tool to integrate the environmental concerns into the transport policy. By influencing spatial structures and the use of these, land use notably affects the length of trips and the choice of transport modes. Integration within the transport modes supports these actions.

The technology penetration, market creation and technology developments are key measures of the progress towards clean energy deployment. However, it should be pointed out that public acceptance is crucial for every integration approach. Very often, it is a major obstacle for the introduction or wider use of some types of policy instruments. Experience also shows that acceptance tends to increase after implementation. Nonetheless, building acceptance is a long process that must start long before the tool begins operation and continue afterwards. Moreover, acceptance depends heavily on the way in which technical information on impacts is provided to the public.

Another important area is an institutional cooperation between ministries (transport, environment and, where applicable, spatial planning and health). This is essential for the development and implementation of integrated transport and environment strategies. Improving the coordination of transport, environmental and spatial planning policy by means of systematic cooperation between transport and other ministries can meaningfully attribute to the development of broadly supported, transparent transport policy.

There is a need for a long-term strategy on alternative fuels that has to meet the energy needs of all transport modes and be consistent with the EU 2020 strategy, including decarbonisation. The security of energy supply to transport is warranted by the wide diversification of sources for different alternative fuels, in particular through the use of the universal energy carriers of electricity and hydrogen, and the close link to renewable energy sources.

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Idea of Sustainable Development of Transport with Special Reference to Air Transportation

Anna Kwasiborska

Abstract The idea of sustainable transport is an important aspect with reach beyond countries of the European Union. Opinion of the European Commission defines conditions that should be fulfilled in order to achieve certain goals. Transport should be the same for the current and future generations, safe and without risks to human health or natural environment and provide communication accessibility. Moreover, to guarantee efficient operation, there should be available choice of means of transport and their integration with other options in proximity of an airport. This chapter presents an important matter of air transport integration with other means of transport. It puts a thesis that different means of transport must cooperate to be included in the system of sustainable transportation, with special attention paid to air and railway transport. It was noted that aim includes definition of air transport role in integration with other means of transport.

Keywords Sustainable transport · Integration of transport · Transport policy

Introduction

Sustainable transport is associated with efficiency, meeting the expectations of society, aimed at economically advantageous, at the same time minimizing the harmful impact of transport on the environment. This includes both the control of emissions of harmful compounds present in exhaust gases, and the (long-term) the transition from means of transport based on fossil fuels for vehicles using renewable energy. The assumptions of sustainable transport should also reduce the scale of destruction of space this is particularly the urban space, due to the dominance of individual car transport, whose examples are extensive parking lots or sidewalks and cars occupying a different space for pedestrians [1].

A. Kwasiborska (✉)
Warsaw University of Technology, Warsaw, Poland
e-mail: akw@wt.pw.edu.pl

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Until recently, transport references showed trends to present rail and air transport as opposing, competing sectors. It is worth to notice the advantages that are possible to achieve when these two transport sectors work together.

Important aspects of transport development are related to integration of air and railway passenger transport in proximity of airports, defining areas where considered sectors have the potential to complement each other and defining factors that affect the decisions of construction of railways that support airports [2].

Dynamic development of air transport, which could be seen in Poland over recent years, is a part of worldwide trends. Passenger and cargo air transport is the fastest growing transport sector, and predictions on air traffic intensity show that growth dynamic will not change until 2030. Passenger and cargo transport from airports to urban areas require implementation of sustainable transport development. This involves appropriate control, coordination and organization of passenger and cargo flows to and within urban areas via other types of transport. Transport in Poland grows dynamically, and the European Union subsidies allow for modernization of railways and investments in airports [3].

Sustainable Transport

Transport is a very important piece in economic infrastructure puzzle and it greatly affects the dynamic growth of cities and regions. Transport facilitates fast and free movement of people, services and goods, which leads to capital flow [4]. Transport allows for economic growth, influences investment development by improving employment and multiplies income. Mobility is very important for domestic market, and also for quality of life for citizens who have the possibility of free travelling. Mobility of citizens to change workplace may be a factor to equalize the efficiency on the labour market. Bearing challenges in mind, the transport development must be sustainable.

The idea of sustainable transport is connected with the idea of world development thanks to the integration of natural environment with social and economic activities. This means efficient transport that meets social requirements, that is economically favourable, at the same time reduces harmful effect of transport means to environment to minimum. Therefore, actions are taken to reduce social demand for road transport. Idea of sustainable transport concerns all countries of the European Union. The European Commission experts' opinion defined the conditions that should be met. Transport should provide accessibility to route destinations in a way that is equal to current and future generations, safely, without risk to people or environment. Additionally, it should work efficiently, offer possibility to choose means of transport, and sustain economy and regional development [4].

Concept of sustainable development is an idea that originates from UN report of 1969. A sustainable development concept appeared, with integration of striving for prosperity and improvement of natural environment condition at its foundation. Therefore, the concept of sustainable development is based on the following:

- economic efficiency—profit for community, with consideration of social and environmental costs;
- care for environment—protection of natural, non-renewable resources, reduction in negative impact on environment; and
- social balance—creation of new workplaces and actions for improvement of quality of life.

The concept of sustainable development is reflected in the supreme legal act of Poland, the Constitution, whose article 5 states: "*The Republic of Poland shall (…) ensure the protection of the natural environment pursuant to the principles of sustainable development*". At the same time, Poland accepted statutory obligations of Rio de Janeiro Agenda 21 decisions—Programme for XXI Century in the Act of 27 April, 2001: Environmental Law, which defines term of sustainable development as social and economic development that includes integration of political, economic and social actions with preservation of environmental equilibrium and permanence of basic environmental processes in order to balance environment availability to communities and citizens, for both current and future generations.

In colloquial understanding, sustainable transport includes means that minimize emissions of carbon dioxide and other substances harmful to environment. However, sustainable transport development is a concept that integrates ecologic, social and economic goals as seen from standpoint of transport policies in specific countries as well as by the European Union as a whole.

Integrated Transport System

Current actions for people and goods movement are aimed to create a system that will optimally satisfy transport needs and will connect functioning of all transport sectors into one entity, internally and externally. This concerns inter-sector actions and whole economy with branches that rely on transport. Those goals are covered by the term of integrated transport system. Great benefits may be achieved from cooperation of railway with other means of transport, in particular with air transport in global transport system. It is important to integrate them spatially to the greatest extent possible, which will allow fully free movement in collective transport. The integration brings the need for organizational improvements that reduce waiting time for passengers when changing means of transport it must allow for planning whole travel at its beginning and allow to purchase tickets for the whole route between starting point and destination. Railway transport should be oriented towards clients' needs in order to take over part of road transport capacity and to cooperate with other sectors, e.g. air transport. It should include offer of intermodal services [5], while being a positive response to the needs of those who consider factors such as punctuality, reliability and use of new media in gathering information and helpful to organize a travel.

Support of railway transport within strategy of sustainable transport seems to be the right idea because of low environmental footprint and thus generation of the lowest external costs. Cooperation of railway with other transport means shows a great potential. However, it must be noted that careful consideration is necessary in decision-making when defining tasks, where railway should play a crucial role, as well as consistent politic actions in European and worldwide scale and systematic financial investments. Railway transport proves perfectly in crowded cities. Rolling stock travels along a separate track. One specific feature of railway traffic is earlier planning, and the time schedules define its functioning. Another important factor is small susceptibility to weather conditions. This advantage is important in comparison with air transport. Both rail and road transport play a crucial role in integration of urbanized areas with air transport. However, goods movement to and within urban areas is mostly carried out via road transport. Surveys carried out in UK capital showed that approximately 18% of vehicle traffic in the city is cars for enterprise provisioning [6]. Another 22% of city road traffic is vehicles for delivery services and of parcel companies that render services to individual clients by delivering ordered items to addressees. Surveys in Germany showed that 80% of all the city areas transport is done via road transport [7]. The reason lies in relatively short travel distances due to use of road network and possibility to deliver goods directly to recipient (which is usually impossible for railway or air transport). Therefore, trucks and delivery vans play a crucial role in functioning of cities by supplying goods to citizens.

It is necessary to notice problems and difficulties that appear when transporting cargo via road transport in urban areas. There are various problems, and they have different origins. They include the following [8]:

- problem of crowded cities and throughput,
- bad condition of transport infrastructure,
- aspects of city transport policy, e.g. restrictions for entry into city area for certain time periods, for vehicle size or weight, or excluding road lanes only for city passenger transport,
- problems with vehicle parking at loading and unloading space, no regulations for these aspects, tickets and fees, no parking lots,
- problems with queues to delivery acceptance points, finding addressees, determination of delivery time at addressee or client's premises.

Delivery of goods from air cargo terminals and organization of cargo transport in cities requires to establish proper cooperation between governors of the cities, carriers, shippers and other entities. The cooperation should allow to supply urban areas and at the same time observe ecology requirements, reduce operations and city traffic to minimum and create transport system that is economic, efficient, prompt, reliable, rational, safe and environmentally friendly [9].

Importance of Air Transport

Air transport is one of the most advanced and dynamically growing branches of transport. Aircraft move along airways and the movement itself requires ongoing coordination; therefore, appropriate airport infrastructure equipped with ground handling systems is necessary. Operation requires high capital investments and well qualified, selectively employed personnel.

Compared to other transport sectors, air transport features high safety, where safe transport process is defined as a process undisturbed by dangerous situations (events, accidents). In aircraft traffic, it is usually based on ensuring appropriate separation distances around a plane [10]. Considering mobility, air transport features easy accessibility of European and world regions and is important to fully benefit from economic potential and unify world markets. Airports and air carriers are the most important air transport entities, but it is the location and development of airports that have great impact on surrounding regions [2].

Development of air transport, which could be seen in Poland over recent years, is a part of worldwide trends. Air transport is the fastest growing transport sector and one of the important sectors in the world economy that generates great income yearly [11]. Additionally, using the air transport allows for short flying times. However, it does not mean short travel time in general, because it is necessary to include earlier presence at the airport to pass safety procedures. Nowadays, on short and medium distance routes between city centres, direct railway connections compete with air transport. Proper infrastructure, railway lines and rolling stock that exceeds speed of 200 km/h allow for fast travels to cities.

Reduction in airport access time and minimizing time of stay at the airport are factors that influence the perception of the transport as one entity. Moving by plane on long distances and getting from conurbation to the airport efficiently is an important factor for passengers.

Until recently, using air transport has been a sign of luxury. Air tickets were priced beyond acceptable levels for most people. Low-cost carriers brought revolution to the market and offer cheap tickets while meeting rigorous safety requirements.

Lower prices of passenger transport result from few factors that reduce costs of flight operations. Low-cost carriers use airports that offer cheaper operation, located at considerably inconvenient distance from destination cities. There are unavailable services, usually offered by other carriers, such as free meals and beverages on board, access to entertainment system, full attendance and luggage options.

Another thing to note is reduction in on-board staff to absolute minimum required by regulations, reduction in aircraft presence on the airport or using selected services from ground handling companies.

Evident disadvantage of air transport is high susceptibility to atmospheric conditions. Heavy rain or fog prevents air traffic. In spite of many attempts and advancements in technology, it is still impossible to create algorithm or a device that could present fully reliable weather forecasts.

Passenger or cargo air transport is not profitable on short distances. Aircraft offers advantages of achieving high flight speeds. Benefits of such features are noticeable on long distances. Aircraft has significantly smaller capacity than rail vehicles, and in cargo transport, it determines profitability of transport services. High cost is a disadvantage of cargo transport via aircraft, and this results from high fuel consumption during a flight.

Factor that enforces maintaining a high safety level is high susceptibility to terrorist attacks. In spite of high standards of safety procedures, it is impossible to fully eliminate the risk of such event occurrence.

Transport in Conurbation

All transport means have their strong and weak points. High speeds achieved by vehicles are connected with unprofitable conditions for short distance services. Air transport on such distances is expensive, which reflects in small interest shown by passengers. Railway transport can offer lower prices, but it requires proper infrastructure and satisfactory level of rolling stock reliability.

Therefore, it is worth to search for ways to integrate these two means of transport, using their strong points. System worth considering would include air traffic that runs transport services on long-distance routes, e.g. international and railway that runs domestic movement on medium distance routes, linking conurbations and inter-conurbation areas. Another thing to take into account would be ways to connect airports with city centres using railways, expected to be the future of transport.

Conurbation is a specific system that contains one large city surrounded by smaller cities and it needs an efficient interconnecting system that meets the needs of the passengers. From the traveller standpoint, apart from satisfactory level of transport options it is also important to provide information to allow travel planning.

Airport operation is defined by close relationship with conurbation it operates for, and which creates demand for air transport services. Determination of proper size of the airport and other transport branches in context of conurbation must be supported with studies, which should include the following conurbation parameters: population in the neighbouring city of the airport under examination and the population of the conurbation. Parameters important for airport evaluation should include communication accessibility in the scale of the city and the conurbation. Considering connection between airport and conurbation, good connection network inside the city and conurbation is important. Such analyses may be helpful in reasonable use of existing infrastructure and development of new airports in Poland —by improvements in coordination of airport infrastructure planning.

Approach to communication of an airport with conurbation requires consideration of anti-noise procedures. The consideration is necessary and may prove to be an important issue when defining guidelines for development plans for existing airports and construction of new airports.

Well-developed network of airports significantly impacts region economy, improves economic activities and facilitates cooperation in terms of economy, politics, science and technology. Many international corporations use aircraft in their activities and this may be important in decision-making process when considering locations of potential economy investments in a voivodship. Additionally, no access to airport may be a decisive factor against specific location for a company seat. Small distance from the airport is important in particular to foreign investors and international companies, since it allows for fast and direct connection with many places in Europe and around the world. In business trips, it allows to achieve one of the most valuable resources in the world of today, which is time. Air transport role is especially important in the most advanced economy sectors.

Good connection network between airports via suburban railway and long distance railway may improve transport network of the country. However, it is difficult to clearly identify the factors that make a good railway connection between airport and the city centre. Decision about railway line construction may bring unforeseen consequences, adversely affecting business activities of the airport. Car park near the airport can be used as an example. Let us assume that most of the passengers use railway connection, and this will reduce income from parking fees, and in the worst case, there will be no return of construction costs of parking lots.

Due to high costs of railway infrastructure construction, it is important that the airport generates large passenger flow. Now the questions arises whether to create direct connection between airport and the city centre, or include airport station into system of the conurbation railway network. Idea of fast urban railway seems reasonable, because it provides high capacity for passenger movement. It is worth to consider if conurbation citizen and a traveller heading to the airport have the same transport needs. If the needs are not equal, then what is similar and what are the differences. Short travel time and time schedules adjusted to flight schedules will be important to a passenger who wants to get to the airport. Therefore, it is very unlikely to create a transport line that meets the needs of commuters living in the conurbation area and airport passengers at the same time.

Airport accessibility is one of the factors that define quantity of people who want to use services available at the airport, and this is the type of passengers that bring income to the airport. Railway suited to the needs of workers or conurbation citizens will not be profitable to the airport, thus reducing number of people who use the airport.

High-speed railway is now successful in Europe and around the world. Initial assumptions that defined high-speed railway as a way to take over passengers who use air and road transport turned out to be true [12]. This type of transport is advantageous in areas such as reduction in travel time, reduction in traffic crowd, better safety in transport, reduction in energy consumption and pollutions, and—which is very important factor nowadays—improves attractiveness of cities and regions it supports, which contributes to social and economic development of the countries. It brings high values of public procurement, which improves economic condition, greatly affects modernization of railway system as a whole, leading to greater efficiency in maintaining railway services and enhances income of infrastructure managing entities and operators.

High-speed railway is not only proper infrastructure, but also rolling stock. Requirements that define these elements are set out in respective documents: Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system [13] and Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the community.

Each of the aspects such as railway connection between city centre and the closest airport and connections between centres of the cities requires a plan that defines the greatest chances to meet the transport needs of people. Construction of railway line to the airport is an important step towards improvement of transport within the region, which translates to connection system in the country. It is important to offer appropriate frequency of vehicle runs. When considering connection with the airport, train schedules must be coordinated with flight schedules, so the departing/arriving passengers do not have to wait too long. It is not a simple task, but it is necessary to aim for the best possible coordination between train and flight schedules. Equally important issue is appropriate promotion of the connection.

Combined ticket is a widely discussed idea, which allows to plan whole travel route at its beginning and includes travel using different means of transport. The idea seems very interesting from the traveller point of view, but it is a complicated issue for companies that offer transport services. The problem is obviously a material issue. Matters of argument are as follows: who should earn income and at what percentage, who should bear the costs and at what percentage and which is the most important, should the control lie within a central authority, regional authority or a private company.

Summary

Efficient connection system in the country serves to satisfy the transport needs of inhabitants. Requirements for modern systems of passenger transport are as follows: short travel time, safety and reliability of transport means, independence from weather conditions, high throughput capacity, travel comfort and use of environmentally friendly technologies.

Air transport is the perfect sector for international services, wherever other means of transport would not allow for the connection at all, or would imply time of the travel that is unacceptable for passengers. Air transport services on short distances are profitable only with the use of private jet aircraft that can carry a dozen passengers or so. Scheduled aircraft flights using short distance jets require substantial flow of passengers that Poland cannot create in the nearest future. Therefore, it is worth to consider air taxis that carry out transport services with business aircraft with capacity of slightly over ten people.

Establishment of proper communication between airport and other means of transport is a good and necessary idea. Ease of access from the conurbation centre is one of the factors that impact airport competitiveness. Availability and close distance to parking lots for people who reach airport by individual transport have similar importance.

Evaluation of transport process quality in conurbation is defined by timeliness (carrying out services in defined time), short time of carrying out, reliability (regarding time and cost) and safety. These are the main criteria when passengers choose certain means of transport over the others. Airport surrounding and connection with conurbation are key aspects to its development.

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A Concept of Freight Traffic Flow Regulations in the City of Gdansk

Daniel Kaszubowski and Filip Heleniak

Abstract The chapter presents a concept of introducing time restrictions for heavy goods vehicles on selected road sections in Gdansk's city centre. To assess the effectiveness of these regulations, available traffic data were used to understand their effect on the level of service. The results show that if HGV traffic was to be banned during specific hours and provided with alternative routes, the risk of difficult traffic conditions will be reduced. Forecasted traffic increase until 2030 was also considered. The solutions were put in the broader context of urban freight transport management with reference to the need for reliable data and cooperation with the private sector.

Keywords City transport planning · Urban freight · Freight traffic management · Traffic regulations

Introduction

Urban transport management as a process must adapt continuously to the changing socio-economic environment and ensure that transport resources are used optimally. Polish and European transport policy has been recently transforming towards sustainability of transport taking account of all types of transport and user groups. Understandably, one of the priorities is to stop the decline in public transport usage and address mobility issues in the broad sense. Urban freight transport, on the other hand, is given less attention. This is primarily the result of a lack of experience and the difficulty in having to respond to the dynamic changes in the transport market, especially as urban consumption needs keep growing. The majority of planning

D. Kaszubowski (✉) · F. Heleniak
Faculty of Civil and Environmental Engineering, Gdansk University of Technology, Gdansk, Poland
e-mail: daniel.kaszubowski@pg.gda.pl

F. Heleniak
e-mail: heleniakfilip@gmail.com

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documents identify transit traffic and heavy goods vehicle traffic with all their negative consequences as the main problem. While this limited approach may be debated, the knowledge available on urban freight transport justifies it. There is a lack of data on logistic chains in urban areas, the methods to analyse them or practical knowledge to help with planning improvements.

Given the challenges presented in the article, a decision was made to verify how the freight transport system can be changed in Gdansk. To that end, a definition and structure of urban freight transport were presented along with an identification of data that are required for the analysis. An overview is given of practical solutions already in use that help to optimise freight transport. This is based on previous analyses [1] and a regulatory framework which is the most commonly used in practice.

Based on the information collected, it was decided that the analysis should look at time restrictions for HGVs on a selected route in Gdansk city centre. The reason for this choice is the availability of vehicle data and the possibility to use a relatively simple method to assess the proposals. The analysis considered heavy goods vehicles whose mass is above 3.5 tonnes using roads that are part of Gdansk city centre's (Śródmieście) primary transport network. Reliable data on delivery vehicle movements are not available although they are responsible for the majority of delivery services to shops and services in the city centre.

Because of the city's spatial structure and the location of the port and industry, i.e. quite close to the city centre, trucks are a serious problem in the area. In addition, the opening of the Martwa Wisła river tunnel in 2016 may give rise to more discussion about city centre traffic.

The intention of the authors is to present the possible ways to manage HGV traffic and how it may affect other road users. On the practical side, suggestions will be offered to emphasise the need to change transport planning policies to reflect the specificity of urban freight transport. This includes having access to reasonable sources of transport information and methods for transforming the data into effective measures of urban transport policy.

HGV Management in Urban Areas

Types of Transport Within Urban Goods Transport

Freight transport is an increasingly frequent topic in discussions on, e.g., updating urban transport policy or having to solve the problems of more and more transport in built-up areas. The definitions of the problem, however, vary significantly, making it difficult to understand the role of goods transport as part of overall transport. As a result, managing stakeholders' interests is becoming increasingly more difficult. The specificity of urban freight transport goes back to the following:

- The goods transported: a variety of suppliers and types of goods, many different supply chains occurring in parallel, changing demand causing smaller loads and more frequent deliveries;
- The characteristics of transport: an almost complete domination of road transport, a variety of types of vehicles, differentiated types of deliveries (direct delivery, combined delivery, etc.) and a high proportion of personal transport.

The functional complexity makes it unclear as to what the demand for urban freight really is in relation to, e.g., the population number or jobs. Available sources suggest a cautious approach when defining these indicators [2]:

- 0.1 delivery or pickup per person per day;
- 1 delivery or pickup per job per week;
- 300–400 truck trips per 1000 people per day;
- 30–50 tons of goods per person per year.

Urban freight transport has the following types of supply chains, each with a different structure, number of participants or demand for logistic infrastructure [3]:

- Direct—without any contact points, e.g. the customer buys online and the producer or seller sends the products directly from the production site or depot to the consumer;
- With one contact point that is usually called the retailer: in this case, the producer uses the network of retailers in order to reach the consumer;
- With one or more contact points to consolidate or deconsolidate the load: these types of points derive from the need to reduce logistic and transportation costs while providing an optimal level of service.

Figure 1 presents functional relations in urban freight described above.

This complexity of existing supply chains means a variety of vehicles which makes organisation and regulation more difficult [4]:

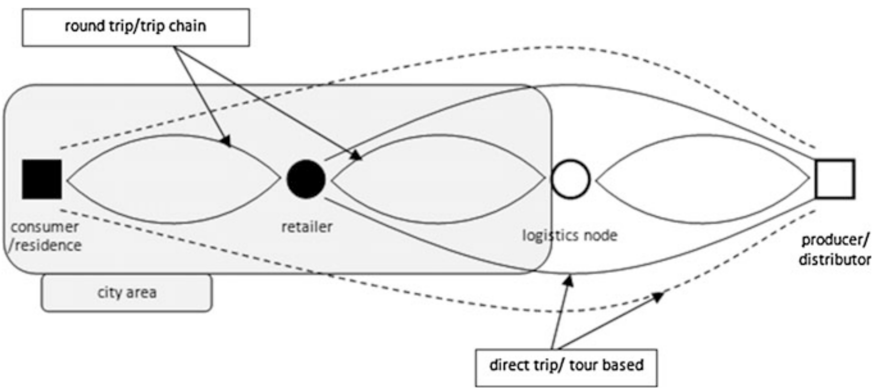

Fig. 1 Functional relations in urban freight. *Source* Russo and Comi (2010)

- Delivery vehicles used for inter-establishment trade (commercial, industrial, services) and home delivery;
- Vehicles for business trips (craftsmen, servicing trips to establishments);
- Own account transport and professional transport;
- Vehicles involved in urban services and management (waste, public works, road management);
- Vehicles delivering to construction sites;
- Private vehicles which carry goods (household purchasing).

The current meaning of goods transport includes freight transported for deliveries and pickups, including home deliveries, delivering works (e.g. construction sites) and simultaneous business and goods supplying and servicing trips [4].

Data Used for Analysing Urban Freight Transport

Any urban freight plans and their implementation must be based on an understanding of the logistic and transport processes in a given area [5]. As much as it may sound obvious, it is anything but especially when confronted with the reality in the majority of towns in Poland and abroad. This is clear from the available research [6]. Clarity is needed on the types of information to be collected, sourcing it regularly and being able to interpret it in relation to user needs and specific problems. We have to have knowledge about the following:

- Characteristics of traffic involving different classes of trucks;
- Logistic parameters of the trips made by these vehicles.

Both areas are closely interrelated when it comes to their functionality which makes managing them even more difficult because of the different sources and uses. The structure of truck and delivery van traffic depends directly on the location, type and concentration of the recipients and their differentiated demand for delivery. Unlike passenger flow analysis in public transport, one major problem that has not really been solved in the practice of traffic engineering is the ability to identify reliably the source–destination relation of freight vehicles. Tried and tested methods of traffic modelling can only be used with difficulty, despite their success in other applications. As a result, we can be relatively clear on the number of HGVs and delivery vans in a given area (e.g. using cordon tests) and their percentage in daily traffic, but we cannot obtain accurate information about what generates the demand for transport services. An extended list of parameters that could be useful for planning urban freight management tools may include the following elements:

- Percentage of vehicle load capacity use;
- Percentage of load space volume use;
- Share of empty runs;
- Time of trip, loading and unloading, waiting to load;

- Trips made in a selected area (km);
- Average distance between stops;
- Number of vehicles per 1 recipient;
- Actual time of delivery versus planned delivery time.

In advance of any critique regarding the high level of accuracy of the list above, it should be said that the level of detail will depend directly on the objective of the analysis. When an urban transport policy is first formulated, information is needed to link traffic with spatial characteristics, e.g. where traffic generators such as commerce, service or production are concentrated. When planning dedicated detailed solutions, on the other hand, e.g. how to introduce HGV time restrictions or designate delivery points, a much higher level of detail will be required.

High-quality comprehensive freight flow and related services data are very helpful with planning and decision-making both in the public sector and the transport and logistic sector. The private sector is the basic generator of information about urban freight, and the data are subsequently used by the public sector [7]. It is gaining access to the information that is the problem, and with a strong differentiation of data sources, using the data becomes even more difficult. While a lot of information is available to the public sector (e.g. traffic studies), it does not represent the specificity of the problem.

The growing need for urban freight information is a reflection of the changing role of city authorities [4]. For a long time, the focus was on building new transport infrastructure to support economic growth seen from the perspective of transferring goods between urban economic centres. As a result, priority was given to long-haul transport solutions. As car ownership in developed countries increased, urban traffic was intensifying forcing the authorities to face up to the new problem or problems occurring with unprecedented intensity. They include heavy traffic, managing limited or excessively used infrastructure and sites, eliminating local problems of noise, emissions, etc. and aiming to reinforce (or keep) the value of city centres seen as vehicle of economic value and areas that integrate all urban functions that provide public services. The factors were there, and with a lack of funding, there was very little the city authorities could do to respect conflicting interests of various user groups and deal with the existing traffic structure and street network. This led to growing pressures on the transport and logistic sector and city authorities. The latter had very few data, tools or points of reference to develop effective solutions within the framework of urban transport policy.

In relation to the above characteristics of urban freight, the following are the reasons for collecting data about freight transport [4]:

- Analyse investment projects and the related organisational changes;
- Assess the volume of transport at the local, regional and national level;
- Model and forecast freight transport to improve efficiency and reduce the negative impacts;

- Ensure consistency with standards and regulations, including those from the EU;
- Commercial applications, e.g. vehicle monitoring and fleet supervision;
- Law enforcement (exceeding speed limits, exceeding maximum authorised mass and other regulations).

With so many different needs, it is necessary to use different forms of data sourcing which, as mentioned previously, makes coordination more difficult. The following methods are used to collect urban freight transport data:

- Interviews with transport managers in companies;
- Interviews with recipients (e.g. shop owners or property managers);
- Interviews with drivers during roadside studies or, e.g., at exits from distribution centres;
- Questionnaires sent to transport companies, drivers, recipients and senders;
- Car park surveys and observations of unloading operations and behaviour of delivery and heavy goods vehicles;
- Traffic measurements (manual or automatic);
- Use of new ITS/ICT technologies such as satellite vehicle tracking (GPS), use of visual checks systems (including automated number plate recognition (ANPR) or weigh-in-motion.

Because of the complexity of the challenge involved in collecting urban freight transport data, the system has a number of shortcomings. They are to some extent universal in the majority of the cases analysed [8] and are true of all European countries without exception. The main shortcomings in this area include a lack of

- Data on the use of smaller delivery vehicles (total mass below 3.5 t);
- Understanding of the nature and structure of supply chains in a given area;
- Data on the use of logistic infrastructure (e.g. distribution and logistic centres, wholesale houses, hypermarkets) which generate a lot of heavy goods traffic;
- Data on the characteristics of loading and unloading operations and a dedicated infrastructure;
- Data on source–destination relations for delivery and heavy goods vehicles in cities and their main routes;
- Information about trips made by consumers to buy products.

When analysing the current situation of how Gdansk is collecting urban freight traffic data, it is still a traditional process. Freight transport is seen as just an element of traffic composition without trying to understand the differences and relations between supply and demand. This is true of most cities and should not be seen as unjustified critique, but as an attempt to set the direction of systemic change in how transport is planned.

Regulatory Solutions Used for Freight Transport Management

Regulations are one of the most common measures for influencing urban freight transport. There are a number of measures which city authorities can use. They are as follows [3, 9–12]:

- Access according to weight, length or other vehicle parameters;
- Access to pedestrian zones;
- Double-parking short time restrictions;
- Closing the centre for private traffic;
- Paid access to selected areas;
- Adequate rotation in delivery zones;
- Night deliveries;
- Harmonisation of regulations, also at regional level;
- Delivery time windows;
- Carrier classification;
- Freight zone classification;
- Street classification, dedicated roads for HGV traffic;
- Limitation of loading and unloading times;
- Signalling of truck routes.

Those solutions are designed to optimise the movements of urban freight transport and can help to build more advanced tools for reducing the demand for transport services or using them to make, e.g., electric vehicles or vehicles meeting stringent emission limits [13]. They are fairly simple to implement as long as the input data are available, and a comprehensive analysis is conducted prior to implementation. An earlier multi-criteria analysis of available solutions for Gdansk showed [1] that regulatory solutions could be a good starting point for the city, especially given the current experience in planning urban freight transport.

One of the most important group of measures available for municipalities is the traffic-related regulatory measures. By introducing these measures, city authorities try to solve problems such as congestion and noise pollution. Other justification for such intervention is that many road users act inappropriately, increasing a risk of incidents. Hence, the purpose of traffic-related legislation is to achieve the safe and efficient movement of road users, whether private or commercial [14]. Introduction of regulations must be followed by proper enforcement system to ensure high level of compliance and as result guarantee achievement of the aforementioned objectives such as reduction of adverse impacts of urban transport activities. Enforcement describes measures that are carried out on behalf of administrative bodies to enforce law regulations. Those enforcement measures can be the following [14]:

- Organisational and operational measures such as traffic signalisation, traffic guidance, parking regulations;
- Physical restriction measures such as gates or bollards;
- Control and monitoring such as video surveillance;
- Manual controls by police officers or other administrative bodies responsible for road freight transport control (i.e. the Road Transport Inspectorate, ITD, in Poland).

In general, freight vehicles regulation and enforcement for the purpose of this paper were divided into two main categories: (1) regulations related to inner city urban distribution and (2) regulations for HGV's. Although there may be many similarities between these two types of measures regarding objectives, different solutions are applied. The main reason is that urban distribution and usually long-haul HGV traffic have different specifics in terms of the fleet characteristics, purpose of the trips, origin and destination, etc. In the following paragraph, selected examples of the HGV traffic regulations will be presented. They are as follows: London Lorry Control Scheme (LLCS), lorry routes in Bremen, Germany and transit ban for HGV in Liege, Belgium.

The London Lorry Control Scheme was introduced as an environmental measure to protect Londoners against disturbance caused by lorries over 18 tonnes at night and at weekends. It is based on the Greater London Restriction of Goods Vehicles Traffic Order from 1985. Its objective is to minimise the impact of lorries especially on residential areas and reduce through traffic but without limiting the city's economic activity to develop. The scheme applies to the whole of the Greater London area, and non-London bound traffic is diverted onto M-25 motorway. Lorries are banned from 9 pm to 7 am from Monday to Saturday and from 1 pm Saturday to 7 am Monday. There are exemption provided for lorries which still have to deliver during the controlled hours. Operators have to apply for a permit explaining the circumstances for the exemption. Enforcement of the LLCS is carried out by enforcement officers supported by CCTV cameras.

Another example of regulations for freight traffic is dedicated lorry route scheme introduced in 1997 in Bremen, Germany. The main driver for this regulatory scheme were problems with through traffic shift to roads in residential areas from main routes caused by significant traffic increase on the latter [15]. The main objective is to bundle HGV traffic with appropriate roads using a signing and information system which provides an assistance for drivers and operator in finding the best way to a destination using only permitted roads. Qualitative results were evaluated with traffic counts before and after the implementation of the measure. Average increase of HGV traffic was about 1.5% on major roads, and for residential areas' roads, a decrease of 40% was recorded [15].

The last measure selected to illustrate the framework of the freight traffic regulations and enforcement is transit ban for HGV. The city of Liege is located at a main route connecting Germany and France. Despite the construction of the new tunnel for transit, traffic drivers used the shorter way across the city outskirts. This resulted in the high share of through traffic on the road network and in the city itself.

High concentration of heavy traffic has led to the depreciation of housing in several areas and impacts in terms of noise and visual hindrance.

To ensure that HGV uses the new connection, the regulation has been introduced to ban transit of vehicles over 7.5 m of length and 12 tonnes of weight on the section of Quai de la Derivation. The ban was accepted with a decree by the mayor of Liege.

Vehicles were stopped by police and diverted to take the highway if their destination has been not local (city or port of Liege). As a result, an average traffic reduction has been observed of 20 and 45% of heavy goods vehicles.

Analysis of the Possibility to Introduce Time Restrictions for Heavy Goods Vehicles

Selection of Routes to Be Analysed

To verify the possibilities for influencing Gdansk's urban freight transport system, an analysis was conducted to assess the effects of regulations that would restrict heavy goods vehicles movement on selected routes in Gdansk during specific times of the day. The idea was to improve traffic conditions for passenger cars and public transport buses and take account of the planned changes in the road network which will change traffic on the analysed sections. This refers, in particular, to the road tunnel under the Martwa Wisła river when it is opened. To narrow down the analysis, a review of Gdansk's main routes was carried out based on five factors. They are as follows:

- Daily traffic volume of heavy goods vehicles and how it is distributed over time;
- Traffic conditions;
- Specification and location of the road;
- Forecasted changes in heavy goods vehicles volumes;
- Planned new infrastructure.

Data which were collected during the implementation of TRISTAR, the Tri-City's traffic control system, were used as basis for identifying daily traffic volumes on Gdansk's main routes. Heavy goods vehicles were divided into three categories by the maximum authorised mass. They have the following parameters [14]:

- Delivery vehicles (heavy goods vehicles with maximum authorised mass below 3.5 [t]);
- Heavy goods vehicles (heavy goods vehicles with maximum authorised mass below 3.5 [t] and less than 35 [t]);
- Heavy goods vehicles with trailers (truck tractors with semi-trailers and heavy goods vehicles with maximum authorised mass above 35 [t]).

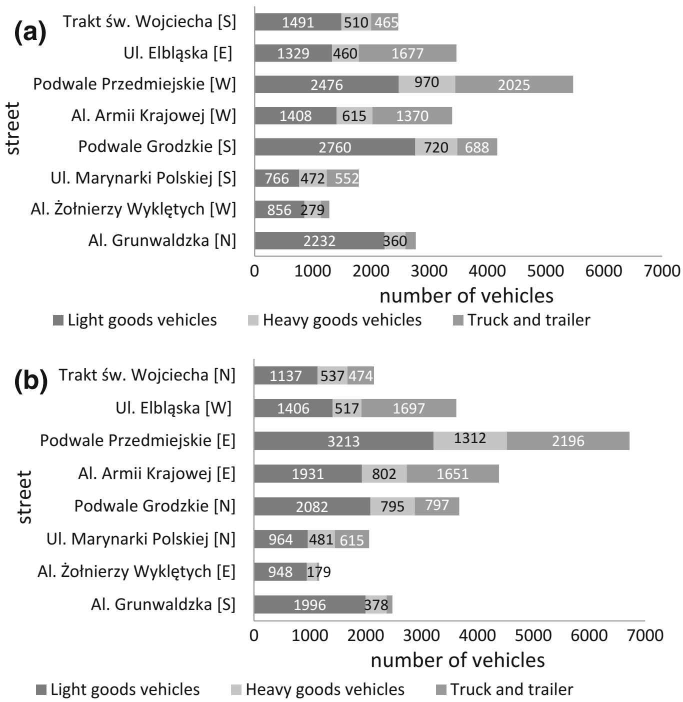

Fig. 2 Daily heavy goods vehicles traffic on collector roads in Gdansk (2012) **a** on exit [15], **b** on entry [15]

Figure 2 shows traffic volumes in two opposing directions—on entry (vehicles going into the city) and on exit (vehicles leaving the city). Next to the names of the routes are geographic directions where the vehicles are headed.

The data analysis shows that routes with the highest heavy vehicles traffic in Gdansk are the arteries of Podwale Przedmiejskie, Al. Armii Krajowej and Podwale Grodzkie–Wały Jagiellońskie.

Please note that a comprehensive study of Gdansk's traffic in 2012 established that these routes are arteries with the highest volumes of passenger car traffic [15].

A combination of these two factors shows that these routes have some of the worst traffic conditions among all of Gdansk's roads. The most common study method, the HCM (Highway Capacity Manual), characterises traffic conditions using the level of service indicator. It is measured on a six-band scale from A to F with A as the best and F as the worst traffic conditions. On Podwale Przedmiejskie, Al. Armii Krajowej and Podwale Grodzkie–Wały Jagiellońskie route, the level of service during the day from early morning to late night is C. This means that the operational conditions within traffic streams make it difficult for cars to manoeuvre and change speed.

A forecast of heavy vehicles traffic (trucks and trucks with trailers) estimates that on average the increase in this traffic on Gdansk's main routes will be 58% on exit and 52% on entry in 2030 compared to 2012. [15]. This justifies the claim that the increase in heavy vehicles alone (excluding forecasts of delivery vans) will reduce the level of service on Podwale Przedmiejskie to D within the whole day, and on the Podwale Grodzkie–Wały Jagiellońskie route, it will be down to D in the afternoon peak hours.

Please note, however, that Podwale Przedmiejskie and Al. Armii Krajowej routes are in fact transit roads. They are dual carriageways with three lanes for each direction and few signalised junctions. As a result, the actual traffic conditions are much better on these two routes than the results suggested by the HCM method because it only looks at the recorded traffic volumes. The Podwale Grodzkie–Wały Jagiellońskie route runs across the Gdansk city centre which makes it a collector road for motorised traffic, trucks and buses. This is because it includes Gdansk's biggest public transport hub integrating regional rail, trams and buses—the Central Train Station.

In addition, with Podwale Grodzkie–Wały Jagiellońskie being part of the urban structure, it provides links to Gdansk's other routes (Al. Grunwaldzka, Al. Armii Krajowej, ul. Marynarki Polskiej, Podwale Przedmiejskie). There are signalised junctions with very busy roads along the entire route. As a result, the actual traffic conditions are much worse than those on Al. Armii Krajowej and Podwale Przedmiejskie. With these factors in mind, it was decided that the analysis should look at time restrictions for heavy goods vehicles on the Podwale Grodzkie–Wały Jagiellońskie route. This choice can be further justified by the fact that a simulation can be made of when heavy goods traffic will be moved to the Martwa Wisła tunnel, due to be opened in mid-2016. This will show how traffic will change once an alternative access to the port and industrial site is provided bypassing Gdansk city centre.

Characteristics of the Variants of Time Restrictions for Heavy Goods Vehicles Access

A time window system was proposed to restrict heavy goods vehicles access meaning a complete ban to use a specific road. To choose the right time windows for the Podwale Grodzkie–Wały Jagiellońskie route, the daily traffic distribution was analysed by types of vehicles. Figure 3 shows the traffic distribution for Podwale Grodzkie–Wały Jagiellońskie by the hours in 2012 on a selected exit.

The volumes are given as the so called number of reference vehicles. This parameter is arrived at by multiplying traffic volumes of different types of traffic by a specific coefficient which takes account of the effect they have on traffic volume. The coefficients for the different types of vehicles are the following [16]:

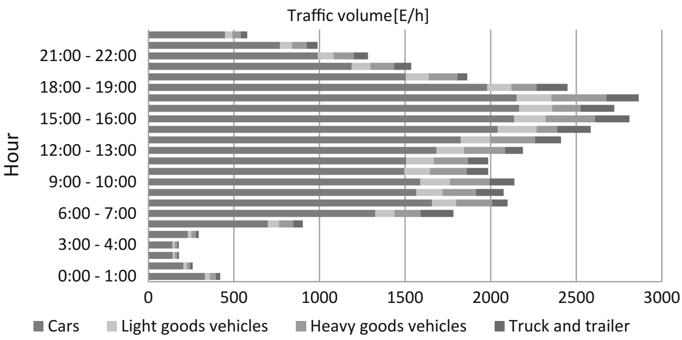

Fig. 3 Traffic volume on Podwale Grodzkie–Wały Jagiellońskie route by the hours (2012)—on exit [15]

Table 1 Proposed time windows for exit and entry directions on Podwale Grodzkie–Wały Jagiellońskie

	Time windows
Exit (S)	3.00 pm–6.00 pm
Entry (N)	6.00 am–10.00 am

- Passenger cars—$E = 1.0$;
- Delivery vehicles (heavy goods vehicles with maximum authorised mass below 3.5 [t])—$E = 1.0$;
- Heavy goods vehicles (heavy goods vehicles with maximum authorised mass below 3.5 [t] and less than 35 [t])—$E = 2.0$;
- Heavy goods vehicles with trailers (truck tractors with semi-trailers and heavy goods vehicles with maximum authorised mass above 35 [t])—$E = 3.0$;
- Buses—$E = 2.0$.

If we apply this methodology, we can say that heavy goods vehicles traffic (heavy goods vehicles with maximum authorised mass above 3.5 [t]) has a stronger effect on total traffic on Podwale Grodzkie than delivery vans, even though nominal heavy goods traffic is lower than that of delivery vans. As a result, and because time window restrictions are difficult to enforce from delivery vehicles, time windows with a complete traffic ban should apply to HGVs (heavy goods vehicles with maximum authorised mass below above 3.5 [t]).

An analysis of traffic time distribution for the above groups of vehicles suggested the following time windows when HGVs would not be allowed to use Podwale Grodzkie–Wały Jagiellońskie (Table 1).

The proposed time window for a complete HGV ban on exit is during the afternoon peak (3 pm–6 pm). This is because traffic during this time is the busiest both for passenger cars and all cars. HGV traffic during these hours in this direction represents on average 9% [15] of total traffic volume of reference vehicles.

The proposed time window for a complete HGV ban on entry is during the morning peak (6 am–10 am). The motivation is the same as for the exit direction—traffic is the busiest both for passenger cars and all cars during this time of day. HGV volumes during these hours in this direction represent on average 10% [15] of total traffic volume of reference vehicles.

Another reason why time windows during these hours for both direction of Podwale Grodzkie–Wały Jagiellońskie make sense is because HGV traffic is the highest or almost the highest during this time of day and because it overlaps with peak hours for passenger transport and the highest bus traffic volumes (representing 7% of total traffic during these hours) [15].

Evaluation of the Results

The simulation shows that time windows restricting HGV traffic on the Podwale Grodzkie–Wały Jagiellońskie route would significantly improve traffic during the analysed time intervals. The results of the analysis are shown in Fig. 4. Numbers 1–6 on the vertical axis correspond to the levels of service from A (6, the highest) to F (1, the lowest).

If they are introduced on the Podwale Grodzkie–Wały Jagiellońskie route, the regulations could reduce total traffic by 10% on average. This will stop the traffic conditions from deteriorating to level D during peak hours until 2030, an unwelcome scenario with bad consequences for all road users, including passenger cars and public transport buses. The analysis focused on a selected road section only. Actual traffic conditions are the result of a number of factors with unclear impacts. The problem can be solved using advanced transport models, simulating changes in the transport system at different levels of accuracy from the operational to the strategic level. Only by applying these solutions, will we know more about how good the planned changes in traffic layout would be.

If it is introduced, the proposed solution could be part of a comprehensive action designed to change the structure of HGV traffic using effectively the available and upcoming infrastructure (such as the Martwa Wisła tunnel). The end result would

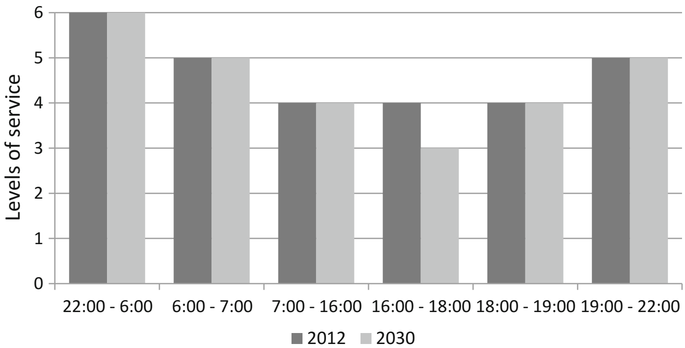

Fig. 4 Traffic-level changes as a result of implementation of proposed truck access regulations

be heavy vehicles using roads that are better prepared technically to handle such loads. Reducing traffic on Gdansk's key element of its transport system will free up unused capacity for other road users. Time-regulated access can be seen as a long-term element of urban transport policy in support of the traditional infrastructural solutions. By coordinating both groups of measures, the effects could be better than if delivered separately. In addition, the regulatory measures could help to form new behaviour of, e.g., logistic operators. If controlled reasonably, HGV access may spur them on to look for new transport solutions. This could be a more flexible delivery plan outside of peak hours. The result will be a more balanced traffic distribution during the whole day. This will require a good understanding of the actual transport and working together with transport companies. It is a must because that way we can ensure that the new regulations respond to the real needs of transport operators. Otherwise, the solutions could not only be ineffective but also disturb local economy.

It must be noted that the concept of HGV traffic time windows had been developed before actual opening of the Martwa Wisła road tunnel in April 2016. Before that date, the city of Gdańsk has introduced even more restrictive regulations for HGV traffic at the road network around the city centre. Total ban for trucks with weight over 24 tonnes has been introduced, and freight traffic has to use the tunnel, southern ring road and other roads suitable for heavy traffic. Determination of the city of Gdańsk to remove freight traffic from the city centre confirms the right approach presented in this paper.

Conclusion

To ensure that urban freight transport is managed effectively and meets the needs of local economy, the organisational effort and a systemic approach will definitely be required. The article gives an example of the possible solutions such as the time restrictions for heavy goods vehicles. While the area of the analysis was limited to one section of Gdansk's transport system, it helped to illustrate the interrelations between different road users. One of the reasons for covering Podwale Grodzkie and Wały Jagiellońskie with the new regulations is the opening of the Martwa Wisła underground tunnel in mid-2016. This emphasised the need for a consistent and forward looking planning of the transport system and one that can incorporate changes. While Gdansk's city centre road network is relatively established, it may have new uses. As an example, there are advanced plans to redesign ul. Podwale Przedmiejskie to change it from a transit road to a more locally oriented road. This type of change usually entails better access for pedestrians or public transport with dedicated bus lanes, as an example. A discussion is needed about how freight transport will fit into this context, an issue that has so far been ignored. The first step presented in the article should be to move heavy goods vehicles to dedicated roads to minimise the negative impacts on the environment. At the same time, new steps should be planned regarding the other types of urban freight transport.

This applies, in particular, to deliveries for businesses and services that concentrate in busy city centres. This does not usually require spectacular investments in infrastructure and does not attract public attention. The possible measures would be to designate sites for unloading in places that attract a lot of deliveries or put up signage for access roads to be used by different categories of vehicles. Such local-level measures have a very strong potential for improving freight transport. Unlike HGV traffic which should be managed at the strategic level, solutions for supplies delivered by delivery vans must be well adapted to the local conditions. The city, as the main actor responsible for the transport system, must face new challenges. This means having to work with the private sector which represents transport operators and their customers. International experience shows that it will take a long time and a clear definition of stakeholder interests and an understanding of the current conditions. As the economy grows, this approach will be indispensable because traditional methods for planning urban transport are not good enough for planning urban freight transport.

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Behaviours of Bus Operators in the Regulated Competition Market—on the Example of Silesia Region of Poland

Grzegorz Krawczyk

Abstract The purpose of this chapter is the analysis of behaviours of operators in the regulated competition market. The subject of study is the public transport market, which is organized by KZK GOP (Municipal Transport Union of the Upper Silesian Industrial District) in Katowice. This chapter contains analyses of: concentration of bus transportation market, results of tendering proceedings and action strategies of operators. This chapter in particular tackles the issue of the process of merging entities into consortia. The main conclusions of the performed analysis concern three issues. Firstly, municipal carriers have the dominant position in the market and usually do not compete with each other. Secondly, there is large pressure from private carriers. Thirdly, the phenomenon of coopetition occurs frequently; depending on the situation, carriers either compete or cooperate in the field of winning transportation orders. Cooperation manifests itself mainly in the process of establishing consortia, which allows the involved entities to meet the requirements specified in the terms of reference.

Keywords Public transport · Market behaviours · Bus operators

Introduction

The public transport market is characterised by natural monopoly. However, in the case of public transport market characterized by a considerable operational work value, market mechanisms can be applied. The model in which operation work is contracted by a public transport organiser through tendering proceedings is referred to as 'regulated competition'. This model assumes competition between public transport operators in the field of executing transport in particular communication routes. The purpose of this chapter is the analysis of behaviours of operators

G. Krawczyk (✉)
Chair of Transport, University of Economics, Katowice, Poland
e-mail: grzegorz.krawczyk@ue.katowice.pl

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providing bus services in public transport in the regulated competition market. The analysis covers the market of KZK GOP (Municipal Transport Union of the Upper Silesian Industrial District), which is the largest public transport market in Poland characterised by market competition. This chapter discusses the specific character of public transport markets, characteristics of the analysed market and analysis of behaviours of operators in 1999–2015. For this purpose, the following issues have been analysed:

- market concentration, on the basis of cumulative and discrete measurements,
- tendering proceedings,
- behaviours of entities, with special regard to the phenomenon of coopetition.

As a result of the analysis, it has been determined that municipal operators have the dominant share in the market, there is a price pressure on the part of private entities and the phenomenon of coopetition occurs.

Models of Public Transport Organization

The municipal transport market is a fragmentary market whose basic specification is determined by [1]:

- transport services in the field of passenger transport as the object of exchange,
- municipal transport companies as service producers and households as purchasers of these services,
- local spatial range limited to the area of one or several cities forming agglomeration with the related suburban areas.

The municipal transport market is characterized by the occurrence of natural monopoly. Natural monopoly is a situation in a goods and services market when occurrence of more than one producer would not be economically justified [2]. This is due to high infrastructural costs and other market entry barriers, which means that the first supplier in a particular market gains a significant competitive advantage over his potential competitors [3]. Natural monopoly is strictly related to the market size [4]. In the case of small towns reporting demand for a relatively low volume of operation work, there might be a situation in which one transport company can be able to satisfy the entire demand. Moreover, this may be more effective than in the event of implementing pro-competitive solutions in such a market.

By adopting the criteria for distinction of the organizer and demonopolization in the field of transport, four organization models can be distinguished (Table 1). Taking up a discussion concerning behaviours of market entities is relevant only in the case of demonopolization of the operator market. Two models which meet the above criterion can be distinguished: transport deregulation and competition regulated by the transport authority. The first of them is not applied in Polish conditions; therefore, the further analyses are focused on the regulated competition model.

Table 1 Models of public transport market organization

		Demonopolization criterion	
		Operator monopoly	Demonopolization of operator market
Separation of functions criterion	Consolidation of functions	Dominating operator	Deregulation of municipal transport
	Separation of functions	Dominating operator controlled by the transport authority	Competition regulated by the transport authority

Source [5]

Due to e.g. occurrence of entry barriers or the functioning of public entities, the municipal transport market is among poorly liberalised markets, which causes domination of oligopolistic structures. The regulated competition market consists in appointing transport authority performing the function of organizer, who commissions operators to perform specific operation work through competitive proceedings. This solution brings economic benefits resulting from market pressure imposed on operators. In order to maintain their market position, they aim at providing services which meet the expectations of purchasers. Purchaser is a transport organizer who is enabled to verify the cost level of operators and select the most favourable offer submitted through tender proceedings thanks to the competition in the market. Reduction of expenses manifested by lower costs of operation work unit is a tangible result of competition between operators. The model of municipal public transport organization, based on regulated competition, has a number of advantages. The main advantages include [6]:

- market verification of unit prices—orders can be won by different operators in terms of entity size, organizational and legal forms of conducting business, as well as ownership and country of entity capital origin,
- impact of public authorities on the size and parameters of transport offer, as well as performance of public control of the organization of municipal transport and cash flows,
- possibility of privatization of public municipal transport operators.

Market Characteristics

The process of economic transition had an impact on significant changes in public transport organization. During the period of centrally planned economy, public transport was provided by special public companies—Wojewódzkie Przedsiębiorstwa Komunikacyjne (WPK, Provincial Municipal Transport Company). During the system transformation, those entities were divided into smaller companies which were either privatised, or became a property of local self-governments. In 1990, the obligation to organise public transport was transferred to municipalities. In the further part of this chapter, the author focuses on the public transport market organized by the Municipal Transport Union of the Upper Silesian Industrial District (KZK GOP). This choice results from the fact that it is the largest market organized in accordance with the regulated competition model [7].

KZK GOP is an inter-municipal association established in 1991 in order to organise public transport in the area of the associated municipalities. Currently, the area of association activity covers 29 municipalities located in the central part of the Silesian Province. KZK GOP organises public transport on 336 bus lines and 28 tram lines. In the case of tram transport, there is one monopolistic operator, whereas in the case of bus transport, regulated competition has been implemented. In this case, KZK GOP contracts transport services based on the results of tendering proceedings. Tenders are announced for one or several lines. Both municipal carriers (originating from former WPK companies) and private entities are functioning in the bus operator market. Since the establishment of KZK GOP, the number of municipalities has changed. In particular, the first few years of functioning of the association were characterised by a dynamic increase of the number of associated municipalities. This was caused by public transport integration in the area of the Association, which increased its attractiveness for passengers and facilitated its organisation. The implementation of market mechanism in the process of public transport organisation required time. The figure presents the formation of the volume of operation work and number of entities functioning in the market in 1999–2015 (Fig. 1).

During the analysed period, the volume of operation work commissioned by KZK GOP was relatively constant—67 million vehicle-kilometres per year on the average. The number of operators in the presented period ranges between 25 and 40. It shall be noted that the number of entities is not directly correlated with the market size. Therefore, the appearance of new players in the market does not result from its increase.

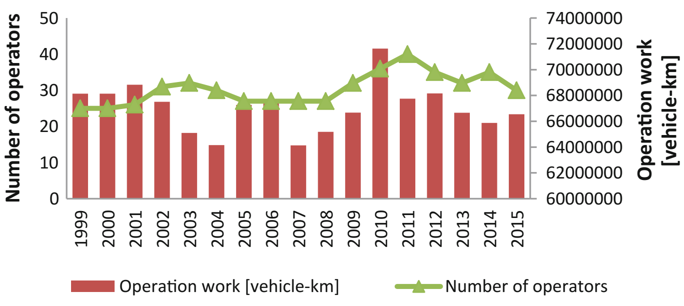

Fig. 1 Volume of operation work and number of KZK GOP operators in 1999–2015. *Source* Own study based on the data of KZK GOP

The market structure, including its concentration level, may have an impact on the behaviours of entities. The notion of concentration, within the meaning of economic sciences, may be defined as a situation in which a small number of companies have a significant share in the market in terms of sales volume, asset value, employment level, etc. In the process-based approach, concentration is defined as an increase of the economic power of business entities. The problems of measuring concentration level are inseparably linked with the analysis of market structures, as well as with efficiency and behaviours of business entities, especially those functioning in the markets with limited competition. With reference to the problems of measuring transport market concentration, the key issue is to define the object of measurement. In the case of contracting services in the regulated competition market, the measurement should be based on the criterion of volume of operation work performed by operators. The application of value indicators for the evaluation of the structure of market share may not be objective, e.g. due to different parameters of operation velocity, or operated routes (empty run) [8].

For the purpose of precise determination of the specific character of the market, the level of concentration was measured on the basis of cumulative and discrete measurements [9]. The values of two indicators were specified: concentration ratio for 4 largest entities [CR(4)] and Herfindahl-Hirschman Index (HHI) [10]. In mathematical expression CR(4) is a sum of shares of four the largest entities and HHI is a sum of squares of shares of all market players. The results have been presented in Table 2.

Table 2 Concentration ratios of KZK GOP market

Year	Number of operators	CR(4)	HHI
1999	25	81	1887
2000	25	81	1863
2001	26	80	1828
2002	31	78	1773
2003	32	76	1697
2004	30	77	1712
2005	27	78	1727
2006	27	70	1584
2007	27	73	1777
2008	27	72	1695
2009	32	70	1602
2010	36	67	1440
2011	40	67	1595
2012	35	71	1597
2013	32	72	1628
2014*	35	78	4454
2015*	30	79	4571

Source Own study

*Consortium of 3 largest carriers was established in 2014

The analysis of the results indicates high market concentration. The value of CR (4) ranges between 67 and 81, which indicates the presence of oligopoly [11]. The HHI index is widely applied by anti-trust agencies and easy to calculate, therefore, it is one of the most popular market concentration indicators [12]. The values of this indicator in 1999–2013 range between 1584 and 1887, which indicates moderate concentration, according to the interpretation of the Federal Trade Commission of the SUA [13]. Additionally, the value of Pearson correlation coefficient between the number of entities in the market and the values of indicators CR(4) and HHI was determined for the data presented in the table. The following results were obtained: −0.69 and −0.65 respectively, which indicates relatively strong inverse relationship between the number of entities and the level of market concentration. In 2014, a consortium of three largest entities was established, which caused a surge of HHI index to the values indicating that the operator market was monopolized (this process was more widely described in the following chapter).

Market Behaviours of Bus Operators

Price is the dominating criterion for offer selection in tendering proceedings announced by KZK GOP. All operation and quality parameters are described in detail in the terms of reference. Therefore, the operators apply price competition between each other, to a large extent. The policy of KZK GOP is focused on gradual improvement of the quality of rolling stock. In the following years, the requirements imposed on the operators have increased, especially with reference to rolling stock—the emphasis has been put on using modern low-floor vehicles, meeting increasingly strict emission standards. The high cost of purchasing modern buses and the necessity of waiting for vehicle supply constitute a market entry barrier. Leasing has been a form of obtaining suitable rolling stock permitted by the ordering party. The operators who want to participate in tenders do not have to possess means of transport at the moment of its announcement; at this stage, they can submit a certificate (from the manufacturer or lessor) confirming the supply or lease of rolling stock in the case of winning the tender. Despite these solutions, having an own vehicle fleet is an important factor in building a competitive position in the market of public transport operators.

When analysing the participation of particular operators in operation work performed by order of KZK GOP, we should pay attention to municipal operators. In 1999–2006, all four largest operators in the market were municipal companies: PKM Katowice, PKM Sosnowiec, PKM Gliwice and PKM Bytom. The main shareholders in those companies were municipalities where the seats of the operators were located. Since municipal companies were distributed within the large area of KZK GOP, there were no conflicts of interest between them. The total market share of the above-mentioned four companies in 1999–2006 gradually decreased from 81 to 70%. PKM Bytom was liquidated in June 2006. As a result of the operator liquidation, there was an increase in the activity of private entities. Since 2007, the group of the largest entities has included a private operator. The described phenomena: downfall of a municipal company, increased activity of private entities and gradual (though minor) decrease of market concentration indicate that the market mechanisms are functioning.

A tendency to form consortia can be noticed in the activities taken by operators. This enables the optimisation of use of rolling stock of operators and combination of technical potential in order to increase their competitiveness. The development of consortia and their market share have been presented in Table 3.

Since 2007, consortia consisting most frequently of two operators have appeared in the market. A systematic increase of the number of consortia acting in the market can be noticed in 2007–2015. This also translates to an increase of their share in the market according to operation work. In 2013, KZK GOP announced a large tender for providing services on 181 bus lines. No single operator was able to guarantee a sufficient number of buses. The requirement was met only by a consortium consisting of three largest municipal operators. This consortium won the tender, due to which more than 65% of the market was taken over by one entity. The signed agreement is valid from January 2014 until the end of 2021. This event halted the previous activities towards the development of market mechanisms. Consortia were mainly established by private entities. Those entities implemented the coopetition strategy by competing and cooperating with one another at the same time. Until 2014, such strategy of private operators would result in limiting market concentration. Municipal entities which had the dominating share in the market were acting on its own account and did not form consortia either with each other or with private entities. It was only the necessity of meeting the requirements of a large tender that induced them to cooperate within a consortium.

Table 3 Share of consortia in the market

Year	Number of operators	Number of consortia	Total share of consortia in the market according to operation work (%)
2007	27	1	6.16
2008	27	3	8.17
2009	32	6	10.47
2010	36	10	15.31
2011	40	13	12.55
2012	35	11	12.92
2013	32	12	10.81
2014	35	16	77.18
2015	30	15	80.25

Source Own study

Conclusions

This chapter presents the development of situation in the market of bus operators acting by order of KZK GOP. This market is organized on the basis of regulated competition model. The implementation of market mechanism has resulted in an increase of market competition and gradual decrease of its concentration. Since 2008, private operators have begun to form consortia, which enabled them to provide strong competition for the dominating municipal entities. By establishing consortia, private operators would implement the coopetition strategy. They took part in certain tender proceedings as individual entities and competed with each other. However, in the case of a lack of sufficient rolling stock reserve, they established consortia in various configurations, cooperating with each other. In consequence, those entities were partly competitors and partly co-operators for one another within one market. Due to their locations, municipal entities would not compete with each other. The impulse for cooperation was the willingness to win a large tender and dominate the market entirely for the period of 8 years. Therefore, it can be concluded that the market structure has an impact on the behaviours of entities. The municipal carriers who had the dominating share in the market have maintained the leading position in the market by forming a consortium. The formation of a consortium was partly forced by the activity of private entities, which would form consortia increasingly frequently, thus implementing the coopetition strategy.

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Implementation of the New Control Command Vital Railway System, Overcoming Associated Challenges

Marek Pawlik

Abstract Due to the long-time separation of the national rail systems, the railway transport is differentiated in technical, operational and organizational solutions. Overcoming technical barriers is obligatory to obtain a competitive railway transport system. Such a system is necessary mainly for the long-distance international freight transportation. Therefore, to achieve Schengen effect in railway transport, European Train Control System has been created as a unified solution. The article points at challenges associated with the implementation of the system and proposes solutions aimed at overcoming them. The key challenges are as follows: the interfacing between existing signalling and control command (vital), the long transition period trackside and on-board causing multi-system operation (to be reduced), the influence on vital operational procedures which are key for transport safety (to be controllable), the minimising influence on cost of railway upgrading projects (to be reasonable). The article analyses possible activities, defines criteria for comparison and points at those which should be undertaken.

Keywords Cab signalling · Control command · Interlocking · Railway safety · Signalling · Train control · Track-train transmission

Introduction

Railway transport is a safe, relatively quick and environment-friendly mode of transport. This statement seems to be obvious. It should not, however, be assumed as granted for ever as a wide range of technical, operational, organizational and economic circumstances are significantly influencing the safety of railway transport and its impact on the environment. Some challenges in that respect are common for railway as a transport mode in general, disregarding the characteristics of the network and rolling stock and operation. Other challenges are typical of particular

M. Pawlik (✉)
Civil Engineering Faculty, Warsaw University of Technology, Warsaw, Poland
e-mail: m.pawlik@il.pw.edu.pl

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countries, for example Poland. The characteristics of the railway transport in Poland and emerging challenges were analysed and presented in "White Paper, Polish railway map of questions" [1]. As the analysis proves, the technical safety can be, and should be, improved. The article is focused on technical safety in relation to the implementation of the new technical solutions. Generally, the most important challenge is to ensure safe working of the electronic equipment, both for the equipment installed on tracks (named the trackside equipment) and for the equipment installed on board of the traction units (named the on-board equipment). Safe working of trackside and on-board equipment requires safe working hardware and safe working software. Safe working is ensured by redundancies, software-based verification functionalities, different compiling applications, safe hardware comparators, special data coding, etc. The equipment for electronic vital safety needs to be constructed according to these principles. However, as shown below, the use of vital trackside equipment and vital on-board equipment is not enough to ensure the safety.

The comparison of the main transport modes (road transport, railway transport, sea transport and air transport) shows not only differences but also some similarities. The main similarities are as follows:

- the internal subdivision into infrastructure and vehicles (roads and trucks, tracks and trains, ports and vessels, airports and airplanes) subdivides responsibility and services between two kinds of stakeholders (infrastructure managers and transport operators) and influences construction, maintenance, financing, and ultimately reliability and safety;
- each type of infrastructure has its performance limits: the maximum gross load (e.g. maximum load per axle), the maximum capacity available at service points (e.g. at a station), the maximum space available for single vehicles (e.g. the structure gauge), the distribution of service points (e.g. the distances between stations), the accessibility (e.g. the distance from transport origin to the nearest service point where responsibility for load can be taken and the distance to transport destination from the nearest service point where responsibility for load has to be handed over), etc.;
- each transport vehicle has its performance limits: the maximum net load (e.g. the number of tons of load which can be taken by a vehicle), the maximum dimensions (e.g. the loading gauge), the availability of different types of vehicles (e.g. availability of platforms for containers), the possible loading and the unloading solutions (e.g. wagon tippers), etc.

The main differences between the modes are the following:

- the road transport: the infrastructure is available practically everywhere, it covers a wide range of vehicle types, service does not require infrastructure-dedicated operational staff, distances generally are limited to 300 km, the load per vehicle is generally limited to 25 tons;

- the railway transport: the infrastructure is only available in a limited number of service points—2500 sidings in Poland owned by industry and logistic operators, it covers a wide range of vehicle types, service requires dedicated staff managing operation along transport routes and in service points, distances are generally limited to 3000 km, the load per train is generally limited to 4000 tons;
- the air transport: the infrastructure is available only in a limited number of service points—14 airports in Poland dedicated to passenger transport and used also for cargo, it covers only a few types of planes, service requires dedicated staff managing operation mainly but not only in service points, distances are generally long as short distances are uneconomical, the load per plane is generally limited to 600 tons;
- the sea transport: the infrastructure is available only in a limited number of service points—4 cargo seaports in Poland, it covers only a few types of vessels mainly for transport of containers, dry bulk and liquids, service requires dedicated staff managing operation in service points, distances are generally long as short distances are uneconomical, the load per vessel is generally limited to 80,000 tons.

The above enumeration shows that the characteristics of transport modes are differentiated, and therefore, multimodal services are reasonable and should be encouraged.

However, due to its historical development, the railway transport still has barriers at national borders. Without overcoming these barriers, an increase of the use of railway transport in multimodal cross-border transport services will not be possible. In practice, without overcoming barriers only wagons will cross borders but traction vehicles and railway staff will not because of diverse technical solutions and operational rules. This is especially problematic within the European Union where several countries are relatively small when seen from the perspective of rail service distances.

Railway Transport Signalling

As already mentioned, the railway technical solutions are diverse in particular countries. Obstacles regarding different traction power supply systems are overpassed by multi-traction vehicles capable to haul trains under 1.5 and 3 kV DC as well as under 15 kV 16.7 Hz and 25 kV 50 Hz AC power supply. Obstacles regarding different track gauges are overpassed by the use of automatic wheel-set gauge changing systems. Obstacles regarding different operational rules are minimised by limited unified European operational rules. Further unification can only be obtained by the unification of signalling. Overcoming these challenges is still a challenge because of the use of different signalling equipment. This challenge

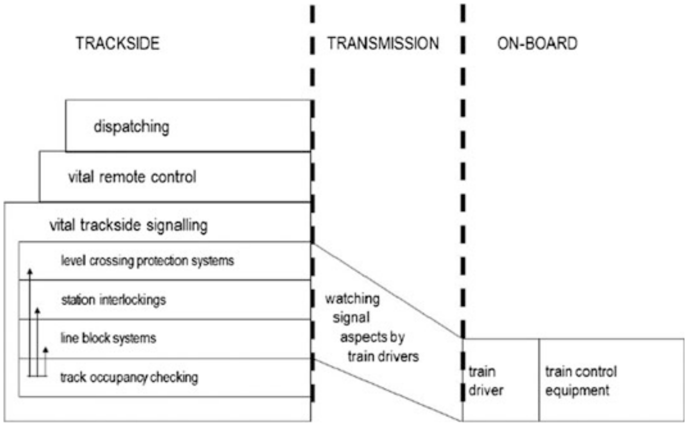

Fig. 1 Traditional signalling without track-train transmission-based control command [2]

cannot be overpassed simply by changing signalling rules all over Europe as this would create unacceptable risk in a long transitional period and would require enormous investments.

Figure 1 shows traditional signalling infographic scheme [2] where line block systems are ensuring train spacing, station interlockings are ensuring the exclusion of conflicting routes and level crossing protection systems are ensuring safety on road–rail crossings. Operation of all those trackside systems is based on the track occupancy checking. Train drivers are due to drive in accordance with signal aspects shown on trackside colour light signals by accelerating and braking trains: routes are set by block systems and interlockings operated by trackside staff. Operational rules are tailored to signalling; therefore, changing them requires not only training of trackside and on-board staff (signalmen, dispatchers and train drivers) but also changing most of the trackside signalling equipment.

The introduction of a unified control command system based on track-train transmission of the movement authorities is a way forward for the unification in operational and signalling domain, [3–5] meaning the transmission of distance, speed and time limits the trains are authorised to use for movements. Similar national solutions are already in use in some countries on selected routes. The introduction of the European unified solution on the majority of tracks gives an opportunity to overpass signalling and operational borders between national rail infrastructures.

Figure 2 shows control command and signalling infographic scheme [2] where European Train Control System (ETCS) [3–5] takes information from trackside traditional signalling and by digital transmission of the movement authorities give the on-board European Vital Computer (EVC) a possibility to apply brakes in case of overpassing authority, and possibility to introduce safe processing of vital data using train characteristic to give train drivers detailed information about running limitations in a unified way on the cab signalling.

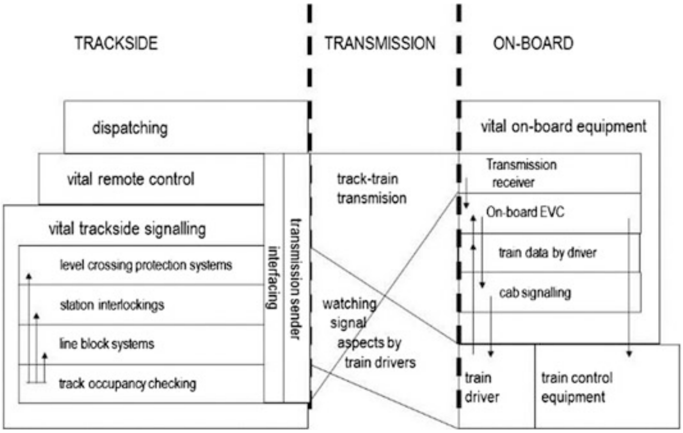

Fig. 2 Signalling with track-train transmission-based control command [2]

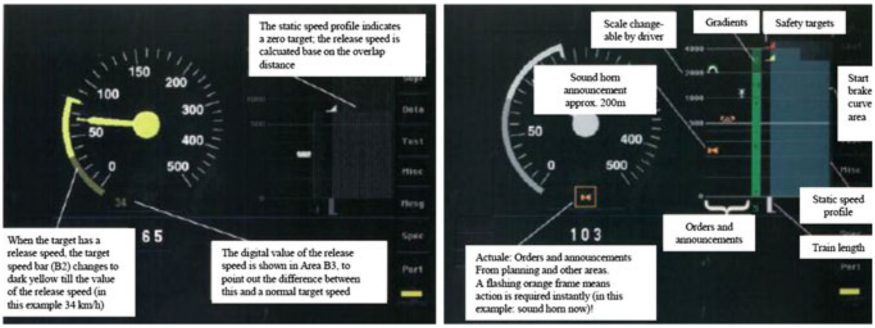

Fig. 3 ETCS cab-signalling principles—area D with dynamic limitations on the *left* and area B with static limitations on the *right*. *Source* [6]

The ETCS cab signalling is a unified solution defined by international project and accepted as guidelines [6] by industry. It ensures uniform way to inform drivers about those limitations using principles shown in Fig. 3. The key areas on the display are static speed limitations together with all spot-related data (area D) and dynamic speed limitations together with dynamic running information (area B).

Control Command Implementation Challenges

The implementation of the control command system requires meeting some safety-related challenges [7]. Generally, the same challenges are related to the implementation of national control command systems (e.g. LZB in Germany, BACC in Italy, ZUB in Switzerland, TVM in France) and the European control command system ETCS. At present, however, the implementation of a new national control command system (instead of ETCS) will take place neither in Poland nor in any other member state of the European Union as it is forbidden by the EU legislation to support European standardisation. The key challenges regarding control command implementation are related to interfacing with traditional signalling, transition periods, changes in operation and the influence on railway transport cost. Those challenges as well as proposals for overcoming them are shown, analysed and summarised below. Taking into account the obvious statement that railway transport requires ensuring safety disregarding technical, organizational and operational changes, the above-mentioned challenges are analysed in safety context by discussing respectively: technical control command safety, organizational control command safety and operational control command safety.

Interfacing Control Command with Traditional Signalling

ETCS as a control command system takes information from trackside signalling to show it at cab signalling and intervene when necessary. From the technical point of view, it can be seen as a complex interface forming part of the chain in which all parts must be safe. Safety of the whole chain is equal to safety of the part with lowest safety that is the highest risk (highest hazard rate). Introducing the ETCS cannot lower the overall safety of the whole chain, and therefore, vital ETCS input data has to be taken in a safe way, processed by vital processes into safe movement authorities, which have to be sent, transmitted and received in track-train transmission in a safe way to be vitally processed on board of the traction unit to ensure vital information which will be used for train driving

$$(1)\quad S_I \begin{bmatrix} S_a \rightarrow 1 \\ S_b \rightarrow 1 \\ S_c \rightarrow 1 \\ S_d \rightarrow 1 \\ S_e \rightarrow 1 \\ S_f \rightarrow 1 \\ S_g \rightarrow 1 \\ S_h \rightarrow 1 \end{bmatrix} \rightarrow 1 \equiv \left.\begin{matrix} \\ \\ \end{matrix}\right] \begin{matrix} \text{SIL4} \\ \wedge\text{RF} \end{matrix} \quad THR_I = \begin{bmatrix} HR_a < 10E\text{-}8 \\ HR_b < 10E\text{-}8 \\ HR_c < 10E\text{-}8 \\ HR_d < 10E\text{-}8 \\ HR_e < 10E\text{-}8 \\ HR_f < 10E\text{-}8 \\ HR_g < 10E\text{-}8 \\ HR_h < 10E\text{-}8 \end{bmatrix}$$

where

S_I safety of the interfacing—technical control command safety
S_a safety of the trackside signalling system
S_b safety of the trackside interfaces—taking information from signalling
S_c safety of the control command trackside data processing unit
S_d safety of the control command trackside data senders
S_e safety of the control command track-train transmission
S_f safety of the control command on-board data receiver
S_g safety of the control command on-board data processing unit
S_h safety of the control command on-board interfaces

and, respectively,

HR_I hazard rate of the interfacing
HR_a hazard rate of the trackside signalling system, etc.

and

SIL4 means safety integrity level 4 as defined in EN 50,126
RF means random failures
$S \rightarrow 1$ means safety strain to 100%—no risk
10E-8 maximum value of probability of dangerous failure as defined by the European standard EN 50 126 as THR
THR tolerable hazard rate—between 10E-8 and 10E-9 for SIL4

Formula (1) shows relationships between safety of individual technical parts in interfacing chain. It has to be mentioned first that no technical system is 100% safe. There is always risk due to nonzero probability of dangerous failures, and therefore, safety “S” has to struggle to reach 1, which, however, cannot be reached. The goal is to minimise risk (hazard rate) as much as possible in order to achieve safety understood as minimising risk to the acceptable level. Appropriate safety proving methodology is described in EN 50 129 [8]. This standard defines the requirements which must be met in order to achieve appropriate safety integrity level (SIL). The SILs are defined from 0 to 4. Higher SIL means higher safety. For signalling, control command, vital data transmissions and processing SIL4 are required. The requirements for SIL are defined for both random and systematic failures. The systematic failures are the ones related to human errors. The ways to minimise risk which are necessary to ensure SIL4 are defined in [8]. For technical systems, especially those assuming the use of the above-mentioned ways, we have to focus on random failures which are related, e.g., to the use of nonideal materials. In that respect, for SIL4 and for random failures, the tolerable hazard rate (THR) is defined as failure rate lower than 10E-8.

Control Command Transitional Periods

All significant changes in huge distribution systems require well-defined and well-organised transitional periods. The way in which control command system is implemented influences safety directly. The goal is to minimise the systematic failures as much as possible—especially failures which are associated with human errors (such as errors in specification, design, construction, installation, operation and maintenance of systems, subsystems and devices). Ensuring shorter transitional periods generally minimises risk, but there is a limit not only due to the cost but also due to safety requirements. If only parts of the main railway infrastructure (some lines or some sections of lines) are equipped with ETCS, higher risk appears especially on edges between equipped and unequipped areas. If sidings, branches, junctions are not equipped with ETCS, higher risk appears on edges between equipped main infrastructure used for trains and complementary infrastructure used for shunting. Moreover, if only some traction vehicles (multiple units, locomotives, shunting locos) are equipped with ETCS, higher risk appears when unequipped traction units enter, run on and leave equipped infrastructure. In all these cases, trackside staff have to serve running vehicles in different ways depending on their on-board equipment. Additionally, in many cases, previous national safety-related track-train transmission systems ensuring cab signalling are still in use. They will be in use as long as they are not upgraded to the European standard. This means that also some traction units equipped with old cab-signalling systems will be running on tracks equipped with ETCS. Different control command systems in use will create additional risk. And finally, implementation means works on tracks as equipment has to be mounted, adjusted and verified. Such works are done on single tracks when trains are running on adjacent tracks or in short time between the trains, and therefore, related risk has to be seen and taken into account in safety analyses concerning transitional period

$$S_T \begin{bmatrix} D_a \rightarrow 0 \\ D_b \rightarrow 0 \\ D_c \rightarrow 0 \\ D_d \rightarrow 0 \\ D_e \rightarrow 0 \end{bmatrix} \rightarrow 1 \quad \wedge \quad S_T = \begin{bmatrix} T_a \rightarrow 0 \\ T_b \rightarrow 0 \\ T_c \rightarrow 0 \\ T_d \rightarrow 0 \\ T_e \rightarrow 0 \end{bmatrix} \rightarrow 0 \tag{2}$$

where

S_T safety in transitional period—organizational control command safety
D_a disturbances—partial trackside implementation for trains
D_b disturbances—partial trackside implementation for shunting
D_c disturbances—partial on-board implementation
D_c disturbances—use of many control command systems
D_d disturbances—works on tracks

and, respectively,

T_a time period of partial trackside implementation for trains
T_b time period of partial trackside implementation for shunting, etc.

and

$S \rightarrow 1$ means safety strain to 100%—no risk
$D \rightarrow 0$ means disturbances strain to no disturbances—no risk
$T \rightarrow 0$ means transition time strain to zero—immediate transition

Formula (2) shows relationships between distinct disturbances and safety in transitional period. It has to be understood that the goal is to minimise disturbances and not to minimise respective time periods to zero. Time periods have to be minimised up to reasonable values. Estimation of respective reasonable values is outside the scope of this article. Long transition period both trackside and on-board causing multi-system operation is not appropriate from the safety point of view, and therefore, transition period must be minimised; however, extra short period of multi-system operation causes high safety risk, and therefore, respective time periods' reasonable values, minimising respective disturbances, have to be estimated.

Control Command in Railway Operation

The operational safety is also influenced by control command implementation. It depends on the competences of safety critical staff, namely dispatchers and train drivers, the scale of double, or even triple, operational procedures for individual dispatchers (traction vehicles not equipped with control command, traction vehicles equipped with national control command and traction vehicles equipped with European control command systems) and the scale of applicability of different procedures depending on vehicles which are driven by individual drivers. It all depends on the staff managing. The competences depend on training and competence verification and differentiation of procedures for single dispatchers and single drivers depend on rules which define work distribution between individuals

$$S_O \begin{bmatrix} C_a \rightarrow 1 \\ N_a \rightarrow 1 \\ N_b \rightarrow 1 \end{bmatrix} \rightarrow 1 \quad (3)$$

where

S_O safety in operation—operational control command safety
C_a competences of safety critical staff namely dispatchers and drivers
N_a number of sets of procedures used trackside by individual dispatchers
N_b number of sets of procedures used on board by individual drivers

and

$S \rightarrow 1$ means safety strain to 100%—no risk
$C \rightarrow 1$ means competences strain to 100%—no human errors
$N \rightarrow 1$ means number of procedures to be used strain to only one set

As safety-related operational risk is directly related to staff management, the associated risk must be controllable.

Control Command Implementation and Operation Costs

Control command systems are implemented to achieve higher safety. The European unified solution ETCS is implemented to achieve seamless cross-border operation and therefore Schengen effect in railway transport. Disregarding whether European or other control command system is implemented, such an implementation significantly minimises risks related to overpassing movement authorities but introduces other risks, especially, but not only, in the transition period

(4)

$$S_I \rightarrow 1 \wedge S_T \rightarrow 1 \wedge S_O \rightarrow 1 \Rightarrow S \rightarrow 1$$

where

S overall safety due to the implementation of control command
S_I technical control command safety (due to the interfacing)
S_T organizational control command safety (due to the transition)
S_O operational control command safety (due to the operation procedures)

and

$S \rightarrow 1$ means safety strain to 100%—no risk

When technical, organizational and operational control command safety strain leads to 100%, the overall safety due to the implementation of the control command system strain leads to 100%.

The cost associated with technical control command safety depends on the type and configuration of the solution. For ETCS, the two main configurations exist—level 1 and level 2. The level 2 trackside configuration is 50% more expensive but minimises amount of staff necessary for operation. The cost depends therefore on a scale of the implementation (number of track kilometres, number of switches, etc.) and configuration. The cost associated with organizational control command safety varies significantly depending on the control command implementation strategy for the railway network and for the park of traction vehicles. The cost associated with operational control command safety is relatively small. However, operational safety is important and cannot be forgotten. An appropriate management of staff competences and work allocation are very important. The overall costs associated with the implementation of the control command must be reasonable and therefore have to be analysed during preparation and revisions of the implementation plans which for ETCS have been prepared by all member states of the European Union and are being or shortly will be revised.

Conclusions

The control command systems including European unified ETCS (European Train Control System) increase railway safety; however, even with ETCS, the railway system is not free from dangerous failures. ETCS is an electronic system and there is no doubt that such systems are sometimes malfunctioning. All the railway signalling systems starting from the very beginning were never free from dangerous failures. They were constructed according to the "fail-safe" principle meaning that in case of failure, safety has to be ensured. Many failures could cause danger and they sometimes did in the past. ETCS enormously supports train drivers, but it must be accepted that "fail-safe" concept is not fully applicable, and therefore, safety has to be verified in another way. The technical safety including interfaces is well defined in the European standard [8] as SIL4. The organizational safety in transition periods has to be analysed using individual concepts, which are outside of the scope of this article. Although the SIL4 concept was not intended to be applicable for operational safety, it can support respective safety analyses. A detailed analysis is possible for defined railway networks and scales of available financing. Such an analysis should be done when defining or reviewing the control command implementation strategies.

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Large-Scale, Economically Feasible and Safe Rearrangement of the Warsaw Rail Transport System

Marek Pawlik

Abstract Warsaw agglomeration rail transport comprising of tram and metro lines ensuring transport within Warsaw and suburban railway connections ensuring transport between a number of satellite cities and main Warsaw railway stations can be rearranged to achieve much better rail transport offer without enormous financing. The article proposes creation of a new services and points necessary investments showing that much better rail transport service is not only technically possible but also economically reasonable and feasible in relatively short time. Safety challenges associated with the proposed rearrangement are pointed and described together with the ways to meet them. The proposed solution allows operational improvement together with not only keeping rail transport high safety level but even lowering risk associated with different types of failures during extended rail service in future.

Keywords Sustainable transport · Development of rail services · Rail transport safety · Control command · Rail service improvement feasibility

Introduction

Using individual transport means, especially private cars, is associated with traffic congestion, parking difficulties and long everyday travel times for citizens. It has been already proved that developing of the public transport is the best way to solve or at least minimize undesirable consequences of the growing mobility in agglomerations. To ensure the high use of public transport, local authorities must attract citizens offering fast, frequent, punctual and comfortable connections between residential areas and all other usual destinations. Different modes of transport can be used: road, rail, water or even monorail. Different transport means

M. Pawlik (✉)
Civil Engineering Faculty, Warsaw University of Technology, Warsaw, Poland
e-mail: m.pawlik@il.pw.edu.pl

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can be used within each mode; for example, rail transport can be based on trams, rail busses, light rail vehicles or trains, while road transport can be based on public bicycles, public minicars, busses, trolleybusses or long articulated busses. Rearrangements of the public transport can be extremely successful if it takes into account, in an appropriate way, all important local circumstances. Differentiation of the local circumstances is so high that the only universal true can be summarized as ‘sustainable well suited to local circumstances transport attracts citizens to use public transport’. Further analysis is therefore dedicated to chosen case—Warsaw agglomeration.

Warsaw Public Transport Overview

Public transport in Warsaw is based on the two transport modes: road transport and rail transport. Water transport is offered only occasionally for tourists.

Road Public Transport in Warsaw

Over one thousand and seven hundred road busses operated by five public transport service providers ensure connections between nearly one thousand and four hundred bus stops [1]. Bus network is so complicated as it is presented in Internet on an assembled map, which in practice allows the Internet users to see city borders and to choose one of the twenty-two smaller street maps showing public transport (see Fig. 1).

Growing congestion and public healthcare challenges requesting pollution reduction resulted in a large number of public bicycles. Over 200 bicycle stations (see Fig. 2) operated by one service provider offer over three thousand bicycles, which can be used 20 min for free (1 h for 0.25 euro, etc.) [2]. The public bicycle story in Warsaw started in 2012. It is young, but quickly developing, strongly welcomed by citizens and supported by the local society and by the local administration. The length of the bicycle roads is still not satisfactory (slightly below 460 km), but it is constantly increasing.

Rail Public Transport in Warsaw

Warsaw agglomeration has quite well-organized rail transport comprising of tram and metro lines ensuring transport within Warsaw and suburban railway connections ensuring transport between a number of satellite cities and main Warsaw railway stations. Electric trams are present in Warsaw since 1908. Many different suburban and regional railway connections are offered since the middle of the

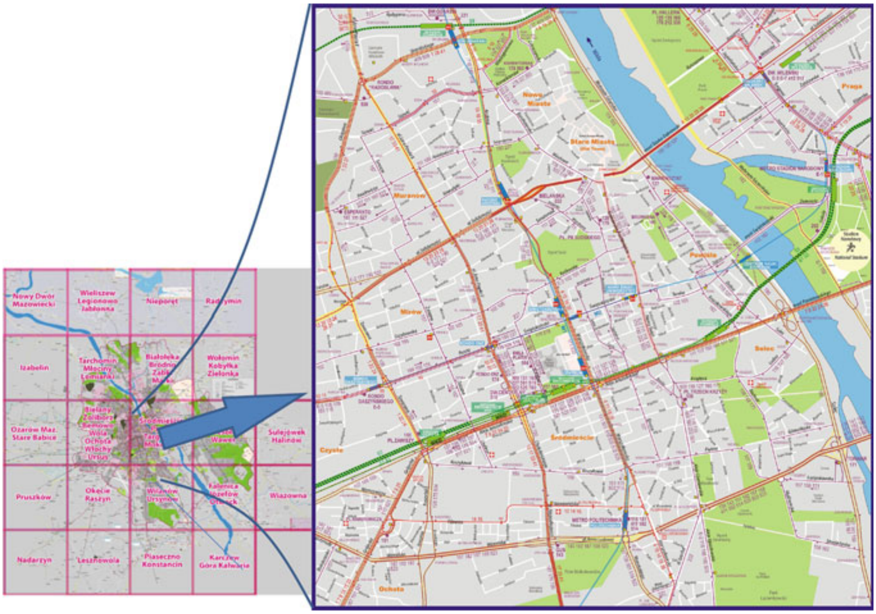

Fig. 1 Warsaw public transport Internet guide. *Source* www.ztm.waw.pl

Fig. 2 Bicycle stations in the centre of Warsaw. *Source* www.veturilo.waw.pl

twentieth century. Presently, trams are operated by one service provider owned by the city of Warsaw, while suburban and regional train connections are operated by two local service providers using the same railway infrastructure.

The first section of the first metro line is in operation since 1995. The operation of the first section of the second metro line started twenty years later in 2015. Construction works started in 2010 and took five years and one and a half billion euro for 6 km and seven stations [3]. That makes 250 million euro per 1 km. Presently, it is foreseen to continue second line construction. The first section is about one quarter of the second line. However, financing is not ensured.

Rail transport network is shown in Fig. 3 where tram lines (thin colour lines), metro lines (M1—thick dark blue line and M2—thick red line) and railway lines (thin grey lines) are shown [1].

Fig. 3 Warsaw rail transport network. *Source* www.ztm.waw.pl

Warsaw Public Transport Challenge

Agglomeration is growing. New city quarters with modern office buildings, shopping centres and residential areas have to be connected in a way that ensures easy access. Streets will not be wider. New bicycle roads will rather make them narrower. Although office buildings and shopping centres are constructed with parking places, the amount of cars is significantly growing faster than the amount of parking places.

Traffic and parking congestion can be minimized, thanks to the public transport if it offers regular, fast and relatively comfortable service. Therefore, dedicated bus lanes and modern busses are already in use. Moreover, some schools, especially along first metro line, start lessons at 7:45, some at 8:00 and some at 8:15 to distribute pupils' add on to congestion in metro trains just before eight o'clock.

Achieving competitive public transport is still a challenge. Public transport means should not be affected by traffic jams on roads, which are full of private cars. Public transport services should be regular, frequent and fast. It has to be comfortable and ensure as far as possible door-to-door connections.

Construction of additional metro lines is a perfect solution, but it is theoretical in case of Warsaw. Long-lasting and costly solution cannot be the only one being applied. Therefore, other rail transport possibilities have to be taken into account. New tramways have to be constructed especially for connecting additional city quarters to tram network. Regional, suburban and local railway services should be used to ensure the better support for agglomeration transport services.

Warsaw Rail Transport System's Rearrangement Proposal

An idea to create a railway city ring in Warsaw has been proposed several times (see Fig. 4). It was seen, however, as not feasible due to the rail traffic congestion on suburban tracks between Warsaw East (Warszawa Zachodnia) and Warsaw West (Warszawa Wschodnia) railway stations.

Fig. 4 Warsaw railway city ring idea (author's own elaboration)

Existing Railway Tracks and Stations

The main railway connection between Warsaw West and Warsaw East stations is formed by tracks dedicated for long-distance trains (railway line no 1: Katowice–Warsaw West–Warsaw Central and railway line no 2: Warsaw Central–Warsaw East–Terespol) and tracks dedicated for suburban trains (railway line no 448: Warsaw West–Warsaw Ochota–Warsaw Downtown (Śródmieście)–Warsaw Powiśle–Warsaw Stadion–Warsaw East and further to Warsaw Rembertów). Long-distance trains use four platforms at Warsaw West, four at Warsaw Central and five at Warsaw East. Suburban trains use two platforms at Warsaw West, three at Warsaw Downtown and two at Warsaw East. Long-distance and suburban tracks are interconnected with switches forming train routes which are used only in case of serious traffic disturbances. Generally, suburban trains are running only on suburban tracks. It is proposed to use railway line no 20 (Warsaw Praga–Warsaw Gdańska–Warsaw Towarowa) and a section of railway line no 9 (Warsaw East–Gdansk Main station) and their interconnection numbered as railway line no 501 to create a railway city ring. As a result, it will be based on the existing tracks.

The proposed ring includes three stations used for long-distance and suburban traffic: Warsaw West, Warsaw East and Warsaw Gdańska and seven stopping points: Warsaw Ochota, Warsaw Downtown (Śródmieście), Warsaw Powiśle, Warsaw Stadion, Warsaw Zoo, Warsaw Koło and Warsaw Kasprzaka and omits station Warsaw Central. Three of them are connected with Warsaw metro stations.

Additional Tracks and Stations

Adding additional tracks between Warsaw West and Warsaw East is not possible due to the city planning constraints. Railway tracks are partly within a cut, partly in tunnel, partly on viaduct, partly on the bridge and partly on the embankment. Track geometry, substructure and superstructure changes are blocked by existing buildings, metro line situated below, main drinking water pipes, multifloor watershed for rainwater and other city infrastructure. Adding additional tracks to other sections is first of all a question of necessity.

Trains scheduled on line no 20, which is a double-track line, leave enough space for additional ones. The same applies to the section of the railway line no 9, although tracks forming this section will be used for long-distance, suburban and local trains at the same time. Interconnection between railway line nos 20 and 9 (railway line no 501, see Fig. 5) contains two single tracks constructed independently, but used as a double-track line from the operational point of view. Trains running counterclockwise will have longer route.

Additional stopping point on a double-track line can be added by constructing two single-edge platforms without touching tracks. Platforms shall be constructed taking into account the applicable requirements including adaptation for people

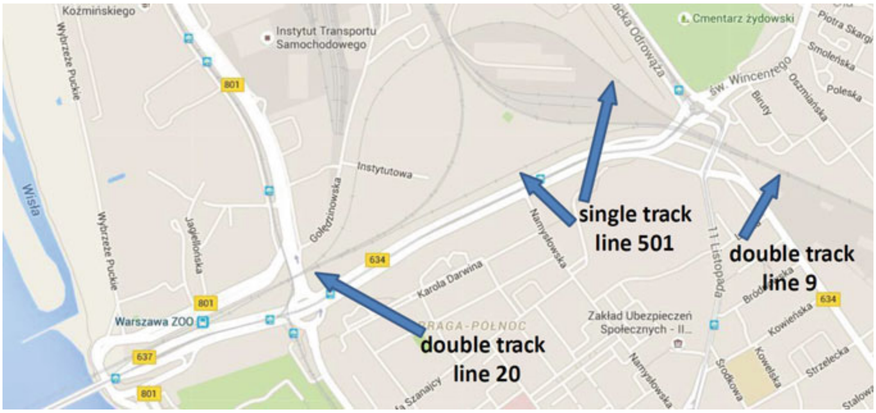

Fig. 5 Warsaw zoo station (north-east corner of the proposed railway ring) (author's own elaboration)

with reduced mobility. From the public transport point of view, five additional stopping points serving big outbound streets are reasonable. They should be constructed at the crossings with the following streets: Solidarności, Św. Wincentego, Św. J. Pawła II, Powązkowska and Obozowa.

Required Cross-Connection Railway Viaduct at Warsaw West Station

Railway line no 448 is entering Warsaw West station from the east via the east station head. Railway line no 20 is entering Warsaw West station from the north, directly to the west station head. Two platforms are used for suburban trains running through Warsaw agglomeration on line no 448: platform 2 with two tracks for trains running in the east direction and platform 3 with two tracks for trains running out of Warsaw. One platform is used for suburban trains running through Warsaw agglomeration on line no 20: platform 8.

As a result, station layout, shown in Fig. 6, does not allow trains to run from line no 20 to line no 448 and vice versa without changing train's head and occupying outgoing tracks of the west station head during shunting. That is not acceptable not only from the point of view of Warsaw railway ring capacity, but also from the point of view of the long-distance railway service. Even individual trains, occupying tracks of six double-track lines leaving Warsaw agglomeration, would cause enormous operational disturbances. That would take place in the case of constructing and using suburban tracks crossing outgoing long-distance and suburban existing tracks at the same level using switches and crossings. Therefore, creating Warsaw railway ring is possible only if a dedicated railway viaduct for two tracks will be available.

Fig. 6 Warsaw West station (south-west corner of the proposed railway ring) (author's own elaboration)

Fig. 7 Railway viaduct along Gdańsk airport at the PKM line (photograph by article's author)

Construction of a long railway viaduct has just took place in Gdansk for suburban railway service between Gdansk and Gdynia [4]. Just constructed railway line no 248 (Pomeranian Metropolitan Railway Line (PKM)) with 800-m-long double-track railway viaduct (see Fig. 7) along Gdansk Airport eases judgment of the construction challenges including time, cost and technical difficulty.

Sample technical solutions solving quoted difficulties shown above in Fig. 7 are non-ballasted tracks equipped with guard rails and rail adjustment switches. Guard rails are placed parallel to regular running rails for keeping the wheels of rolling stock in alignment in case of derailment to minimize damage to the structure in case of restrictive clearance. Rail adjustment switches ensure the compensation of the rail length required due to temperature changes [5].

Control Command—Increasing Capacity While Keeping Safety

Railway viaduct at Warsaw West station will ensure closing Warsaw railway ring using tracks dedicated to suburban railway services. However, public transport minimizes congestion if it ensures regular, fast, frequent, punctual and comfortable connections between usual destinations. The following question is therefore whether closing ring allows the introduction of such service without reduction of the suburban services already in use.

Presently, daily, over five hundred trains are using two tracks dedicated for suburban trains between stations Warsaw West and Warsaw East. That makes 5 min 45 sec average headway between trains running in the same direction. Adding six Warsaw railway ring trains per hour increases traffic by half (nearly 50%). This means that signalling system must be capable to ensure safety for trains running with two and a half minute headway. That requires implementation of the communication-based traffic control system.

Many European railways are using that kind of systems supporting drivers by cab signalling and automatic braking intervention when necessary. That kind of system was not in use in Poland up to December 2014. Now, such system is used for high-speed trains on a section of the Central Trunk Line allowing trains to run 200 km/h. Introduced system is defined by publicly owned European specifications of the European Train Control System (ETCS) [6].

ETCS level 2 configuration, shown in Fig. 8, can be used to ensure safety for trains running with so small headways. Tracks have to be equipped with spot transmission devices sending data used for distance measurement (Eurobalises in case of ETCS), and trackside area control system (Radio Block Centre in case of ETCS) interconnected with interlocking on one side and with wireless communication system (GSM-Rail in case of ETCS) on the other. Traction units have to be equipped with spot transmission receivers (Eurobalises antennas in case of ETCS), wireless communication (GSM-Rail) and on-board processing unit (European Vital Computer in case of ETCS) interconnected additionally with distance measurement system (odometer) and braking system of the train and with cab signalling (Euro-cab).

Such trackside configuration is installed and commissioned on the PKM railway line dedicated for suburban railway services [4]. It is not in use yet, as on-board equipment installed in multiple units used on this line is not commissioned at the moment (see Fig. 9).

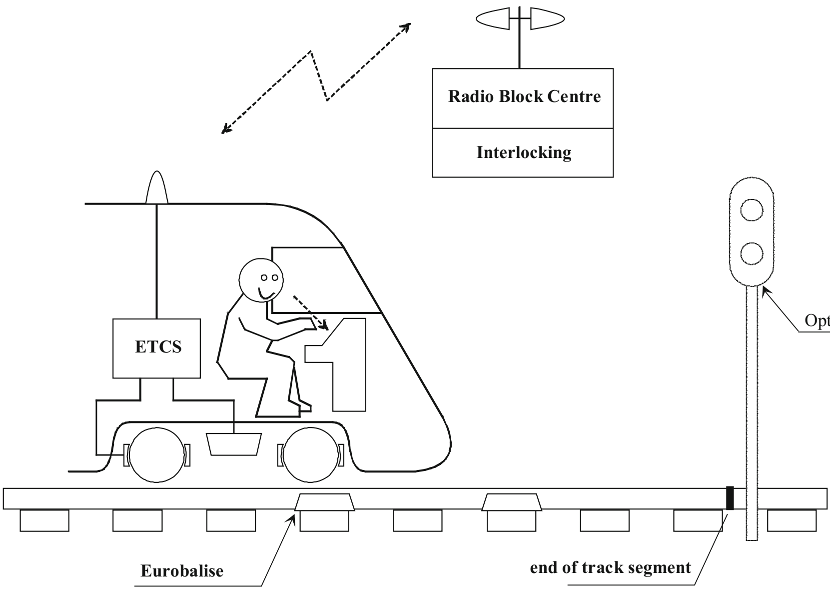

Fig. 8 European train control system level 2 equipment. *Source* ETCS system requirements specification 2.3.0

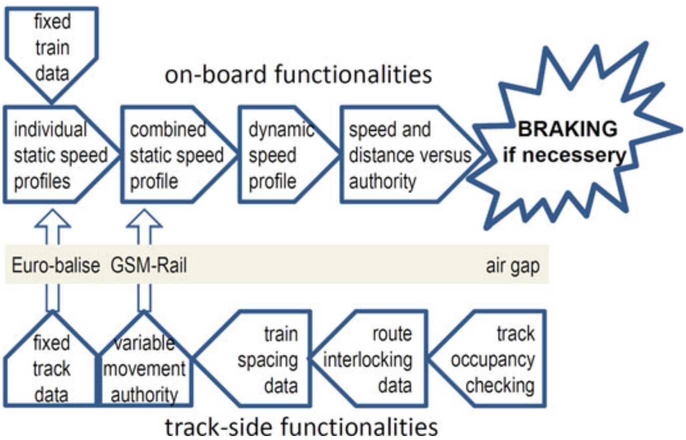

Fig. 9 European train control system level 2 functionalities (block diagram based on ETCS system requirements specification 2.3.0)

Track is subdivided into sections. Each section can be allocated for a train only if it is not occupied by another train. Sets of sections are used for setting routes at stations and defining train spacing on sections between stations. Tracks along stopping points are treated as a part of section between stations. Movement authority, which is defining maximum distance and maximum speed the train is allowed to run, is sent via wireless data connection. Fixed track data, e.g. track geometry, are sent via spot transmission devices, which are used also as reference points. Train data entered before journey by train driver together with received data are used to define several applicable speed profiles named ‘static’ as they do not take into account train running dynamics. Static speed profiles are stepwise speed restrictions in relation to distance. The most restrictive combined static speed profile is calculated and used as a basis for calculating exact points where automatic braking intervention must be imposed. Dynamic envelope is used to ensure respecting speed and distance limits. If for any reason driver drives a train in a way that does not ensure respecting limits, on-board equipment intervenes and slows down the train and stops the train if necessary.

Safety During Construction Phase

Constructing railway viaduct requires special care when works are conducted near and over tracks on which trains are running. Appropriate set of rules have to be elaborated, accepted and applied. Such sets of rules are always used, when construction works take place on railway properties. Operational rules define the ways used to protect construction sites. Obviously, work safety regulations are also applicable.

Implementing ETCS is more challenging.

Traction units have to be removed from operation for ETCS on-board equipment installation. On-board equipment commissioning can take place only on equipped track. Such tracks, which can be used without introducing any traffic disturbances, exist in Poland. This is a railway test ring located halfway between Poznan and Wroclaw, which is being equipped with ETCS just now.

Trackside equipment directly mounted on tracks comprises Eurobalises and GSM-Rail antennas. Special care is required during the installation of the so-called distributed antennas in tunnels. Such technical solution using concentric cable has to be used in railway tunnel from Warsaw Ochota via Warsaw Downtown (Śródmieście) to Warsaw Powiśle station. Set of rules, conceptually similar to those applicable in case of viaduct construction, have to be elaborated, accepted and applied. Trackside equipment commissioning requires using traction units already equipped with positively verified ETCS equipment. Such traction units already exist in Poland.

Introducing additional trains, on a busy railway line no 448, requires equipping with ETCS also trains, which are presently serving suburban traffic using this line. Shortening train headways is possible only between equipped trains. Mixed traffic with equipped and unequipped trains will not ensure capacity for new service based on Warsaw railway ring.

As railway lines in question are managed by Polish Railway Lines S.A. and transport service is provided now by two companies and may be provided on the ring by another one, detailed planning and restrictive execution will be critical.

Cost Assessment and Financing Possibilities

As already stated, construction of the totally new double-track metro line took 5 years and one and a half billion euro for 6 km and seven stations equipped with signalling, communication-based train control and communication systems, which makes 25 million euro per 1 km.

Construction of the already mentioned totally new double-track PKM railway line took two and a half year and 250 million euro per 17 km and eight stations equipped with signalling, communication-based train control (ETCS level 2) and communication systems, which makes 15 million euro per 1 km.

Direct cost comparison cannot be used for simple decisions but allows easy general comparison as the influence on public transport can be seen as generally comparable.

Warsaw railway ring (WRR) cost can be estimated on the basis of the values of the assets of the Pomeranian Metropolitan Railway Line (PKM). Respective comparison using PKM asset values made available by PKM Ltd is shown in Table 1.

Construction of the Warsaw railway ring formed by existing double-track railway lines (no 9, 20, 448, 501) will probably take around two and a half year and 125 million euro per renewal of the 20 km of lines, construction of five new stations and renewal of three existing ones and equipping that infrastructure with signalling, communication-based train control (ETCS level 2), and communication systems, which makes six and a quarter million euro per 1 km.

Two and a half year is assumed to be required for the construction of the Warsaw railway ring similarly to two and a half year used for construction of the PKM line. This is because on one side construction of the PKM line took place in an area where there was no railway traffic, but on the other side scope of works to be done for Warsaw railway ring is significantly smaller. This two and a half years of construction cannot start immediately as they have to be preceded by half year for the preparation of the feasibility study procurement, one year for feasibility study including the preparation of the design and construction procurement, half year for design and construction procurement and half year for design.

Summary of cost and time:

- Warsaw metro—250,000,000 euro per 1 km, 5 years for preparatory works for 6-km metro line and 5 years for construction works;
- PKM line—15,000,000 euro per 1 km, 2.5 years for preparatory works for 17-km railway line and 2.5 years for construction works;

Table 1 Estimation of the value of the assets required for WRR based on the PKM asset values

	Value of the main assets (million euro)	
	PKM line	WRR ring
Track substructure and superstructure PKM → construction of 30 km of ballasted track WRR → renewal of 40 km of ballasted track	60.00	12.00
Civil engineering structures with ballast-less track PKM → 800 m estacada and two 200-m viaducts WRR → 500-m viaduct	50.00	22.00
Railway stations (stopping points) with associated infrastructure PKM → construction of 8 new stopping points WRR → construction of 5 new stopping points and renewal of 3 existing stopping points	12.00	10.00
Control centre (building and its infrastructure) PKM → local control centre serving 17-km line WRR → local control centre serving 20-km line	4.00	4.00
Control command, signalling and communication PKM → interlocking, ETCS l2, GSM-R (17 km) WRR → interlocking, ETCS l2, GSM-R (20 km)	10.00	13.00
Bus stops and pavements with sheds and lighting	4.00	4.00
Telematic systems at stations PKM → passenger info (voice and visual), security monitoring (video and access), etc. WRR → passenger info (voice and visual), ticketing, security monitoring (video and access), etc.	4.00	6.00
Noise barriers (WRR may require more barriers)	1.00	2.00
SUM	145.00	73.00

Author's own elaboration

– Warsaw railway ring—6,250,000 euro per 1 km, 2.5 years for preparatory works for 20-km railway ring and 2.5 years for construction works.

Financing for the construction of the further sections of the second metro line in Warsaw is not ensured. Improving the public transport is required. The 125,000,000 euro required for Warsaw railway ring is much more probable.

European support for the implementation of the ETCS (European Train Control System) makes 80% European cofinancing of eligible costs highly probable. The 25,000,000 euro of the required Polish cofinancing which will be distributed into five years should be affordable. Decision, however, has to be taken on political level in cooperation with European Commission.

Summary

Warsaw railway ring idea can only be implemented if some basic requirements are fulfilled. First of all, a relatively long viaduct has to be constructed to close railway ring formed by railway lines nos 9, 20, 448 and 501. The place where viaduct must be constructed is marked in a left bottom part of the map shown in Fig. 10.

Secondly, whole ring has to be equipped with centralized signalling, communication-based train control (namely ETCS level 2) and communication systems. If all trains running on the ring, including of course these trains which are running between Warsaw West and Warsaw East stations on suburban tracks, will be equipped, smaller headways between trains will be possible. Smaller headways will increase the capacity by 50% and allow the introduction of additional frequent and regular (e.g. every 10 min) connections along Warsaw railway ring.

Thirdly, limited amount of stopping points along the ring have to be enhanced by constructing five additional stopping points binding road-based public transport serving big outbound streets with new railway transport service. That will create railway ring with fifteen stops (railway stations and stopping points), out of which three are directly interconnected with metro stations (marked with red points on the map shown in Fig. 10).

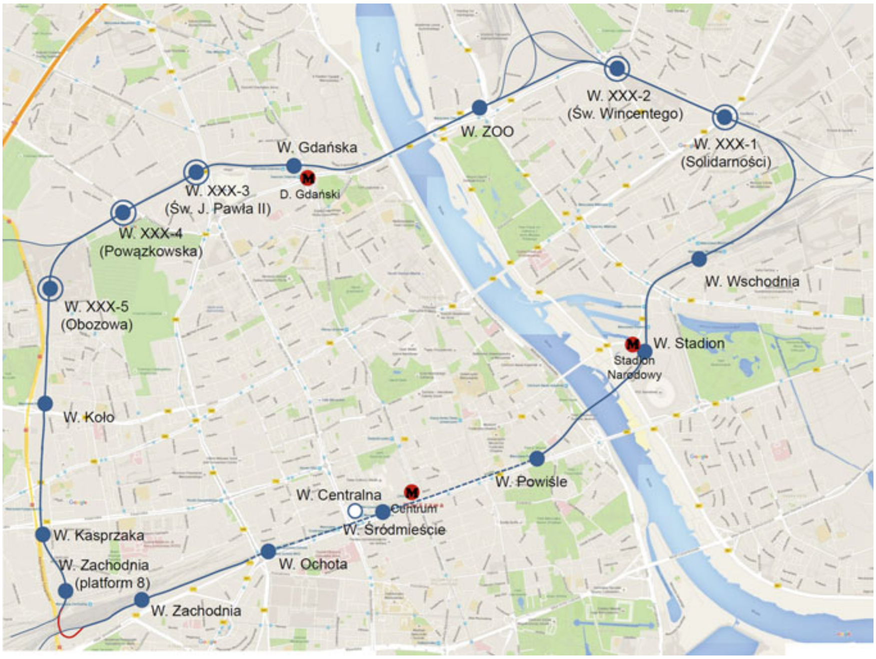

Fig. 10 Warsaw railway city ring proposal (author's own elaboration)

Last but not least, all stops have to be prepared for easy interconnections between road-based public transport and rail-based public transport. Infrastructure shall be constructed taking into account adaptation for people with reduced mobility. Construction possibility and necessity of park and ride infrastructure at new road–rail transport nodes have to be analysed.

Large-scale, economically feasible and safe rearrangement of the Warsaw rail transport is possible. In case of implementation, it will significantly improve the Warsaw public transport system. The proposed rearrangement does not exclude the construction of foreseen additional sections of the second Warsaw metro line.

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Sustainable Transport of Supplies in the City Centre as a Part of the Concept of Good Neighbourliness

Krzysztof Lewandowski

Abstract Each city is possible to perceive as a space where people live and work. Any city cannot function without supply of goods for commerce, services and industry. City logistics, it is a comprehensive strategy to rationalization of the spatial and functional urban agglomeration system to meet the needs of residents and visitors, implemented by coordinating all activities in the area of the city and its surroundings for long-term development goals of the city and the region. In this paper presents the key assumptions of the idea of good neighbourliness for delivery in the city centre.

Keywords City logistics · Delivery · Sustainable transport in urban areas · The concept of good neighbourliness

Introduction

Every city is seen as a space where people live and work. No city can function without supplies for trade, services and industry.

Supply is understood as the movement of goods to a specific customer at a specified time [1]. A network of organizations participates in the process of handling the goods (production, transport, distribution) participates, through linkages with suppliers and customers, in a variety of processes and activities, creating value in the form of products and services supplied to end consumers [2].

K. Lewandowski (✉)
Wrocław University of Technology, Wrocław, Poland
e-mail: krzysztof.lewandowski@pwr.edu.pl

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Stakeholders of Supplies in a City

In a city, there are different stakeholders who are directly or indirectly involved in the supply process at each parking or place for stopping on the street in the city [3, 4]. The criteria for their interest can be classified as follows [5]:

- for residents—the following aspects are important: time of supplies, the frequency of supplies and noise at a supply (in relation to nuisance of activities of the trader and in relation to the competitive occupation of a parking place),
- for merchants—the following aspects are of importance: the time of supplies, the frequency of supplies, reliability of supplies, cost of the supply and terms of supplies,
- for suppliers is the time, frequency, reliability, cost and terms of supplies are also important,
- for drivers—it is the time and frequency of supplies that matters (in relation to the competitive occupation of a parking place),
- for tourists—the time of supplies is important (in relation to the competitive occupation of a parking place),
- for the city authorities—the time and frequency of supplies are important (with respect to the good image of the city centre not blocked by delivery vehicles, enabling visits by tourists and occupation of space for parking the car).

The Costs of Supplies for Stakeholders in the City

In order to develop a rational solution for the system of supplies, it is justified to identify the costs incurred by stakeholders.

The cost is a purposeful expenditure of money and an employee's working time, but the cost can be produced by an external activity of some entity. In this context, we can talk about accounting costs [6] and external costs [7].

Stakeholders of supplies in the city bear direct, indirect and external costs, which can be classified as follows:

- residents—bear the direct costs of the nuisance of supplies as a noise at a supply, manifested by mental fatigue, irritation, etc.
- merchants—have a direct cost of supplies, as the price of ordered goods, the cost of losing potential profits due to the failure to meet the assumed time of supplies and frequency of supplies,
- suppliers—bear the direct cost of supplies, as the price of ordered goods and labour costs of technical equipment—fuel, lubricants, insurance, etc., the costs of losing potential profits—contractual penalties due to the failure to meet the assumed time of supplies and frequency of supplies,

- drivers—bear the direct costs of labour of their own technical equipment—fuel, lubricants, insurance, etc., due to the fact that the time of supplies and frequency of supplies coincide with their arrival time at a specific place and forces them to search for other, distant places for parking their car,
- tourists—bear the direct costs of labour of their own technical equipment—fuel, lubricants, insurance, etc., due to the fact that the time of supplies and frequency of supplies coincide with their arrival time at a specific place and forces them to search for other, distant places for parking their car,
- the city authorities—bear the direct costs, for the same time of supplies and frequency of supplies to many traders in the city centre, when it is blocked by delivery vehicles, it affects the good image of the city, because it does not promote visits by tourists by blocking the limited number of parking spaces.

For each stakeholder, the listed costs are direct. But when they assess their impact on the others, the costs of their actions are direct, indirect or external. Therefore, the classification depends on the reference point.

Indirect costs can be expressed as a cash equivalent [8], if there is no data directly from another stakeholder. External costs are the costs that are moved to the surroundings without compensation [9].

The Principle of Cost Reduction in Supplies in the City Centre

The identified costs of supplies in the city centre indicate that stakeholders have a common subject of interest, but with different intentions.

The objective of symbiosis requires compromise of each party. One should not treat the subject of interest in this matter as a field of conflict, but as the area of cooperation for the common benefit.

The starting point is to determine the demand for goods in the region of the city. May be helpful here the, so-called, logistic map of the city, i.e. an illustration of the scale of the goods and the days and time of supplies.

Data for its development can only be obtained through field research and with the voluntary participation of all entities in the particular region of the city.

The next step is to determine among the stakeholders places for unloading goods. It is the city authorities who may be the initiator or the coordinator of the agreed grass-root initiatives for the implementation from the civil fund.

A given area of the city is divided into catchment areas. Business operators must agree among themselves on the location of points in order to minimize the road to that entity, for example: restaurants, grocery stores. The selected point is specifically marked for the use of suppliers. One point of supplies should serve for approx. 50 m of the route in each direction on which stakeholders from business entities are present.

The next action involves establishing the conditions of supplies. Residents make their comments regarding the time of supplies. Representatives of business operators have to agree with them on such hours that do not interfere with night time or do not block the exit from the property/yard, etc.

At the next stage, the city authorities prepare a new regulation of traffic in that area of the city. It includes special horizontal and vertical marking in places of supplies and construction of information boards at the entrances to the zone covered by this regulation. Special points of supplies are designated.

Planning costs are included in the normal labour costs of the city officials, and the construction of road signs and markings is included in intentional expenses which fall within the responsibilities of the local government contained in the statutes.

Cities, striving to reduce traffic in the city centre and restrict free parking, must remember that the prohibition of entry and stopping of delivery vehicles result in a decreasing influence of business operators in this region, and thus a reduction in taxes paid to the town treasury.

The final step is to publicize the new traffic regulations in the area of the city, which is a prerequisite for reducing the cost of other stakeholders. It has to be made public at least 30 calendar days prior to the entry into force of this regulation.

The known examples of the many cities indicate that any of the authorities' actions not supported by the grass roots lead to new, unsolved conflicts between stakeholders in the centre.

Synergy in the City Centre

Through the identification and classification of supply costs for stakeholders in the city, it can be noticed that the separate activity of each of them in their own interest causes an adverse effect on the activities of other stakeholders. It is reasonable to change this situation by undertaking actions that integrate. The key is to progressively eliminate and cross the barriers that have so far limited the cooperation in supplies in the city, by integrating stakeholders. This can be compared to obtaining a synergistic effect through the evolution of integrating activities.

Therefore, first of all, they must achieve the effect of symbiosis, i.e. strict coexistence for common benefits [10]. Then they can get the synergy effect through the integration of many operators who create a common goal (product), which reduces the cost of its preparation and promotion, and also increases the chances of market success. A joint action allows to obtain a greater effect than the sum of individual actions [11].

The city, as a place where over many centuries have formed various non-farming professions, changed along with the available technology given at the time. The idea of city management has evolved from treating it as a place of settlement to the place which brings together residents of different personal characteristics and professions. If we want to achieve synergy in city management, as the first we must achieve the symbiosis, well known from the biology, as the close and often long-term interaction between two different biological species. The symbiosis in city management means close and long-term cooperation of two different stakeholders of supplies in the city, for example residents and supplies for use one place for parking in night hours for residents and delivery processes at the day hours for suppliers.

If we know that synergy is the creation of a whole that is greater than the simple sum of its parts. In city management, it means reductions of the conflicts in different aspects of life in the city. One of them is usage of one the parking or place for stopping on the street in the city. Achieving synergy for freight deliveries in the city centre, where there is a continuous conflict for space for cars, allows minimizing the impact on the surroundings, i.e. good neighbourliness.

The Idea of Good Neighbourliness

A well-known Polish song begins with these words:
How good it is to have a neighbour.. [12].

What do we mean by the concept of a good neighbour?

Commonly it is understood that a good neighbour is characterized by:

– friendliness,
– tactfulness,
– respect for another neighbour,
– is not indifferent to wrongdoing,
– is not invasive in their activity in the surrounding area.

How to formulate the idea of good neighbourliness in the management of the city?

It can be assumed that urban logistics is a comprehensive strategy to rationalize the spatial and functional urban agglomeration system to meet the needs of residents and visitors, implemented by coordination of all activities in the area of the city and its surroundings for long-term development goals of the city and the region.

Thus, one can identify the main assumptions of the idea of good neighbourliness for supplies in the city centre as:

- In the sphere of people working in the city, activities cover legal regulations on the supplies in the city.
- In the sphere of resources occurring within the city, they include nuisance of the selected modes of passenger and goods transportation because of good neighbourliness, mutual respect and not disturbing each other accidentally or out of spite.
- In the sphere of planning new activities in the city, they include examination of the mutual influence on the perception of good neighbourliness.

- In the sphere of marketing of activities in the city, it includes determination of places of supplies for trade and services as a way of eliminating competition for a place for cars in the city centre.

However, the idea of good neighbourliness is not only associated with the implementation of supplies, but also with the management of the city. This means that the scope of its application can be extended.

If we know that the city is an area combining the functions of housing, services, entertainment, education, leisure and manufacturing, we can immediately notice that the idea of good neighbourliness must be general enough to be able to cover all the features focusing life in the city.

Therefore, the idea of good neighbourliness in the city logistics may be formulated as follows:

The element of strategic long-term management of the city is the idea of good neighbourliness, which protects the interests of all parties, not favouring or rejecting, by taking actions that integrate all of the parties in terms of sustainability with a particular focus on ensuring the mobility of the population with public transport and the supply of trade and manufacturers in the city, in order to minimize the external costs of transport, so that all these activities are allowed to obtain mutual friendliness and respect of all parties.

This fits in with the idea of urban logistics that can be defined as follows:

Urban logistics is a comprehensive strategy of development and management of the city to meet the needs of residents and visitors, by coordination of all activities in the area of the city and its surroundings for long-term economic development goals of the city and the region.

Discussion

The problem of defining the purpose of the concept of good neighbourliness in urban logistics is undertaken to expand the scope of interest of urban logistics with the approach of social impact. The subject of attitudes and social relations is located in sociology in the field of research about society. The element of social interaction in the logistics management of the city arises from the fact that it concerns not only economic, technical and legal matters, but also above all the human being understood as a social being.

The presented proposal of the concept of good neighbourliness in urban logistics is debatable, and it is aimed at provoking a debate. The idea itself is a framework, not a definition. Therefore, it is reasonable to indicate a different opinion about it, to which I invite you.

Summary

This article presents the problem of sustainable transport of supplies in the city centre, which has been shown in a broader perspective than before. The analysis of problems for all stakeholders of supplies in the city showed the need for firstly symbiosis and then the synergy in order to obtain the disappearance of unsolved conflicts between stakeholders in the centre. This indicated that there is a need to add an additional objective in city logistics—the idea of good neighbourliness.

Thus, it is reasonable to undertake interdisciplinary research to specify its principles.

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Universities as Part of the Urban Transport System—Analysis Using the Example of the Gdansk University of Technology and Medical University of Gdansk

Aleksandra Romanowska, Romanika Okraszewska and Kazimierz Jamroz

Abstract Many cities perceive academic function as a distinctive feature, representing the rank and prestige of the city. Universities provide places for work and learning for a high number of people and represent a significant proportion compared to the total city population (even 22%). Many of Polish universities are located in the urban structure in the form of spatially concentrated campuses, where the number of people working and studying reaches from a few thousand to several dozens of thousands. Because they are the destination for a number of daily, obligatory school and work-related trips, universities can therefore be perceived as the city's significant traffic generators. The paper describes problems resulting from the existence of universities in the city structure for both neighbouring areas and cities' transport systems, based on research conducted for two universities in Gdansk. The research included traffic and parking counts and surveys of transport behaviour conducted among employees and students.

Keywords University campus · Traffic generators · Trip generation · Sustainable travel

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A. Romanowska (✉) · R. Okraszewska · K. Jamroz
Highway Engineering Department,
Gdansk University of Technology, Gdansk, Poland
e-mail: aleroma1@pg.gda.pl

R. Okraszewska
e-mail: rokrasze@pg.gda.pl

K. Jamroz
e-mail: kjamroz@pg.gda.pl

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Introduction

In academic year 2014/2015, there were nearly 1.5 million students in Poland which represents almost half of the country's population at the nominal age of higher education (19–24). Compared to 1990, the increase has been threefold [1]. With a higher gross enrolment ratio, university staff has been rising, too. In academic year 2012/2013, universities employed nearly 100,000 teachers and 75,000 non-teaching staff [2]. Poland's entire university community represent nearly 5% of the country's population. The percentage is even higher in cities, reaching 22% [3]. Student numbers are the highest at public universities. This will range from a few thousand to several dozens of thousands [2].

Because they are the destination of daily and obligatory trips to work and school for so many people, public universities become any city's or region's major trip generators. The catchment area is not confined to areas close to the universities with both students and staff commuting from different parts of the city and even the region (Fig. 1). As a result, universities have an important effect on the urban

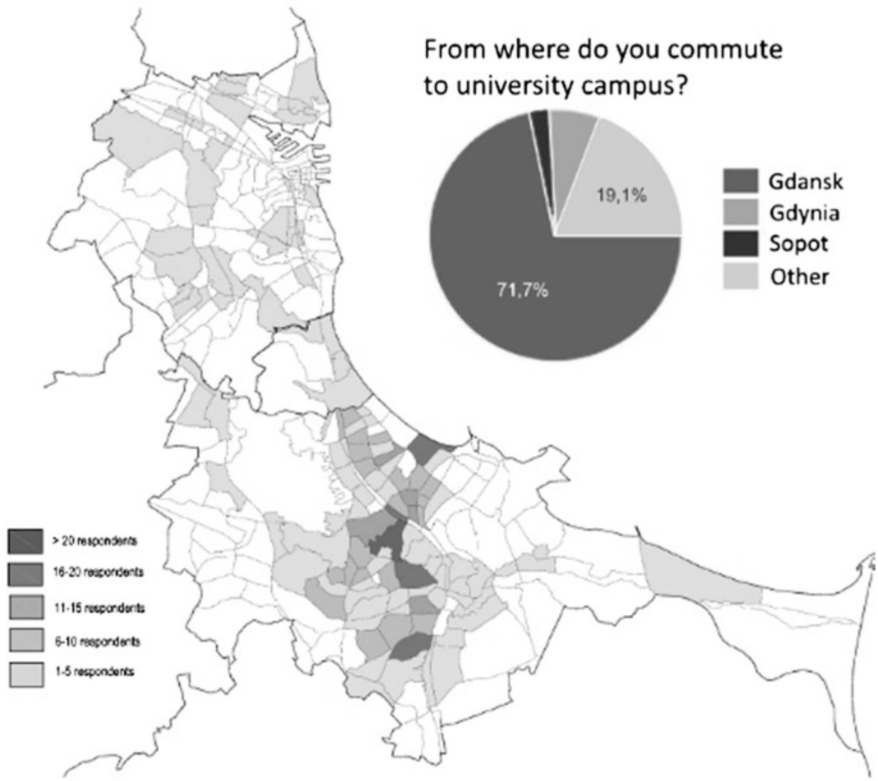

Fig. 1 Distribution of travel origins to the Gdansk University of Technology campus based on a survey of university students' transport behaviour (n = 461) [4, 5]

transport system and the impacts of the numerous trips they generate may be felt in the immediate district and the city. This includes difficulty in parking, more car traffic and a higher demand for public transport within the university's catchment area.

The objective of the paper is to identify the problems of how large universities fit in with the district's or city's transport system. The work is based on research [4–8] conducted for the Gdansk University of Technology and Medical University of Gdansk. The article presents the results of analyses looking at the transport services available to both universities, traffic generation, modal split and travel preferences of students and staff.

Universities as Large Trip Generators

The scale of universities, their location within the urban space and the available transport services may differ significantly from country to country. A review of international literature [9–12] suggests that trips and how they are made differ between Polish and international universities. US studies show that the daily number of car trips generated by universities may be as high as 2–3.3 trips per student [9]. There is, however, a significant difference between travel patterns of Polish and foreign universities, with modal split as one of them. The share of US student car trips ranges from 20 to 50% in urban areas with as much as 75% in suburban areas [10, 11, 13, 14]. Polish surveys [6, 15, 16], on the other hand, show car usage at about 20% or less for commuting students. As a result, the impact of Polish universities cannot be seen by analogy to Western examples. This can only be understood through research and studies conducted in Poland.

There has been little research in Poland on the effects of universities and their campuses on urban transport systems. A survey was conducted of the transport behaviour and preferences of Krakow University of Technology [16, 17] and Gdynia Maritime University [15] staff and students. The study helped to understand the characteristics of trips and how they are made to and from the university. What is not known is how much traffic is generated.

Conducted in some Polish cities, Comprehensive Traffic Surveys (KBR) have data about the number of trips made to and from universities. A 2009 KBR survey for Gdansk [18] shows that student mobility in the home–school and school–home relation is 1.13 trips per student. In the case of workers working away from home, the rate is 1.43 trips in the home–work and work–home relation per worker. When these rates are applied to Gdansk, the share of university generated trips may be as high as 10% of all trips in the city. More detailed analyses concerning the Gdansk University of Technology [6, 19] showed that the number of visitors to the campus is 20,000 people daily (of which 85% by students) which adds up to 40,000 trips each day generated by a single university. Because it is a high number of trips, it may have a significant effect on the operation of the transport system in both the immediate district and the entire city.

Universities in City's Transportation System—Case Study of Gdansk

Gdansk, with 13 universities including 6 public ones, is an important academic centre of Poland. A total number of students in academic year 2014/2015 accounted for 77 thousands, 80% of which at public universities. Only two biggest universities —University of Gdansk and Gdansk University of Technology—educated more than 50 thousands of students. With a different location, profile, number of students and other characteristics, each of Gdansk's universities in different ways affects the city's transportation system. Considering all of them, the influence can be significant, taking into account that the share of students compared to city's population (which accounts for 462 thousands) is almost 17%.

To investigate the impact and its scale for the city, two universities were analysed within the current research: the Gdansk University of Technology (PG) and Medical University of Gdansk (GUM). Both universities are located in neighbouring districts along the city's main transport axis (Fig. 2) and have compact campuses within the city structure with just some of their facilities located outside the main campuses. While they have a similar location and spatial structure, each university has its own characteristics. The Gdansk University of Technology is a technical school where more than 24,000 students train to be engineers and Masters of Science. The majority of its academic functions are confined to the campus. While the GUM has four times fewer students, the university also comprises a university hospital nearby—the University Clinical Centre (UCK). It is the destination of an additional 2500 staff and a high number of patients and visitors.

The PG's academic community accounts for about 5% of Gdansk's population and exceeds population of the district it is in. The GUM is similar with the academic community and UCK workers, patients and visitors accounting for as even

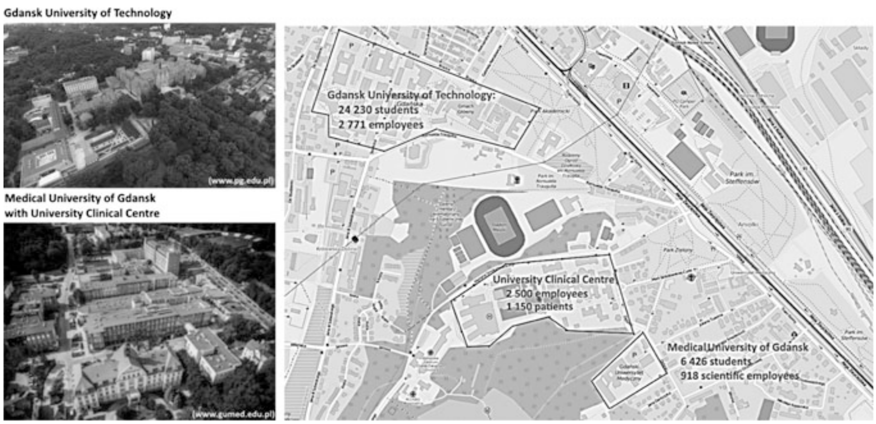

Fig. 2 Location of the Gdansk University of Technology and Medical University of Gdansk with the University Clinical Centre. *Source* © Authors OpenStreetMap CC-BY-SA

more than the district's population. Having both universities in their area is a nuisance for the residents and a major factor in travel characteristics. Understandably, the universities play an important part in the city's transport system.

The transport services of both universities comprise internal services within the campuses and external services linked to the adjoining streets, public transport stops, car parks and university buildings outside the campuses. Because of the objective of this paper, its focus is mainly on external services, a determining factor of the universities' position within the city's structure.

Between 2014 and 2016 in Gdansk, surveys were conducted as part of student and technical projects [4–8]. They examined the transport behaviour and preferences of staff and students, the traffic generated, parking and accessibility of the PG and GUM.

Conducted mainly among the students of both universities, a pilot study of transport behaviour and preferences identified public transport as the main mode for commuters (selected by 55–60% of respondents). This is because both universities are well served by public transport with city rail, trams and buses in relative proximity to the schools. During peak hours, trams and trains leave every few minutes and getting to many parts of Gdansk takes from 10 to 43 min (Fig. 3). In the case of those commuting from outside Gdansk, travel time may be longer and take more than 60 min (as declared by 11–12% of respondents). Using the surveys [7] and available data [20], an estimation was made of the number of PG students and staff using nearby trams during the afternoon peak. It represents about 2.5% of

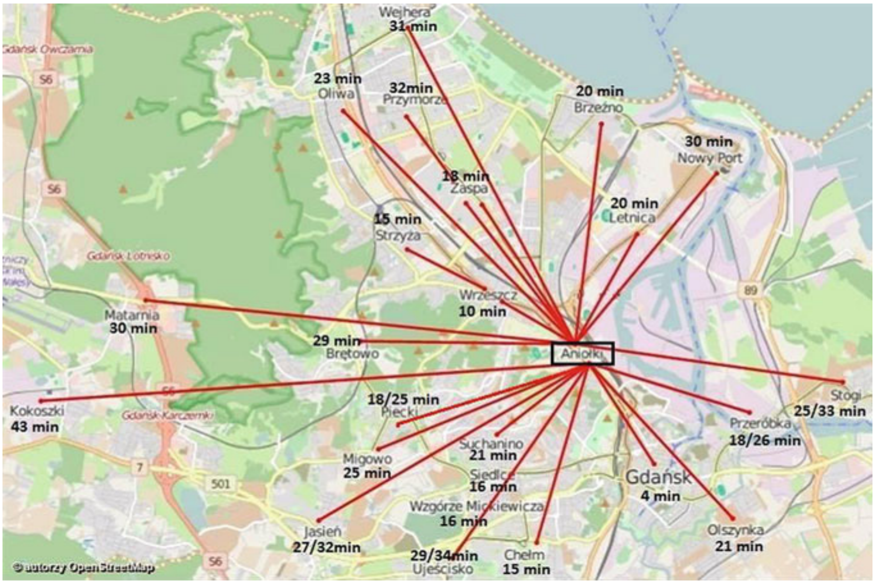

Fig. 3 Travel time by public transport to the GUM [8]

all public transport passengers and about 5% of all tram passengers in Gdansk. An analysis of the section of the tram line running close to PG campus (conducted with the use of Gdansk's transport model) gives an estimated number of students and staff travelling by tram on this section in the afternoon peak, which represents even 10–15% of all passengers in both directions.

Walking represents about 14–17% of journeys to both universities. However, people who use public transport have to walk from the stops to the university (in both cases, public transport stops are a few hundred metres away from the schools). All non-walking journeys measured at campus gates account for 80–90%. Surveys of pedestrian traffic at the PG showed that within a day a total of nearly 30,000 people go through the gates both in and out (Fig. 4). A similar survey was conducted at the GUM and UCK in the afternoon peak hour and showed the number of pedestrians coming in and going out to be 1500 people/hour.

With so many people walking from home or a public transport stop to university and back, ensuring the right conditions for pedestrians is key—quality of pavements, length of pedestrian journey, pedestrian safety and accessibility for people with restricted mobility. Pedestrian traffic conditions and accessibility for people with disabilities were analysed for the PG and GUM/UCK. As regards walking from public transport stops, both universities are within about 5 min on foot from the nearest stops. Accessibility for the disabled (especially in the case of the UCK, the destination for patients, including older and disabled people) is much worse for both universities. GUM and UCK analyses showed that a pedestrian moving at an

Fig. 4 Cartogram of daily pedestrian traffic on PG campus and footpaths leading to the campus [6]

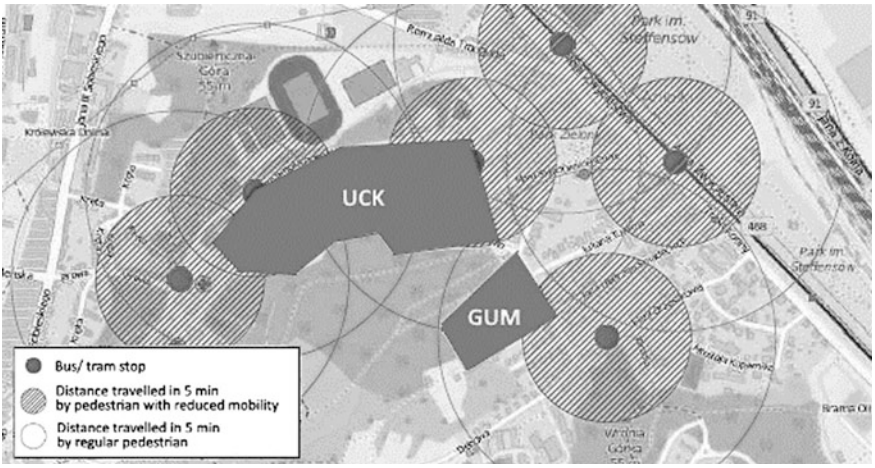

Fig. 5 GUM and UCK accessibility for pedestrians with restricted mobility [8]

average speed of about 5 km/h from any of the nearby public transport stops will reach the campus and hospital within 5 min, and a sick patient or older person moving slower will take twice as long to cover the distance (Fig. 5). In the case of the PG, the analysis included the campus itself and showed that people with restricted mobility would find it difficult to move about the university site. This is because of high kerbs, steps, lack of ramps at entrances to buildings or uneven pavements. While the conditions for pedestrian traffic do not translate directly into the university's position within the city's transport system, these types of hindrances while commuting and while on site may be the decisive factors for students, staff or visitors when choosing a mode of transport.

In terms of all possible travel choices, nearly every fourth person chooses the car to go to and from the university. Using car traffic counts, it was estimated that during the morning peak hour alone, there are as many as 850 pc/h coming to the PG and about 600 pc/h going to the GUM and UCK. Analysis of car traffic in the afternoon peak hour gave an estimated share of PG-generated car traffic at 5% and up to 90% (in the case of streets that serve the university site directly) of traffic on streets adjacent to the campus.

Heavy car traffic generated by the universities translates directly into car parking problems on site (and the UCK) and in the immediate surrounding. In both cases, access by car to the campus is restricted and available only for holders of access cards (about 20% of those commuting by car). Daily the PG campus is used by 2800–2900 vehicles driving in and out. Other motorists look for car parking on public car parks, on streets, pavements, unregulated car parks or park illegally (the last two account for 40% of those parking). A study at the PG showed that on a typical day, car park occupancy is 73% on the campus and 85% outside the campus. In the case of the GUM and UCK, it is 62% on the campus and hospital site with

85% outside. With such a high occupancy (especially outside the campus), finding a parking space takes even more than 9 min (according to a GUM survey: half of the drivers take more than 6 min to find parking, 20% more than 9 min). Because they cannot find parking, many drivers park illegally or in places that are not designated as parking. Illegally parked vehicles may affect pedestrian traffic (e.g. parking on pavement and vehicles reducing visibility at pedestrian crossings). It may also be a nuisance outside the campus for residents living nearby. The problems arise primarily due to the high demand for parking space of both the residents, academic community, and, in the case of GUM and UCK, patients and visitors. The demand for car parking by the GUM and UCK academic community was calculated and compared to the parking needs of the residents. Compared to the entire district, the demand for parking would cover even 10% of its area (Fig. 6).

Because they are situated along Gdansk's main transport axis, both universities are well positioned for access to the city's cycle network. Gdansk's cycle network has 117 km of dedicated cycle roads. Despite this, cycling accounts for a small percentage of to/from journeys to the university at about 3%. The number of cyclists changes with the seasons and weather. A survey at the PG (made in November) showed that several to tens of cyclists cycle in and out of the campus in an hour. The cycle infrastructure outside and inside the campuses only comprises parking and bicycle stands (when the weather is good, the PG's facilities have almost 100% occupancy).

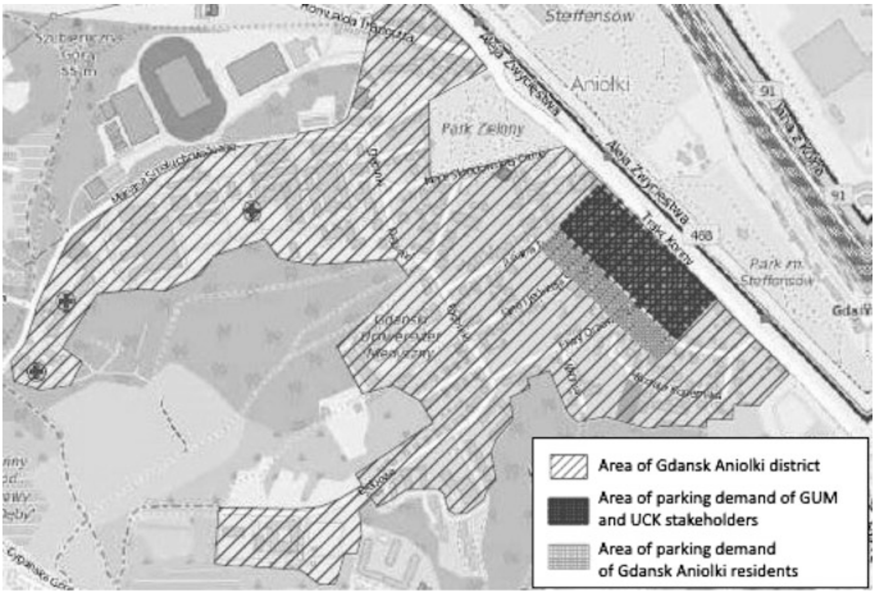

Fig. 6 Area of parking demand of GUM and UCK stakeholders versus the parking demands of the residents [8]

The bicycle as a mode of transport has an enormous potential for travelling to both universities. It should be encouraged by the universities' location and links into the cycle network and the ability to educate students on the preferred modes. But in fact, the poor infrastructure and a lack of promotion discourage the majority of the academic community from cycling. It is not seen as a real alternative to public transport or the car.

Conclusions

The examples of the Gdansk-based universities show that they generate up to several dozens of thousands of trips a day which makes them important traffic generators for the city. While the impact on the transport system is the strongest in the immediate surrounding of the universities, the high number of trips has an effect on the city as well. The examples of universities situated in Gdansk show that:

- Students commuting to university use public transport most often; university student and staff trips in the academic year increase passenger flows in public transport (with one university generating several per cent of overall passengers),
- While the car is not the most common choice of transport, the university's car traffic has an effect on the adjoining street network through increased traffic and a higher demand for parking on site and outside the university,
- If the parking demand of the academic community is not satisfied, the university may become a nuisance to the neighbouring properties and deteriorate significantly the conditions for pedestrians and cyclists within a radius of up to several hundred metres,
- The number of pedestrian trips generated by single university counts for several dozens of thousands daily; this makes accessibility for pedestrians so important (distance, condition of infrastructure, pedestrian safety) and may influence the choice of mode, and
- Despite its strong potential as a mode, the bicycle continues to be underused with only a few per cent of students using it to commute.

The paper aimed to identify the impacts a university may have on the city and its transport system in the district and the city as a whole. The study concerned two Gdansk-based universities leading to some preliminary conclusions on the scale of the impact. A more detailed assessment requires further research to include universities in different locations, a different structure and characteristics. When considering the effects a university has on the whole city, it would be interesting to establish the impacts of overall academic community journeys on the city's transport system. This will be addressed as part of an extended research.

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Analysis of the Cost Intensity of Transportation in the Polish Rescue Services System

Michał Suchanek and Adam Mytlewski

Abstract Polish Rescue Services System is one of the most important parts of the whole healthcare system in Poland. The paper is concentrated on the financial aspects of the transportation system of Rescue Services, precisely on the cost analysis. The place of the Rescue Services in the Polish healthcare system is presented. The different types of sanitary transports are discussed, and the calculation of the daily costs of ambulance teams is calculated and analysed. Such an analysis leads to a proposal of an optimisation model based on the classic transportation problems in operational research, which could be applied practically if the current division of the rescue areas was changed.

Keywords Rescue services · Cost intensity · Medical transport

Introduction

The care of public health is one of the first and foremost obligations of every government, which is also the case in Poland. This leads to a highly formalised structure of healthcare entities. The formalisation is especially high in those areas where the danger towards patient's life and health is especially visible. One of these areas is the Polish Rescue Services System which consists of many different sub-systems, out of which one of the most important ones is the transportation sub-system. From logistic point, the transportation services in the Rescue Services Systems are no different than classic transportation services. The difference lies,

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M. Suchanek (✉) · A. Mytlewski
Department of Economics and Management of Transportation Companies,
Faculty of Economics, University of Gdańsk, Sopot, Poland
e-mail: ekomsu@ug.edu.pl

A. Mytlewski
e-mail: mytel@gnu.univ.gda.pl

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however, in the different way of measurement of the quality of those services, which is not done upon the moment of service but throughout the whole treatment process. At the same time, the quality of the treatment process is highly dependent on the quality of the Rescue Service at the very beginning of this specific healthcare cycle. This leads to a different set of goals regarding the transportation system and in turn, to a different structure of costs and a different potential for optimisation. In the paper, the cost values for the ambulance teams are calculated and the structure of those costs is further analysed, which in turn is the basis for the adaptation of an optimisation model, based on the classic transportation algorithms.

Rescue Services as a Sub-system in the Polish Healthcare System

The legal basis for the Polish healthcare system is laid out in a number of different legal acts, most importantly in the constitution, in which the 68. Article states that every member of the society has the right to the healthcare services and that those services are provided equally for every citizen regardless of his financial status. Those services are paid for from the public funds and that also includes the emergency Rescue Services.

The structure of the Polish healthcare system is a result of further legal acts, determining the regulations regarding the healthcare entities, the medical practitioners, including MDs, nurses, and auxiliary personnel and also the medical corporations. The financial situation is regulated through the system of healthcare services financed from the public funds, controlled by the National Health Fund. The citizens themselves come into contact with healthcare system either through acquiring healthcare services from different healthcare providers (e.g. hospitals, clinics and individual MDs) or, in a state of emergency, through the system of Rescue Services which is separately regulated by its own corresponding legal act and is directly subordinate to the prime minister (Fig. 1).

The Rescue Services System as such is comprised of two primary sections. The first section is made up of all voivodes in the country who are the representatives of the governmental administration and are responsible for coordination, control, planning and co-financing of the system. The second section is the executive one. It is made up of hospital emergency wards and of the Rescue Services teams which are complementary towards each other. Specifically, in the system there are four types Basic Rescue Services Teams, Specialist Rescue Services Teams, Airborne Rescue Service Teams and Hospital Emergency Wards [2].

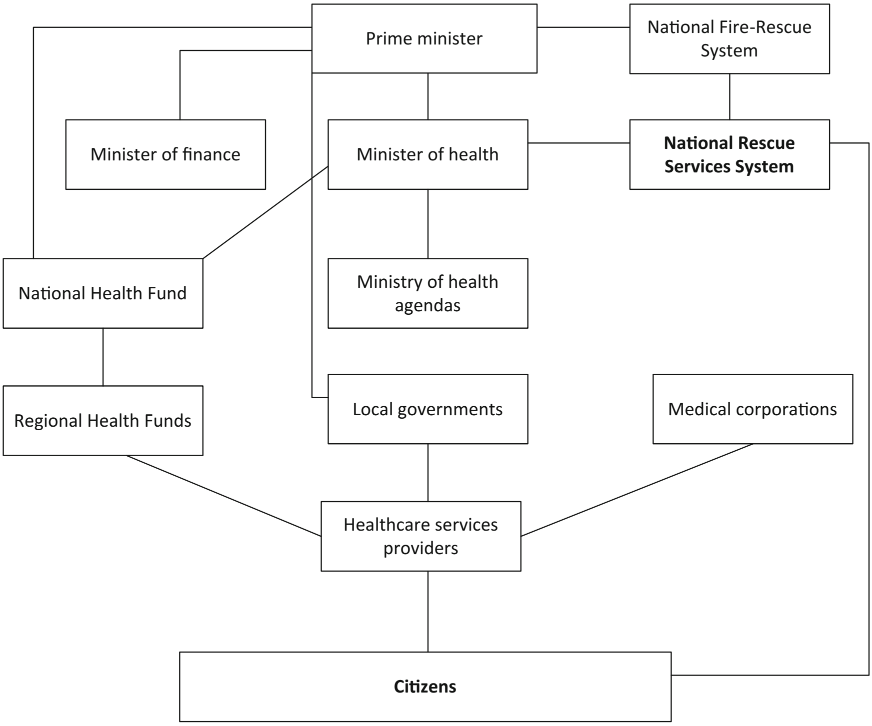

Fig. 1 Structure of the Polish healthcare system. *Source* Based on [1]

Transportation in the Rescue Services System

The legal regulations regarding the Rescue Services System in Poland specify the category of the sanitary transport, which is divided as follows:

- Rescue Service transportation,
- sanitary transport in the basic health care,
- remote transport in the basic health care and
- sanitary transport with an "N" ambulance.

The Rescue Service transportation, which includes the ambulance system, is connected with carrying out duties connected directly with saving lives in emergency situations. The rescuers which arrive at the scene in an ambulance perform first aid assistance, supply the patient with all the necessities and transport him to a hospital, if needed. The rescue team transports the patient to the nearest possible hospital emergency ward or to a hospital pointed out by the dispatcher or the coordinating doctor. There are two types of the Rescue Services ambulances: the basic ambulances and the specialist ambulances. The main objective of the basic ambulances, which are staffed with at least two licensed rescuers, including a qualified nurse, is to transport the patient from the scene of the incident to the closest medical ward, according to the principle of “load and go”. The specialist ambulances are sent by the dispatchers to those incidents, in which there is a possibility of aiding the patient directly at the scene of the incident. It is staffed with at least three licensed rescuers, including a specialist doctor and a nurse or a rescuer. The choice of which team to send to the scene of an incident is made by the dispatcher upon receiving the call, performing the initial interview and evaluating the situation.

Sanitary transport in the basic healthcare can be used by those patients, who have the necessity to receive a healthcare service in a certain healthcare provider or if there is a need to maintain the continuity of treatment. The sanitary transport includes the transport of the patient to the place in question and back and the decision on the necessity of transport is made by a specialist doctor. He is also the one who makes the decision regarding the payment for the service, which can be full, partial or null, depending on the illness and movement disorders.

Remote sanitary transport in basic healthcare can only be used in extraordinary situations and its performance has to be evaluated and approved by the director of the Regional Health Fund. It is provided if a patient, due to random causes, has to use healthcare services abroad and his condition is stable but does not allow for such a movement or in a situation in which a patient has to receive, due to a justified medical cause, a healthcare service in a specialist clinic which is located further away than 60 km from his house.

Sanitary transport with a neonatologic “N” ambulance is provided if there is a sudden decline in the medical state of a newborn child, specifically if there is a respiratory insufficiency, cardiac insufficiency or directly before or after surgeries performed in specialist hospitals [3].

The Costs of Transport in the Polish Healthcare System

Every submitted need for a transport service of people or cargo has a certain economic and social significance and is integrally connected with the proper functioning of the society and the country. The transportation services in the Polish Rescue Services System are connected with the performance of very specific transport services, and its effectiveness is an extremely significant factor for the overall quality of the healthcare services, and thus, it directly determines the state of the public health in the country.

The high significance of the transport services as well as its robust cost intensity implicates the need for a calculation of the costs of the healthcare teams so as to be able to plan the funding and identify the possible room for improvement.

The costs of the rescue teams can be estimated based on data regarding the two main cost categories:

- Direct costs of the rescue teams, specifically:
  - personnel costs and
  - running costs.
- Indirect costs of the rescue teams, most importantly including the administrative costs and the costs of the medical dispatchers.

The direct personnel costs are caused by the wages, salaries and all the benefits of the medical personnel working in the rescue teams, i.e. doctors, rescuers, nurses, paramedics and drivers.

The remaining direct costs are the result of the use of materials and energy, most importantly: medicines, dressing materials, antiseptic gauzes, disposable needles and syringes, cleaning materials, petrol, diesel or gas for the ambulances, spare parts and also external services of maintenance and repair of the ambulances and the remaining medical assets and the external services of contracting work.

The calculation was performed separately for the basic and the specialist rescue teams, on average in 2014, per one working day, in PLN (Table 1). The calculation was based on the division of costs according to their kinds—group "4" of the enterprise chart of accounts.

Table 1 Calculation of the daily costs of rescue teams in Poland

Cost group	Average daily cost of the specialist rescue team in 2014 (PLN)	Average daily cost of the basic rescue team in 2014 (PLN)
Depreciation	71.10	66.58
Use of materials and energy	152.52	189.74
External services (work related)	825.66	684.63
External services (other)	894.46	410.56
Taxes and duties	14.91	12.21
Salaries and wages	1308.44	892.13
Social insurance and benefits	261.46	152.02
Other direct cost	8.03	16.64
Total direct costs	3536.56	2424.50
Attributable indirect costs	603.19	565.90
Total cost	4139.75	2990.40
Total work-related costs	2395.55	1728.77

Source Own calculations based on [4]

The average daily cost for the specialist rescue team is 38% higher than the average daily cost for the basic rescue team. This is a result of the difference in two basic cost groups—the total work-related costs (including the cost of contracts with the involved medical practitioners, the cost of salaries and wages and the cost of social insurance and other benefits for the workers) are 666 PLN a day higher (38% higher) and the cost of other external services (connected with the maintenance of the specialist medical machinery) which is twice as high for the specialist rescue team. Overall, the highest expenditures are connected with the personnel (57% for both kinds of teams), other external services (22% for the specialist team and 14% for the basic team) and the use of materials and energy, mostly petrol (4% for the specialist team and 6% for the basic team). The first two of the aforementioned groups of costs are connected with reaching a proper quality of the medical Rescue Services. However, the cost of the use of materials and energy is mostly a result of the use of fuels and is thus correlated with the distance the ambulances cover. Those costs can be optimised based on a dispatcher choice and a proper route selection.

In practice, the costs of transport itself in the Rescue Service System in Poland is often much higher than it could possibly be due to an artificial division of metropolitan and rural areas into areas which are subordinate to a certain hospital emergency unit and to a certain dispatcher. This leads to a situation in which ambulances cannot cross the borders of their area even if the distance to cover would be a lot shorter for them than for an ambulance which is dispatched from within the area. This leads to a situation, in which the routes and therefore the costs of transport are optimised within the domain of a certain dispatcher while they are far from being optimised globally, within the whole system. Currently, in the Polish Rescue Services System, the voivodes are in power to change the delimitation of the dispatcher areas and thus change the system into a system of above regional patient service, which could then be easily optimised by a transformation into a classic transportation problem. In such a transportation problem, the Rescue Service would be the product, the patients would be the recipients and local Rescue Service dispatch stations would be the suppliers.

Formally, for the Rescue Services System, the transportation problem can be defined as follows:

- S—the number of the dispatch stations,
- R_s—number of regions covered by the dispatch station,
- T_{sr}—average distance from s-station to r-region,
- W_{-r}—number of ambulances dispatched to the r-region,
- W_s—number of ambulances dispatched from the s-station,
- x_{sr}—the variables—number dispatches from s-station to r-region and
- GF—goal function.

$$\mathrm{GF} = \sum_{s=1}^{S} \sum_{r=1}^{R_1+\cdots+R_S} x_{sr} * T_{sr} - > \min \tag{1}$$

$$\sum_{r=R_s+1}^{R_s-1+R_s} x_{sr} \leq W_s * M_s; \quad s = 1, \ldots S \tag{2}$$

$$\sum_{s=1}^{S} x_{sr} \geq W_{-r}; \quad r = 1, \ldots R_1 + \cdots + R_S \tag{3}$$

Assuming that the regions are delimited, it is possible to optimise the dispatch system in the Rescue Services System regarding the total distance covered and in consequence to achieve the minimal possible fuel consumption cost while still providing an equal availability of the Rescue Services for all the patients in a certain area [5].

Conclusions

The cost intensity of transportation in the Polish Rescue Services System is significant and is a result of a number of factors. While calculating the costs of the ambulance rescue units, one has to take into account the costs of all the personnel, external services, including the maintenance of the specialist machinery and the cost of the use of materials and energy, including the cost of fuel. The personnel costs, which are the dominant group, are a result of the legal obligation regarding the indispensable staff in an ambulance unit. The machinery costs are also more connected with the service of first aid than the transport itself. However, the fuel costs are a result of the dispatch decisions and route choice and can therefore be subject to optimisation. However, the current divisional structure of the Rescue Services areas creates with artificial borders. That makes it impossible to optimise the system cost-wise. If the system were changed, which it can be if the voivodes so decide, then it could be optimised using the algorithms of classic transportation operational research.

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Cost Criteria as a Means to Support Travelling Mode Related Decisions—A Case Study for the Central Part of Silesian Voivodeship (Poland)

Marcin Staniek and Grzegorz Sierpiński

Abstract This study addresses the analyses related to travelling between selected points in 19 municipalities of the central part of Silesian Voivodeship by means of a car and public transport (entailing change options and use of all the available means of transport, i.e. bus, tram, trolleybus and railway). The focal point of the related study was to analyse the costs connected with passenger car driving as well as fees charged for travelling by public transport. Yet another aspect taken into account was travelling time. For the purposes of the research, the GT Planner tool was used, being an outcome of works conducted under the international Green Travelling project implemented within the framework of the ERANET Transport III programme. The final results were developed with reference to time and cost criteria. The relevant analyses were conducted for two optimisation criteria, i.e. the quickest and the cheapest route. As regards the quickest route, the studies covered a time interval from 6 a.m. to 10 p.m. which made it possible to capture the variability in the measures analysed in time.

Keywords Multimodal trip planner · Sustainable transport · Travelling costs · Transport modes

Introduction

Travelling modes used in towns result from the capabilities offered by the existing transport systems, including their technical, legal and organisational features. Numerous transport-related studies imply (including [1–5]) that from the user's perspective, the most relevant factors affecting the choice of the travelling mode are travel time, length and cost. The latter, when taken directly into account, may be of

M. Staniek (✉) · G. Sierpiński
Faculty of Transport, Silesian University of Technology, Katowice, Poland
e-mail: marcin.staniek@polsl.pl

G. Sierpiński
e-mail: grzegorz.sierpinski@polsl.pl

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lesser importance than time (since the traveller is aware of the necessity to cover certain costs up to an acceptable level); however, being one of component features, it may have a significant effect on making travel-related decisions.

The amount of fare charged for using public transport is a significant element in developing sustainable transport policy within the given area [6–11]. Therefore, this problem may be analysed globally for the chosen area from the perspective of those having the actual impact on how traffic is managed in towns (i.e. regional authorities, traffic managing institutions and public transport operators). The second aspect connected with travelling costs is how to perceive the problem from the traveller's point of view. A client of the system in question (i.e. a person who intends to travel from point A to point B) does not undertake an analysis of the transport policy premises, but is only focused on the fare system (in other words, the former are accepted as a matter of fact). Such a person often lacks comprehensive knowledge concerning different alternative ways to make the given trip, hence the need for tools which may provide support in delivering full information.

The purpose of the study was to highlight possibilities of using contemporary trip planners to identify a multicriterial approach to the problem of choosing a travelling mode, emphasising the costs to be incurred by the user. This aspect is often disregarded in tools of such kind, and even if it has been covered, it is typically impossible to collate different ways of travelling or compare search criteria [12].

For the sake of the case study, the central part of Silesian Voivodeship was chosen (19 municipalities). It is one of the most highly urbanised areas in Poland. A considerable portion of this space is metropolitan in nature. This area, only next to Warsaw, is also known of the highest population potential (more than 6.5% of the entire Polish population) [13]. It comprises more than a dozen towns of average size and with population of ca. 120 thousand which, at many points, border on one another in developed areas. It is a true challenge for the public transport system, since very large numbers of travels are made on everyday basis.

The research problem was divided into two essential parts, and this structure has been reflected in the study. In the first part, cost-related differences have been discussed with reference to sample-chosen transport connections made between specific points in more than a dozen towns of the central part of Silesian Voivodeship. The analysis covered direct costs related to both individual and public transports, and at the same time, a multimodal travelling option was taken into account. In the second part, on the other hand, the results of analyses of the time and cost dependences have been discussed with reference to different travel types. The tool used in both cases was a trip planner developed under the international Green Travelling project implemented within the framework of the ERANET Transport III programme. Owing to the above planner, the user is able to collate numerous different solutions, which makes it possible for a traveller to identify the available options for travelling between specific points on a preset cost level.

Fare Types Charged from Public Transport Users

The charges paid by public transport users may vary in form. Examples were presented in Table 1.

The ticket types used by public transport users were described in Table 2. There are various forms of charges as well as tickets. The fare amount is adjusted to different user groups, offering them travel discounts (e.g. schoolchildren and students, pensioners, and veterans). Sometimes, the travel cards or similar cards also allow for using other municipal services, covering charges for parking, theatre entry, etc.

It is obviously very important that a common fare standard is introduced by all public transport operators within the given territory. This is the first step towards further adjustment of this transport form to travellers' needs.

Under the research discussed in the study, surveys were conducted within the area functioning as a testing ground under the Green Travelling project being implemented. Research area consists of the following cities (Fig. 1): Katowice (1), Chorzów (2), Zabrze (3), Gliwice (4), Mysłowice (5), Sosnowiec (6), Dąbrowa Górnicza (7), Czeladź (8), Będzin (9), Bytom (10), Ruda Śląska (11), Świętochłowice (12), Siemianowice Śląskie (13), Tychy (14), Mikołów (15), Knurów (16), Tarnowskie Góry (17), Piekary Śląskie (18) and Jaworzno (19).

Table 1 Selected forms of charges paid in public transport

Form of charges	Description
Fixed fare	Fare amount does not depend on the distance covered
Zone fare	Fare amount depends on the number and the type of zones through which one travels
Time fare	Fare amount depends on the specific period of time starting from punching The ticket in the first public transport vehicle (this option permits changing)

Source Refs. [6, 14]

Table 2 Selected ticket types in public transport

Ticket types	Description
One-way tickets	Valid during travel between origin and destination locations
Period tickets	Valid for 1 day, 3 days, week, month or quarter
Travel cards	Using in prepaid system and purchase the right-to-use public transport in advance

Source Own research

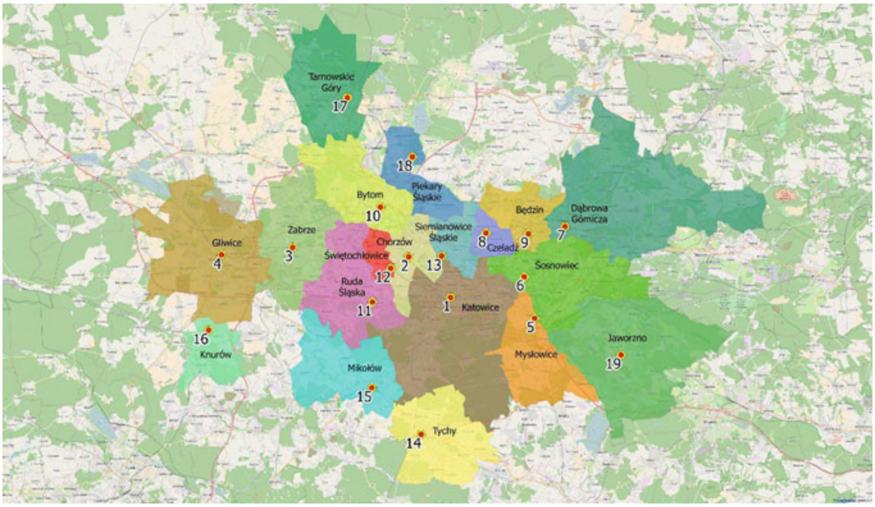

Fig. 1 Map of the central part of Silesian Voivodeship with borders of the 19 municipalities surveyed and the test points marked. *Source* Own research

In each of the 19 municipalities, one public transport stop was chosen, characterised by the largest number of departures of public transport vehicles in the given town, on working days and on Sundays (city number refers to public transport stop number).

There are several providers of public transport services operating independently within the area examined. They include KZKGOP (whose services include bus and tram transport and are subject to common tickets), PKM Jaworzno (ensuring bus transport within borders of the town of Jaworzno and neighbouring municipalities) and MZK Tychy (providing passenger transport services in the town of Tychy by means of buses and trolleybuses as well as bus transport to adjacent municipalities). There is also railway traffic within the area studied, managed by several institutions, including EIC, Inter City Inter Regio, Koleje Śląskie, Przewozy Regionalne and TLK.

A common tariff applies in the bus and tram lines administered by KZKGOP. They are divided into zones and offer time tickets as well. This enables travellers to choose the most convenient way to cover the required payment. There is also a selection of period tickets offered. One can also make use of the ŚKUP system (kind of urban card), which has gradually been evolving throughout the recent years [15]. Passengers using the services rendered by PKM Jaworzno pay for transport by means of the Jaworzno urban card (Jaworznicka Karta Miejska). In this case, individual zones have been established. One can also buy a one-day or a one-week ticket [16]. MZK Tychy has introduced time fares (20/40/90 min) and period tickets [17]. As far as railway services are concerned, the carrier with the most extensive offer in the area subject to the survey, i.e. Koleje Śląskie, offers section tickets (depending on the distance travelled), line tickets for chosen connections (lines) and network tickets, the latter being free of any kilometre or connection limitation.

Figure 2 clearly shows that the area covered by the research is characterised by a dense network of public transport connections, particularly bus lines. However, a dense public transport network does not necessarily translate into an efficient system adjusted to travellers' actual needs. In this respect, the system's inhomogeneity (lack of common tariff policy among all entities rendering public transport services) generates higher costs. In particular, when time and costs matter, public transport should constitute a real alternative to individual transport (passenger cars, in this case). The foregoing appears to be particularly relevant in the light of the necessary changes in the modal split expected to take place within the incoming years [18]. In numerous publications elaborating upon this matter, one may find explicit indications of the interdependence between the

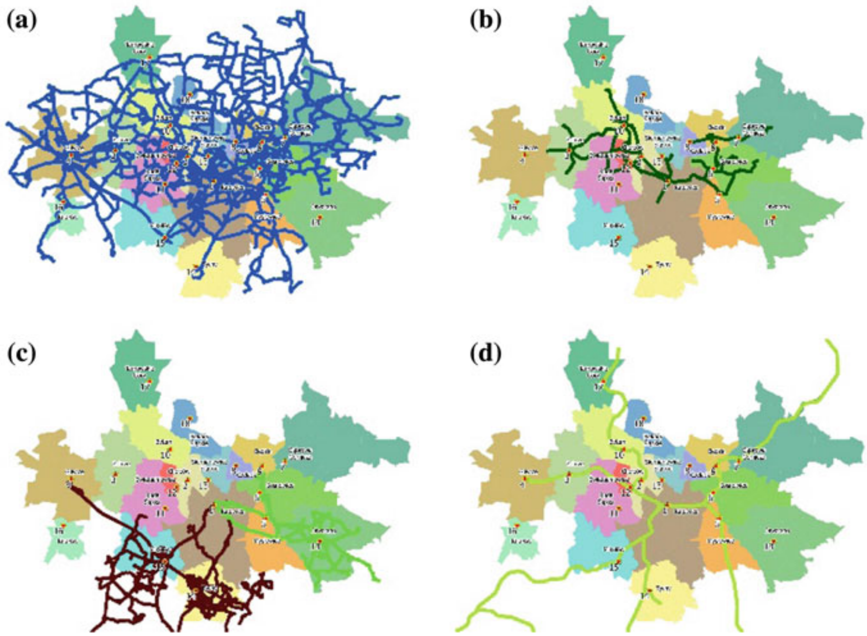

Fig. 2 Layout of public transport lines in the research area: **a** bus lines administered by KZKGOP, **b** tram lines, **c** lines serviced by MZK Tychy (*brown*) and PKM Jaworzno (*green*), **d** railway lines. *Source* Own research

fare development policy [6, 19] the time-related availability of public transport [20–23] and the final modal split of traffic (these relations have been discussed in numerous papers, including [5, 24–27]). It is from the foregoing premises that further contents of this study arise, where comparative collations have been provided for the travels determined to be the cheapest or the quickest, entailing the use of a passenger car and public transport, respectively (including change options). Travelling routes defined for the criteria referred to as "cheaper" and "quicker" were prepared using the GT Planner tool [28, 29], being a multimodal trip planner developed under the Green Travelling project [30]. However, the said collations entail direct costs only, which means, in the case of public transport, fares charged for travelling (one-way tickets) and as for the passenger car—fuel costs (service, maintenance and other costs have been disregarded) [9].

Comparison Between Public Transport Charges and Costs of Individual Transport (Car)—"Cheaper" Criterion

In order to compare the expenses incurred by persons using public transport and those involved in travelling with a passenger car in the routes established between the selected 19 points, the following cost index has been introduced (1):

$$w_{\mathrm{C}} = C_{\mathrm{PuT}}/C_{\mathrm{CAR}} \quad (1)$$

where

w_{C}—cost index; C_{PuT}—cost of travel by means of public transport [PLN]; and C_{CAR}—cost of travel by means of a passenger car [PLN].

Table 3 provides a breakdown of cost index values. It implies that for 53.51% of the connections made, public transport charges are lower than the cost involved in travelling with a passenger car. Great range of cost index is visible—minimum value 0.40 and maximum 4.52. In the first case (minimum value of cost index) for a long travel, ticket cost was much cheaper than the cost of fuel. In the second, very short travel caused that much cheaper is to take a car than buying a ticket (even though part of the route was realised by foot).

Sample travels made using a passenger car and means of public transport for the cost index both higher and lower than 1 have been illustrated in Fig. 3.

Another value established for each travel was the following time index (2):

$$w_{\mathrm{T}} = T_{\mathrm{PuT}}/T_{\mathrm{CAR}} \quad (2)$$

where

w_{T}—time index, T_{PuT}—total time of travel with public transport [s]; *and* T_{CAR}—total time of travel with a passenger car [s].

Table 3 *Cost index* w_C for routes examined according to the "cheaper" criterion

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1		1.69	0.68	0.49	1.32	1.38	0.79	1.27	0.98	0.90	1.41	1.77	2.41	1.59	1.45	0.66	0.51	0.71	1.24
2	1.95		0.91	0.60	1.27	0.89	0.90	1.48	0.87	1.46	1.76	4.92	2.42	1.16	1.16	0.98	0.65	1.01	0.98
3	0.69	0.94		1.62	0.92	0.71	0.59	0.82	0.68	0.95	1.57	1.61	0.71	0.93	0.81	0.95	0.67	1.00	0.66
4	0.73	0.60	1.64		0.72	0.74	0.66	0.64	0.55	1.34	0.99	0.98	1.10	0.40	0.55	1.45	0.59	1.56	0.55
5	1.22	1.18	0.91	0.72		2.70	2.16	2.18	3.25	1.13	1.34	1.15	1.90	1.23	1.47	0.71	0.76	0.76	2.14
6	1.36	0.91	0.67	0.53	2.19		1.63	1.67	2.81	0.98	0.97	1.11	1.18	1.78	1.18	0.70	0.92	1.26	0.78
7	0.78	1.24	0.60	0.66	2.10	1.51		1.78	2.83	0.93	0.77	0.85	0.90	1.67	1.30	0.57	0.83	1.79	0.69
8	1.82	2.06	0.81	0.84	2.06	1.67	1.38		2.42	1.03	2.02	1.33	2.23	1.00	0.83	0.68	0.82	0.85	1.13
9	0.98	0.75	0.45	0.72	1.92	2.53	3.11	2.52		0.75	0.60	0.68	0.96	0.96	0.98	0.68	0.69	0.83	1.31
10	0.97	1.94	1.05	1.34	1.18	0.82	0.94	1.11	0.78		1.20	2.07	1.54	0.97	0.89	0.96	1.05	1.71	0.78
11	1.41	1.65	1.09	0.82	1.37	0.92	0.76	1.01	0.89	1.27		3.06	1.69	1.57	2.25	0.62	0.83	1.08	0.86
12	1.81	4.27	1.26	0.66	1.17	1.23	0.85	1.80	0.69	1.56	2.71		2.25	0.91	1.24	0.81	1.33	1.84	0.93
13	2.50	2.83	0.83	0.59	1.92	1.31	0.88	1.53	0.96	1.19	1.36	1.90		1.30	1.10	1.05	0.59	0.94	1.05
14	1.48	1.11	0.92	0.48	1.27	1.72	1.66	2.01	0.96	1.09	1.44	0.91	1.19		1.49	0.86	0.77	0.95	0.92
15	0.95	1.14	0.68	0.58	1.19	0.86	0.96	0.83	0.98	0.85	1.36	1.23	1.06	1.47		0.73	0.93	0.88	1.29
16	0.43	0.96	0.80	1.68	0.72	0.72	0.56	0.69	0.92	0.93	0.61	0.81	1.05	0.86	0.92		0.83	1.17	0.77
17	0.51	0.69	0.68	0.59	0.95	0.84	0.81	0.99	0.68	1.03	0.83	1.30	0.87	0.94	0.92	0.84		1.11	0.57
18	0.71	1.11	0.67	0.78	1.10	0.88	0.88	0.86	0.81	2.04	1.12	1.89	1.41	0.95	1.34	1.15	1.14		0.76
19	1.21	0.95	0.66	0.61	1.07	0.80	0.71	1.26	1.33	0.84	0.86	1.02	1.06	0.91	1.18	0.77	0.58	0.78	

Source Own research

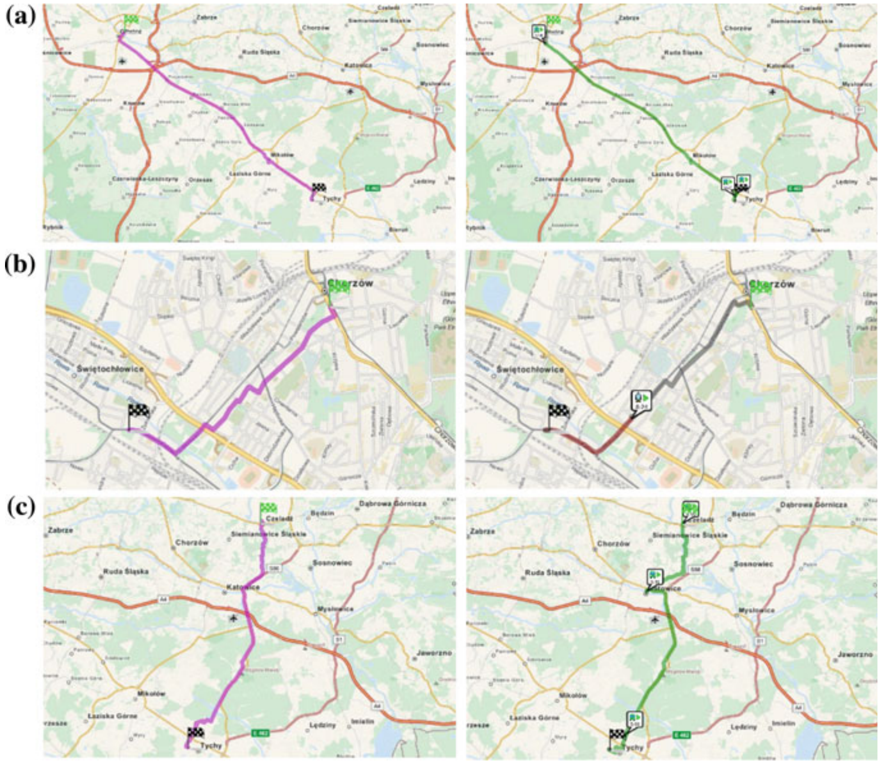

Fig. 3 Chosen travels by passenger car (*on the left*) and public transport (*on the right*) for the "cheaper" criterion: **a** points 4 → 14, cost index 0.40; **b** points 2 → 12, cost index 4.92; **c** points 8 → 14, cost index 1.00. *Source* own research

Since there are several factors of importance for a travelling person, taken into consideration while making a choice of the travelling mode, a quality index was assumed entailing both the said travel attributes (time and cost) (3):

$$w_Q = w_C \cdot w_T \tag{3}$$

where

w_Q—travelling quality index.

The values obtained from such a comparison have been collated in Table 4. This time, only 24.56% of the analysed connections of public transport is better than the car. The maximum value of the quality index (due to the much longer journey time of public transport) amounted to 17.01.

Table 4 Quality index w_Q for routes examined according to the "cheaper" criterion

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1		2.06	0.79	0.49	2.00	1.84	2.02	1.43	1.51	0.82	4.42	2.47	3.08	1.72	3.99	1.46	0.44	0.88	1.02
2	2.23		1.03	0.57	2.66	1.77	2.70	2.19	1.72	1.19	2.23	15.21	3.59	1.30	3.20	1.60	0.53	1.34	1.39
3	1.11	1.08		0.95	8.03	1.25	0.64	1.11	0.73	1.01	1.77	2.28	0.69	1.07	1.39	1.42	0.79	2.23	0.90
4	0.70	0.61	0.93		0.80	0.89	0.57	0.61	0.48	2.53	1.29	1.15	1.33	0.35	0.43	1.91	0.66	3.98	0.64
5	1.85	2.57	1.61	1.03		8.00	2.60	3.70	6.05	1.33	1.84	2.75	3.46	2.00	2.48	1.31	0.83	0.83	2.72
6	1.41	1.35	1.28	0.75	3.71		2.32	2.17	1.46	1.46	1.64	1.56	1.62	1.94	1.67	1.19	1.06	1.72	1.35
7	1.13	1.69	1.92	0.60	3.57	1.35		3.36	4.48	1.29	1.57	2.18	1.43	2.22	1.69	0.79	0.99	17.01	1.23
8	3.30	5.35	1.11	0.99	3.12	2.49	1.30		2.34	1.61	3.02	2.29	6.07	1.39	1.12	0.83	0.93	1.11	1.72
9	1.65	0.77	0.49	0.63	3.97	4.52	7.96	6.70		0.76	1.08	1.35	1.47	1.62	7.32	6.74	0.94	0.75	1.35
10	1.21	2.24	1.24	1.68	2.19	0.95	1.13	1.31	0.87		1.26	2.32	2.18	0.95	1.30	1.97	0.70	2.22	0.96
11	1.98	2.42	1.38	0.87	2.34	1.07	1.38	1.41	1.67	2.28		6.45	2.33	2.62	3.01	0.80	0.91	1.57	1.15
12	2.23	5.85	1.79	0.79	2.64	2.45	3.39	2.25	1.66	1.65	2.26		3.96	1.07	2.33	1.36	1.35	3.13	1.14
13	3.47	5.74	1.37	0.87	3.87	1.86	1.12	2.06	1.47	0.96	1.84	3.08		1.38	2.18	2.08	0.48	0.92	2.11
14	10.16	1.53	1.26	0.47	2.29	14.46	1.83	3.74	1.72	1.65	2.25	1.32	1.51		2.16	1.78	2.23	1.22	1.24
15	1.34	2.24	1.24	0.51	2.03	1.29	2.01	1.07	1.67	1.03	2.77	2.13	1.69	1.50		0.80	1.23	1.08	1.54
16	0.56	1.47	1.38	2.97	1.06	0.96	0.75	0.81	7.78	1.21	0.86	0.99	1.97	1.49	1.19		1.19	10.52	0.91
17	0.59	0.57	0.91	0.74	2.87	0.87	0.99	1.37	0.89	0.93	0.80	1.42	0.85	0.98	1.05	1.26		1.22	0.54
18	0.70	1.46	1.09	2.11	0.98	1.13	1.14	0.81	0.72	1.73	1.26	2.97	2.25	1.23	2.28	10.79	1.28		0.65
19	1.99	1.29	1.14	1.01	1.21	0.72	2.69	1.53	1.54	5.38	1.01	1.81	1.21	4.21	1.29	0.88	0.47	0.66	

Source Own research

Comparison Between Public Transport Charges and Costs of Individual Transport (Car)—"Quicker" Criterion

Having applied the criterion of the quickest connection to public transport, individual routes were defined for travels made between 6 a.m. and 10 p.m. with a 2-h interval. By that means, it was possible to compare costs of travel in time. The results thus obtained implied that for some connections (points analysed), regardless of the time when the route was calculated, the public transport fare would always be higher compared to the cost of fuel consumed by a passenger car. For these places, potential alterations and improvements to the transport situation should be taken into consideration. For 342 connections analysed between the selected 19 points, for all hours subject to the analysis, on average, more than 42% of travels by means of public transport proved to be cheaper compared to those made with a passenger car (cost index $W_C < 1$). Table 5 provides average values for each hour interval.

Results illustrating the variability in cost index w_C in consecutive time intervals for six sample connections have been collated in Fig. 4. The connections chosen for purposes of the diagrams were characterised by considerable variability in the fares charged for travelling depending on the time interval (such results were caused by taking different chains of connections and different means of transport into consideration).

Case (a) represents a situation when using public transport in all time intervals would always be cheaper than travelling with a passenger car. Further cases illustrate worse scenarios, all leading to the extremely unfavourable situation marked as (f), where the public transport fares for every single time interval were higher than the costs connected with the passenger car choice.

Table 5 Percentage share of travels (among the 342 ones examined) for which cost index $w_C < 1$ (cost of travel with public transport being cheaper than using a passenger car) for routes examined according to the "quicker" criterion

Departure time	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	All
%	43.71	44.05	42.22	38.82	39.76	50.15	40.95	42.31	43.99	42.88

Source Own research

Fig. 4 Variability in cost index w_C with reference to consecutive time intervals for the chosen travels by passenger car (*orange*) and public transport (*blue*) examined according to the "quicker" criterion: **a** points 16 → 7, **b** points 16 → 9, **c** points 3 → 1, **d** points 9 → 2, **e** points 6 → 12, **f** points 6 → 5. *Source* Own research

Conclusions

The analysis of costs related to travelling between the points selected within the research area has implied that public transport is not the cheapest solution. Depending on the situation (distance between the travel start and destination points as well as departure time), travelling by public transport may be even 3.5 times more expensive than using a passenger car. It should be noted that the analysis addressed in the paper applied to stops from which public transport vehicles departed in the largest numbers which may have corresponded to points generating (against the running frequency) the most intense traffic. In case one should wait too long directly at the selected stop, a travel by public transport was defined in the trip planner using another stop, with the necessary distance involved to be covered on foot. Such a solution made it possible to find a more time-optimised connection. Consequently, the results thus obtained do not apply to the given point, but also to its direct vicinity, assuming the acceptable walking distance threshold. Therefore, one may suggest a need for changes to be introduced in the existing timetables in order to reduce costs of travelling between towns. Further analyses will entail actual needs of travellers, as determined based on transport studies.

Using the aforementioned tool, namely GT Planner, the user is able to collate numerous different solutions, which makes it possible for a traveller to identify the available options for travelling between specific points on a preset cost level. On the other hand, a more extensive analysis of multiple connections available in time, with different criteria being applied, may highlight organisational gaps in the system of public transport services rendered in the given area and provide firm grounds for the public transport reorganisation. This problem has been addressed in a separate study.

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Strategic Analysis of Risk of Employing in Public Utility Transport Enterprises

Krzysztof Szałucki and Joanna Fryca-Knop

Abstract Strategic risk of employing is of particular importance in the case of public utility transport enterprises, due to the importance of the human factor to their functioning, development and to ensure undisturbed public access to the services of collective public transport. Hence, the need for strategic analysis of risk is associated with employing in these entities, in which the interdisciplinary nature requires identification of both quantitative and qualitative attributes of that risk. In connection with these conditions, an attempt has been made to establish the facts of the importance of the risk of employing in strategic planning of public utility transport enterprises and their values in decision-making. This was the basis for predicting the future behaviours of the surveyed entities.

Keywords Risk of employing · Strategic risk of employing · Strategic analysis of risk · Public utility transport enterprise

Introduction

The changing business conditions imply an increase in the level of uncertainty associated with decision-making, which in turn generates the risk understood as the combination of the probability of an event and its consequences [1]. It is strongly typed in the business of modern enterprises. In its structure, risk is complex and multidimensional, relates to different areas of activity of the enterprise, among which there are also employment, and specifically the employment decisions areas.

K. Szałucki (✉) · J. Fryca-Knop
Faculty of Economics, University of Gdansk, Sopot, Poland
e-mail: k.szalucki@gnu.univ.gda.pl

J. Fryca-Knop
e-mail: j.fryca@ug.edu.pl

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Analysing both Polish [2–4] and foreign [5–7] literature, the growing interest in the study of factors affecting the risk of employing could be seen. In the majority, they relate to operational risk analyses, and much less space is dedicated to strategic risk of employing. It is particularly important when it concerns of public transport enterprises, due to the importance of the human factor for their functioning, development [8] and to ensure unhindered public access to the services of collective public transport. Hence, the need for strategic analysis of risk associated with employment in these entities, in which interdisciplinary nature requires identification of both quantitative and qualitative attributes of that risk.

At this point, the following questions should be raised: What is the practical utility of the Tri-city public utility transport enterprises study the risk of employing and whether they take them into account in their strategic plans? The answer to these questions can in fact be used to predict the organizational behaviour of these entities, which are the result of employing decisions they take.

Hence, the purpose of this study was to examine the risk of employing recognizing it as a strategic issue of public transport utilities. In the theoretical part of the study, the risk of employing has been characterized focusing on its role in shaping the market behaviour of public transport enterprises resulting from their decisions strategic. In the empirical layer while presented and discussed, the results of studies aimed at determining the facts concerning the significance of the risk of employing in strategic planning of public utility transport enterprises and their values in decision-making. This was the basis for predicting future behaviour of these entities. The study concerned selected public utility enterprises which perform transport services in the Tri-City Metropolis. In 2016, the personalized interviews were carried out with managers of these entities.

The Diversity of Behaviours of Public Utility Transport Enterprises as a Result of Mismatch of Competence in the Labour Market

A labour market is a place where people are allocated among available jobs, labour resources are being utilized, and decisions are coordinated about their use. They exemplify on the preferences of the participants as to the quantity and quality of exchange itself that is work. These preferences can be identified by the behaviour of these entities, both occurring on the supply and demand side of the market. In the latter case, we are dealing with employers, often enterprises, and those who need for work primarily depend on the type, scope and conditions for doing business. Their behaviour, which is one of the ways to be active, they have an organizational nature. They can be defined as an external picture of the activities undertaken by the enterprise in the labour market, which is a response to external and internal stimuli [9], which provides comprehensive information about it [10].

Among the entities filling the demand side of the labour market, there are public utility transport enterprises. They play a particularly important role in the economy and thus also on the labour market. Their main function is in fact ongoing, uninterrupted satisfaction of the collective needs of citizens through the provision of publicly available services [11]. In the case of transport operations, they should relate to the performance of transport services in the city and suburban areas, namely urban transport. At this point, it should be noted that in the process of providing those services involved are two basic groups of entities, separated due to the different functions they perform in it, namely organizers and operators. According to the act of collective public transport [12], organizers create the possibility of meeting the needs of transport. So these are usually local authority units responsible for the operation of collective public transport in the area. For it, however, as the specific tasks are carried out, responsible are operators. These may be local authority budgetary establishments, as well as entrepreneurs authorized to do business in passenger transportation provided that they have concluded with the organizer of collective public transport a long-term contract. On this basis, they are taking action leading to the need for specific tasks on the line of communication specified in the contract adopted by its principles. Directly implements them, however, the carrier, which is entitled entrepreneur on the basis of confirmation of the application transport. This distinction is extremely important because of the relationships that imply the preservation of public utility transport enterprises concerning the principles and mechanisms to ensure appropriate quantity and quality of labour resources necessary to implement programmable transport work.

Performing services on the market of collective public transport enterprises engage diverse human resources. Usually, they are represented by:

- employees working in the sphere of operation (mainly drivers);
- employees working in the sphere of technical background;
- employees working in the sphere of organization;
- employees working in administration and office; and
- employees working in service.

For in the labour market, we can observe differences in quantitative and qualitative mismatch within each group, providing staffing is associated with different levels of uncertainty identifiable by enterprises. The most serious mismatch between demand and supply of labour applies to drivers and technical background employees. It can be considered that this is the most conflicting area of the market that causes the differentiation behaviour of individual public utility transport enterprises.

In order to analyse them on many levels, it is worth to use the classification of organizational behaviours of enterprises, which are presented in Table 1. Twenty-one criteria have been isolated in it allowing for bipolar behaviour analysis, assuming that the actual behaviours of individual enterprises are within the proposed extremes.

Table 1 Classification of organizational behaviour of enterprises

No.	Criterion of division	Behaviours
1	The way of activity against surrounding	Organizing ↔ organizational
2	The degree of indispensability of resources	Concentrative ↔ deconcentrative
3	The way of organizing/degree of formalization of structures	Institutionalized ↔ individualized
4	The way of understanding responsibility	Collective ↔ individual
5	The way of activity disclosure	Formal ↔ spontaneous
6	The degree of independence	Centralistic/extorted ↔ independent
7	The way of identifying future/strategic goal	Insolvent ↔ expansive
8	The way of identifying an environment	Aggressive ↔ passive
9	The way of evaluating a success	Risky ↔ cautionary
10	The way of decision–making	Emotional ↔ speculative
11	The way of perception of reality	Systemic ↔ incidental
12	The way of identifying events	Untypical ↔ typical
13	The way of determining the past	Novel ↔ traditional
14	The degree of compliance with the rules	Standard ↔ non-standard/innovative
15	The degree of determination principles/degree of innovation in action	Creative ↔ imitative
16	Market activity	Active ↔ inactive
17	The strength of the influence on the environment	Leadership ↔ imitative
18	The way of forming roles	Specialized ↔ diversified
19	The way of determining market strategy	Pro-marketing ↔ pro-productive
20	The degree of seizing the area	Global ↔ local
21	The continuity of undertaking the tasks	Operative ↔ strategic

Source Adapted from Majecka [10]

Role of the Risk of Employing in Long-Term Decision-Making

Behaviours of individual enterprises operating in the market of collective public transport are the identifiers of specific management decisions made in the sphere of employing by these entities. At the same time, being a useful source of knowledge they allow to explain behaviours, their anticipation and exercise control over them [13]. Those enterprises wish to provide access to public services make decisions to secure human resources, with which decisions the specific organizational behaviours are related to, which are both determinants of decision-making processes and the result of these decisions [14].

These decisions relate to the problems of employment, that is shaping the quantity and quality of available labour resource necessary for the proper performance of current and future objectives of the enterprise. Their range so includes implementing individual HR functions. In this case, decisions should be aimed at ensuring the enterprise with the required number of employees with the right competencies in the right place and time and creating conditions which stimulate the efficient behaviour of employees in line with the overarching objective of public utility transport enterprise. Their character is short term and operational. At the same time, the employment decisions should be seen also in the context of the strategy implemented by the enterprise. When they relate to the strategic level, their scope should refer to anticipate future human capital of public utility transport enterprise, allowing for delivering value to stakeholders and then the creation of programs aimed at achieving the targets [15]. In this context, these decisions will have long-term and strategic nature.

The decisions concerning with employment, as well as decisions on other spheres of entrepreneurial activity, involve risk [16]. However, its meaning, a way of interpreting, as well as its forming by the organizations, was changing and still evolving [17]. The risk may be regarded as an opportunity for enterprise development [18] or as a loss resulting from the failure to achieve results [19]. Its types derive from different literature approaches.

A specific type of risk is the risk related to employment that A. Lipka defines as engaging in conditions of uncertainty in activities relating to human resources, which may fail [2]. The risk of employing can be defined as the risk of loss (financial, image-related or relations) resulting from human imperfection and the imperfection of the processes of their formation [20]. Because these processes can involve a short as well as a long time horizon can be seen on two levels—operational risk and strategic risk [21]. The first of these should be related to the implementation of the HR function, thus leading to the short-term planning of operational managerial decisions. In contrast, strategic risk of employing is about building human capital of the enterprise [22]. So from necessity, it requires long-term planning which is the basis for managerial decisions of a strategic nature. Systematics of identifiable types of risks associated with employment of employees is shown in Fig. 1.

Strategic risk in the analysed area may be due to three major problems: first, from the deficit or surplus of employment which are quantitative expressions of design options for future business activities, which, however, to a large extent are conditioned by the quality of the available potential. Hence, the strategic risk of employing also results from the competency gaps and redundancy competence of determining the degree of match quality employees to the nature of the activities programmed for them. In addition, it is worth paying attention to the uncertainty associated with decisions concerning continued employment of labour, especially in the long-term horizon. It implies the possibility of loss of enterprise crucial knowledge for the proper conduct of future activities of these entities and therefore strategic risk.

In the face of the specifics of the relationship in which enterprises remain public transport organizers demarcating the area of discretion, extremely important is the analysis of strategic risk of employing. Enterprises are facing the need for

Fig. 1 Classification of employing risk. *Source* Adapted from Gołębski M.: Parametryzacja funkcji personalnej jako narządzie zarządzania ryzykiem kadrowym, pp. 527. Zeszyty Naukowe Uniwersytetu Szczecińskiego, No. 855, Finanse, Rynki Finansowe, Ubezpieczenia, No. 74, Vol. 1, Szczecin (2015)

contracted services of municipal transport. Since these are long-term agreements, their implementation requires monitoring of risk, including the risk of employing because it is a medium of information for strategic decisions of these entities.

Strategic analysis is a collection of activities to diagnose the enterprise, and its environment enables the creation of strategic plans taking into account the risk of employing and their effective implementation [23]. It allows the public utility transport enterprises to have the knowledge about strategic risk binding with the limitations of quantitative and qualitative employment. This is the starting point for the formation of this risk. To make these actions effective, it seems necessary to establish the factors that affect the risk of employing in collective public transport, since they will be a source of imperatives that affect the determination of strategic risk of employing and its values.

In practice, public utility transport enterprises represent diverse attitudes of strategic differently coping with the risk of employing. This is due to the specific risk values in specific economic units estimated both quantitatively and qualitatively, recognized values by these units, and in general—which have strategic potential. Recognition of these categories, even though it is not an easy task, can predict the future behaviour of the surveyed enterprises in the market of collective public transport.

Risk of Employing Study as a Strategic Problem in Selected Public Utility Transport Enterprises

Risk of employing study as a strategic problem requires first to determine the transport enterprises which were taken into account have a strategic potential for the existence and further action, consistent with the specificity of the supported market [24]. This meant the need to resolve the problem of the ability to plan their own activities in the horizon of over two years, programming occurring in the planning of the issues and risks, and identifying imperatives in them for the case on the subject of employment.

Carried-out study of the selected public utility transport enterprises, without any doubt and difficulty, confirmed the ability of these entities to strategic planning. However, the imperatives were disputable that should be taken into account in shaping the attitudes of strategic of enterprises. It was difficult to achieve a uniform assessment of the attitudes of the surveyed public utility transport enterprises. Course of exchange of views, however, led to the structuring and identification of the following strategic risk factors:

- Group of imperatives that can be described as a classic in determining the strategic risk in public utility transport enterprises:
  - degree of certainty to maintain transport production in a particular industry;
  - immutability of preferences in the individual customer selection using service of enterprises;
  - the level of competitiveness characteristic of a given market segment of collective public transport;
  - maintaining the qualitative characteristics of transport production, characterized by a particular segment of the transport services market; and
  - maintain to keep up with technological advances occurring in the field of technical solutions of rolling stock.
- Group of imperatives, which can be described as pragmatic in determining the strategic risk in public utility transport enterprises:
  - level of skill and acceptability implemented in the enterprise long-term planning;
  - level of skill entry requirements in macroeconomic development projects of enterprises, first of all investment projects;
  - confidence to maintain the necessary level of employment in the enterprise, including the level and structure;
  - confidence to maintain—in the area of macroregional—the necessary transport services market taking into account its level of service and growth; and
  - degree of adapting standards of business law, with particular emphasis on the principles of transport law.

With fixed imperatives of strategic risk, it is evident that the problem of employing is one of the factors that also have to be settled during the period of many years, as revised terms of macroeconomic and microeconomic market of transport services. Executives of surveyed transport enterprises have underlined, however, that it considered strategic risk in employing only in relation to their opinion, two key professional groups: drivers and employees of technical background.

Strategic analysis in relation to the drivers of public utility transport enterprises primarily concerns the issue of employing this professional group. Among full-time drivers, employed under a contract of indefinite duration, there is a perception of having to deserve attitude to this way of working. Hence, the driver who is starting work is employed from the rules on fixed-term contracts, often part-time. This raises the problem of strategic maintenance of such forms of labour relations and the consequences of achieving the full staffing in the group of drivers.

Another problem of the strategic analysis of drivers of public utility transport enterprises remains a matter of employing this professional group on a contract of employment in a part time. In this group, usually work-experienced drivers have a contract of indefinite duration in another enterprise or run their own business. Analytical challenge in the strategy of public utility transport enterprises remains the long-term supply of this labour market. This market is relatively flexible, but very shallow when it comes to ensure the implementation of work schedules and stability interpretation of labour law in this area.

A completely different range of topics deals with strategic analysis when it comes to employing technical background employees. The study of this subject has shown that there are not enough employees in the labour market. Another problem is sought professional qualifications of such employees. There is no doubt that vocational education of this group of employees has ceased to exist in Poland. Technical universities, in terms of graduates with engineering profession, prepare employees for other roles than those sought by the public utility transport enterprises professionals. Presented by the management of public utility transport enterprises, this problem seems to be deep and unanimously articulated.

On the basis of these studies, one can determine the risks inherent in the issues of employing as a strategic problem occurring in public utility transport enterprises. The issue of employing drivers is characterized by relatively low strategic risk. While the risk of issue in employment of technical background of public utility transport is clear and growing. It comes even to start a qualitatively higher—from the very fact of employing—a phenomenon which is a ruinous competition in the market occupied by a specific small amount of public utility transport enterprises, and in this case, it is already competition based on creating non-economic conditions.

The problems presented above are associated with the strategic horizon formation of processes employing in public utility enterprises shape the behaviours of these entities. With attitudes presented by the management of the surveyed public utility enterprises that will be preferred—just in strategic horizon—the organizational behaviours are as follows [10]:

- concentrative,
- individualized,
- formal,
- expansive,
- aggressive,
- creative,
- diversified,
- local and
- Pro-productive.

Strategic Analysis of Risk of Employing Challenge for Public Utility Transport Enterprises

Strategic risk in business of public utilities transport enterprises is characterized by a very important relativity [25]. However, its analysis should be performed in accordance with a specified algorithm procedure, the fundamental values and steps in the proceedings as follows [23]:

- striving to identify the situation, accompanying one problem by creating a project of the course on a certain number of years ahead;
- selection of methods and techniques of such analysis, aimed at aggregating necessary—just for making strategic decisions—information; and
- tracking the volatility surrounding areas and modes of operation of an enterprise in order to continuously adapt target states.

Strategic analysis of place of public utility transport enterprises in employment indicates that over the next two to five years, these units will prefer those behaviours highlighted above, to minimize the risk of doing business in their market area.

Reducing the strategic risk related to employment through behaviour by the concentration of public utility transport enterprises is primarily aimed at ensuring the reliability performance of the contracted transport work. Public utility transport enterprises contract the current operational activity of its own concluding entrusting contracts, which essentially are multiannual. Employment is one of the basic factors of production of transport, guaranteeing the achievement of the necessary and the potential transport capacity. Therefore, the concentration of the appropriate number of people is a condition not disputable and that cannot be omitted. Strategic risk associated with not meeting the appropriate concentration employees in enterprises of public utility transport should, however, be assessed as relatively small.

Strategic risk resulting from the need to demonstrate the individualized forms of behaviours in terms of employment in public utility transport enterprises due to the fact not possible adoption by these units responsible for such processes. Due to the fact that the public utility transport enterprises are usually capital organizations in the form of limited liability enterprises, it is anticipated that the forms of individualized behaviours will be standards. From the current perspective, you cannot see the factors that could disrupt the individualized forms of action. From the perspective of the operational management of strategic risk, this defined factor is minimal.

Now, the formalism behaviour of public utility transport enterprises does not raise any doubts, and the foreseeable future will also be performed. Strategic risk associated with any informal behaviours of public utility transport enterprises in terms of employment should be seen in today's volatility of labour law in that regard. Collective public transport is condemned to flexible forms of employing, especially in the group of drivers. The limitations of these particular features significantly increase the direct cost of labour, which in turn will force the management of public utility transport enterprises to look for extremely individual forms of employing. However, those do not provide the confidence in the regularity of performing the same transport work. Strategic risk associated with these very aspects of employing is currently relatively small. Thus, in the coming years, the programmed strategy should be considered as increasing.

Strategic risk, which is caused by extensive forms of behaviours of public utility transport enterprises, caused to primarily the need to pursue strategic goals by units effectively running them. These are by far as follows: the exchange and development of technological means of transport production, and maintaining or increasing their own position and market value. The expansion strategy in the field of employment is therefore a prerequisite for the realization of strategic objectives in the long term if they are to be met. Strategic risk associated with possible non-compliance of these conditions in the market for public utility transport should be considered as a small, but steadily and clearly occurring.

Employing in public utility transport enterprises, in particular technical and operational employees, requires absolutely attitudes and aggressive behaviours. The strategic perspective competing for this group of employees against each other, such as attitudes and behaviours of other transport operators, should be uncompromising. The argument strengthening such approach is the process of innovation throughout the economy. Therefore, strategic risk related to the employing of specialists in the field of techniques and municipal transport technology, to the fierce competition of the market, should be considered important.

Creative behaviours of public utility transport enterprises arise now and will arise in the future due to the course of technical, technological and organizational progress, which will take place in a collective public transport. Each subsequent purchase of new transport rolling stock characterized by significant innovation triggers the need for permanent training of the crew and the exchange of background technical equipment. Employing in just such conditions becomes and will be a decision issue. Strategic risk for these processes is already noticeable and in the years ahead will certainly grow.

The most difficult problem is associated with the strategic risk, which must be seen in the functioning of public utility transport enterprises, and there is the issue of orientation training for its own employees, respectively, in the direction of specialization or diversification. Specialization of work, in particular in relation to the technical support staff shaping technical readiness of the rolling stock, is essential. However, the process of specialization of work does not cause significant conditions for a strategic risk to appear in public utility transport enterprises. Otherwise, such a situation occurs in new technologies of transport means, taking into account environmental standards or saving use of non-renewable materials. Progress in this area, even shaped the requirements of ISO [26], is dynamic and certainly evokes the need to diversify the professional skills of their employees. Employing of them will—according to the management of public utility transport enterprises—be an increasing problem. Hence, the risk of strategic employing resulting from these conditions should be considered more and more important.

Public utility transport enterprises are business entities strongly and permanently associated with spatially well-defined markets of movement services. They almost never behave globally, and implemented transportation tasks treat almost as inherited. Not much economic factors are able to alter such a market order. Therefore, public utility transport enterprises are characterized by local and pro-productive behaviours. They perceive in just such attitudes of its own security market, both associated with these processes issues concerning employing do not bring any risks, and strategic space does not change this trend.

Conclusions and Recommendations

The risk associated with employment in public utility transport enterprises is one of the issues quite differently approaching to the level of the decision-making problem. Executives of these business units considered them real, but only in operational or situational approach. However, the research of approach of strategic risk of strategic employing in public utility transport enterprises has demonstrated conclusively that such uncertainty also exists in reality. Strategic analysis of this issue has demonstrated, in turn, that the risk of long-term employing can be identified by the—already existing—forms of organizational behaviours concerned transport enterprises and, more, can define their quality trends.

An open problem remains credibility of identification of strategic risk of employing in public utility transport enterprises through the proposed approach. The credibility of this must be determined through attitude of management as a team of people with a distinctive professional experience. Such recognition, however, is seen only in the ex post field. On the other hand, the problem of employing in public utility enterprises will be shaped in a way previously not seen. Hence the need to establish in relation to this problem the ex ante field. It requires a systematic scientific research and reflections absolutely rational, which allow to forsee public utility transport enterprises behaviours.

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Micro- and Macroeconomic Factors of Fares Changes in Urban Public Transport

Anna Urbanek

Abstract Organization of urban public transport is the municipality's own task. It is expected that fares will not only provide appropriate income, but also will become a relevant tool for the development of transport policy in cities. Decisions concerning ticket prices for urban public transport demand taking into account numerous factors and variables, among others, those concerning costs of service provision, financing possibilities, potential demand for services, and several social postulates concerning transport services offer. The aim of the paper is to make an attempt to identify the micro- and macroeconomic factors influencing changes of fares in urban public transport, as well as to examine their influence upon the development of ticket prices in Poland.

Keywords Urban public transport · Microeconomic factors · Macroeconomic factors · Ticket prices · Transportation · Fares · Pricing

Introduction

In most cities worldwide, the provision of urban public transport is a task of public authorities and—in accordance with the principle of subsidiarity—that task is most often executed by towns or unions of towns. Towns have the assets that serve the purpose of providing urban public transport services, they decide about the size of transport offer and quality of services, and they also are entitled to decide about price level. It is expected that prices for urban public transport services on the one hand will provide the required revenues, and on the other hand, the prices of services are meant to promote the use of public transport. Prices of urban public transport tickets are also a part of the public authority policy concerning redistribution of funds between various social groups. The latter is most often manifested

A. Urbanek (✉)
Department of Transport, University of Economics, Katowice, Poland
e-mail: anna.urbanek@ue.katowice.pl

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by the scope of reduced rates and fully subsidized free ridership, the consequence of which, in turn, is the necessity of subsidizing such services by means of public funds.

Urban public transport, like other sectors of the economy, is also influenced by various other factors, both the macroeconomic ones, which are of global and aggregated type, and microeconomic ones, which have their sources in decisions taken by specific parties, and consumers/passengers.

The issues of pricing have their scientific output in urban transport economics [1–6]. On the other hand, the literature of the subject hardly deals with issues connected with factors that influence such decisions, as well as the importance that the influence of those factors has on changes in prices of urban public transport services. The paper identifies the basic micro- and macroeconomic factors, which influence fares changes in urban public transport, and attempts to make a preliminary assessment of the influence those factors have upon ticket price development in the biggest Polish cities.

Macroeconomic Factors of Fares Changes in Urban Public Transport in Poland

Macroeconomic factors result from macroeconomic environment, in which the organization is located. They are factors defined at the level of state, upon which organizations have no influence, which they have to adjust to. Those factors are due—among other things—to the economic policy of the state, legal acts and regulations, economic standing of the state, demographic trends, and the development of new technologies and their accessibility [7].

Among the macroeconomic factors that have marked influence upon the development of prices for services of urban public transport, one should list first of all those, which influence the costs of provision of such services. In towns, in which transportation authorities have been established, the macroeconomic factors will be those that influence the expenditures of transport organizers, who commission transport services from urban public transport operators. The basic unit used in settlements between urban public transport organizer and operator is—first of all—the rolling stock operations, which are ordered, at appropriate rates. The level of rates is usually one of the crucial parameters used for the overall assessment of rationality and capability of purchasing transport services.

Table 1 presents the annual average rates per 1 vehicle-kilometer paid to the biggest transport service providers in selected Polish cities, in 2007 and 2014. The focus has been on data concerning cities with the biggest populations in Poland (exceeding 300 thousand inhabitants), for which information on rates in the studied time was available. In big cities, the urban public transport systems are indispensable parts of the urban fabric, and to a large extent, they are necessary for its efficient functioning. The economic standing of biggest cities thus substantially reflects the general economic trends in the sector of urban public transport in Poland. In case of Katowice, the information concerning the organizer of urban public transport has been taken into account, that of the Municipal Transport Union of the Upper Silesian Industrial District (Komunikacyjny Związek Komunalny Górnośląskiego Okręgu Przemysłowego—KZK GOP), which at present contains—besides Katowice—29 municipalities located in the central part of the province of Silesia.

It results from the comparison made in Table 1 that over the examined period of 7, the transport rates per 1 vehicle-kilometer, paid to service providers, increased significantly. In bus transport, the average increase noted in 2014 was 44.5% in comparison with 2007, while in case of trams, the growth over the same period amounted to as much as 96.3%. The average price was calculated as weighted operations provided by the companies examined.

The level of rates depends on the costs that operators bear, which in turn are influenced by numerous macroeconomic parameters. As can be concluded from standard breakdown of costs in transport, besides the price of fuel or electricity—in case of tram transport—they are labor costs, rolling stock purchase costs, financial

Table 1 Rates per 1 vehicle-kilometer (average for 12 months) paid to the biggest transport service providers in selected Polish cities, in 2007 and 2014

Transport organizer	Means of transport	Biggest transport provider/average	2007	2014	Change 2014/2007 (%)
			Rate (Polish złoty–zł)		
Warsaw	Bus	MZA Warszawa Sp. z o.o.	6.36	9.17	44.2
	Tram	Tramwaje Warszawskie Sp. z o.o.	6.88	13.90	102.0
Gdansk	Bus	ZKM Gdańsk Sp. z o.o.	5.02	8.02	59.8
	Tram	ZKM Gdańsk Sp. z o.o.	4.05	8.30	104.9
Szczecin	Bus	SPA “Dąbie” Szczecin Sp. z o.o.	4.50	5.32	18.2
	Tram	Tramwaje Szczecińskie Sp. z o.o.	5.28	13.03	146.8
Bydgoszcz	Bus	MZK Sp.z o.o. Bydgoszcz	5.28	6.90	30.7
	Tram	MZK Sp.z o.o. Bydgoszcz	3.04	8.59	182.6
KZK GOP Katowice	Bus	Total	3.60	5.59	55.3
	Tram	Tramwaje Śląskie S.A.	6.39	10.44	63.4
Bus transport		Average rate	5.13	7.41	44.5
		Average yearly dynamics of changes			5.4
Tram transport		Average rate	6.02	11.82	96.3
		Average yearly dynamics of changes			10.1

Source Own study on the basis of Ref. [8]

costs, and various tax burdens. Additionally, a substantial percentage of transport agreements assumes adjusting the rates paid to operators (as in case of KZK GOP in Katowice) by the price index for goods and services (inflation), as well as liquid fuels price index or—in case of tram transport—prices of electricity. Another model are contracts, which assume the compensation for deficiencies generated during the provision of services in urban public transport. For example, in case of Silesian Trams Company (Tramwaje Śląskie S.A.), the rate is adjusted by the price index for consumer goods and services, electricity prices, increase of remuneration costs, what is also the compensation for the costs of investment activities, costs of loans, as well as taxes and local charges connected with investments in infrastructure and rolling stock.

Table 2 presents selected data and macroeconomic indicators published by the Polish Central Statistical Office (GUS) in the years 2007–2014.

As can be concluded from the analysis of data from Table 2, in the years 2007–2014, the prices of consumer goods and services increased by 23.8%, while at the same time, the prices of diesel fuel increased by 14.5%, and gasoline by 9%. Labor costs increased significantly in the same period analyzed. Minimum gross salary increased by as much as 79.5%, which was a more dynamic growth over the 7 years considered, than that of average gross salary, and the latter increased by 41.3%.

Table 2 Selected data and macroeconomic indicators of GUS

Year	Price index for consumer goods and services (previous year = 100)	Unleaded gasoline, octane number 95, per 1 l (zł/l)	Diesel fuel per 1 l (zł/l)	Average gross salary (zł)	Minimum gross salary (zł)	Price index for rolling stock (previous year = 100)	Price of a single full-fare ticket for travel in city bus (zł)
2007	102.5	4.42	4.20	2672.58	936	98.3	2.02
2008	104.2	3.66	3.69	2942.17	1126	97.3	2.17
2009	103.5	4.29	3.80	3101.74	1276	98.9	2.20
2010	102.6	4.81	4.64	3224.13	1317	99.1	2.23
2011	104.3	5.45	5.61	3403.51	1386	97.2	2.46
2012	103.7	5.53	5.64	3530.47	1500	97.7	2.64
2013	100.9	5.38	5.46	3659.40	1600	99.3	2.73
2014	100.0	4.82	4.81	3777.10	1680	97.7	2.72
Change 2014/2007 (%)	23.8	9.0	14.5	41.3	79.5	−13.6	34.7
Average yearly dynamics of changes (%)	2.7	1.1	1.7	4.4	7.6	−1.8	3.79

Source Own study on the basis of Ref. [9]

Assuming, with a certain level of simplification, that the cost structure of a transport company contains fuel costs—amounting to some 30% of total costs, depreciation—20%, labor costs—40%, and other costs—10% of total costs, one can notice—looking at the increase of fuel costs, labor costs, rolling stock costs, and price index for consumer goods and services, it is significantly lower than the increase of rates for transport services. This may be the cause of considerations concerning the discrepancy between prices of production factors and prices of final products, which would require further in-depth studies.

It can be assumed that to a certain degree, the increase of costs of providing services (among others, the rates paid to operators) leads to increased costs of services, that is, the price of tickets in urban public transport, as it is necessary to obtain funds in order not to reduce the transport services offered. As can be gathered from Table 2, over the study period, the average price of a single full-fare ticket in urban public transport in Poland increased by 34.7% and that increase was lower than the increase of rates paid for transport services to operators of urban public transport. Table 3 presents the prices of full-fare personal (non-transferable) season tickets, monthly or 30-day ones, valid for all means of transport in the entire urban transport network, in eight biggest cities in Poland. When calculating the average ticket price, the number of inhabitants in the analyzed cities has been taken into account.

A significant price increase can also be observed in case of the most common season ticket, namely a monthly or 30-day ticket. In eight of the biggest Polish cities, the price of that ticket was some 56% higher in 2014 than in 2007. In some cities, e.g., in Wrocław or Gdańsk, we can observe a drop in the price of such tickets, which is probably due to the policy implemented, that has the aim to increase the attractiveness and competitiveness of urban public transport, by reducing prices.

Table 3 Prices of full-fare personal (non-transferable) season tickets, monthly or 30-day ones, valid for all means of transport in the entire urban transport network, in selected cities, years 2007–2014

No.	Transport organizer	2007	2008	2009	2010	2011	2012	2013	2014	Change 2014/2007 (%)
		Ticket price (zł)								
1.	Warsaw	90	116	na	116	116	156	196	196	117.8
2.	Kraków	94	126	na	148	148	144	144	144	53.2
3.	Łódź	88	88	na	88	88	96	96	96	9.1
4.	Wrocław	108	98	na	98	98	98	98	98	−9.3
5.	Poznań	65	81	na	81	81	141	185	185	184.6
6.	Szczecin	138	138	na	138	138	162	162	162	17.4
7.	Gdańsk	132	98	na	98	98	102	102	105	−20.5
8.	KZK GOP Katowice	96	104	na	104	112	138	150	150	56.3
Average price		96.8	106.7	na	109.1	111.3	134.5	150.8	151.0	56.0

Source Own study on the basis of Ref. [10]

The development of ticket prices in urban public transport is also influenced by the overall economic situation of the country, which is reflected in the financial standing of municipalities, and revenues generated by municipalities, thus in the possibilities, municipalities have to provide funds in their budgets and to spend the funds on co-financing local public transport.

The overall economic situation in a country also influences the social sphere; thus, by establishing prices for urban public transport services, a substantial percentage (numerous groups in society) of inhabitants is entitled to pay reduced fares or use public transport for free. Sometimes a reason for it is the difficulty in reforming the structure of reduced fares and free ridership, which to large extent are inherited, as they were introduced a few dozen years ago. There are many more examples of extending the entitlements to pay reduced fares, and including more social groups in them, than of reducing such entitlements. For example, KZK GOP tried, several years ago, to reduce the right for using public transport free of charge for people over 70 years of age, and entitle them to 50% reduced fares. That attempt failed, mainly due to concerns related to negative public social perception of such a change.

Table 4 presents, in the form of indicators of dynamics of change in comparison with the year 2007, the challenges concerning financing of urban public transport, faced by Polish cities with populations exceeding 300 thousand inhabitants.

Table 4 Indicators of population density changes, changes in transport services provided, as well as public financing of urban public transport in the biggest cities in Poland in 2014, in comparison with 2007

No.	Municipality	Change 2014/2007			
		Population density (inhabitants/km^2) (%)	Change in vehicle-km amount per one inhabitant (%)	Subsidies to local public transport per 1 vehicle-kilometer (zł/vehicle-km)	Share of subsidies to local public transport in municipality income (%)
1.	Warsaw	1.7	11.6	114.3	9.3
2.	Krakow	0.7	−12.7	222.0	3.7
3.	Łódź	−6.3	−7.4	55.1	−0.6
4.	Wrocław	0.2	−1.0	6.9	−1.7
5.	Poznan	−2.7	−2.1	44.0	0.8
6.	Gdansk	1.3	6.2	137.1	4.1
7.	Szczecin	−0.2	2.2	122.9	2.9
8.	Bydgoszcz	−1.6	−6.7	71.6	0.6
9.	Lublin	−2.9	20.0	118.2	2.6
10.	Katowice	−3.3	11.7	125.4	3.7
Total/average		−0.8	3.0	102.1	4.5
Total/average excluding Warsaw		−1.7	−2.4	76.8	1.5

Source Own study on the basis of Refs. [8–10]

As can be concluded from Table 4, in the majority of cities studied, the population density has dropped, which means that the number of inhabitants has dropped, as the size of the municipality (in terms of territory) remains the same. First of all, this is due to the phenomenon of urban sprawl that is extending the territories of cities. Inhabitants of big cities often change their place of residence and move to suburbian areas, which are less densely developed, and commute to work in the city, mainly by car. In consequence, not only the population density gets reduced, but also the number of passengers in urban public transport drops. An increasing problem for cities is, thus, the necessity of providing urban public transport services for suburbian areas. This may be proven by increased transport offer, which is confirmed by the higher level of vehicle-kilometers per 1 inhabitant.

Organization of local public transport has become an increasing financial burden for municipalities. The amount of subsidies to local public transport per unit of transport work increased significantly over the period studied, by 102% on average. What is more, the share of subsidies to local public transport in spending from own income of the studied municipalities increased by 4.5% points. In Krakow, despite a significant reduction in the transport offer in the years 2007–2014 (the vehicle-kilometer per 1 inhabitant factor was reduced by 12.7%), the expenditures related to subsidies for local public transport, from municipality own income, increase by as much as 3.7% points.

The Influence of Microeconomic Factors upon Changes in Prices of Urban Public Transport Services

A significant part of the phenomena influencing the increased costs of organization and provision of urban public transport services is due to microeconomic factors, which have their origin in individual decisions of subjects. Microeconomic factors result from the elements of microeconomic environment, in which households and enterprises function, and which they can influence. In case of enterprises, the microeconomic environment involves entities from their immediate surroundings, with which the enterprise enters into interactions (e.g., competitors, suppliers, and customers) [7].

Among the microeconomic factors that have influence upon the development of urban public transport ticket prices, one can include the size of transport operation services ordered, requirements formulated by city authorities as for quality parameters of services provided by operators, as well as other tasks executed by transport organizers, including also investment projects, for example, modern passenger information systems, or IT systems assisting the management of urban public transport.

A crucial microeconomic factor, influencing the level of rates for transport services, are the increasing requirements concerning rolling stock quality, in particular as to the age of rolling stock. Modern rolling stock is, as a rule, fully adjusted to the needs of the disabled, while buses also comply with stringent flue gas emission norms. The purchase of new rolling stock is, of course, connected with costs for the transport company, and costs that operators bear are then transferred to transport organizers, in the form of higher prices of services. Table 5 lists the information on average age of rolling stock in the years 2007 and 2014 for the biggest service providers in cities in Poland, for which data were available.

As can be concluded from Table 5, most of the service providers analyzed in the cities concerned: over the 7 years replaced the rolling stock with more modern one, which can be proven by the fact that the average age of the rolling stock has not increased in line with the time, over those 7 years. In some cases, e.g., Warsaw, Lublin, Poznan, or Szczecin, the average age of rolling stock was significantly reduced in 2014—in comparison with 2007—which proves the high level of investments in the purchase of new means of transport.

Table 5 Average age of bus and tram rolling stock for the biggest service providers in selected cities in Poland, in 2007 and 2014

Transport organizer	Means of transport	Biggest service provider	2007	2014	Change 2014/2007 (number of years)
Warsaw	Bus	MZA Warszawa Sp. z o.o.	10	7	−3.0
	Tram	Tramwaje Warszawskie Sp. z o.o.	22.4	16.5	−5.9
Cracow	Bus	MPK Kraków S.A.	7	8	1.0
	Tram	MPK Kraków S.A.	27.1	34	6.9
Łódź	Bus	MPK Łódź Sp. z o.o.	7	7	0.0
	Tram	MPK Łódź Sp. z o.o.	22.5	29.7	7.2
Poznan	Bus	MPK Poznań Sp. z o.o.	8	6	−2.0
	Tram	MPK Poznań Sp. z o.o.	29.1	24.4	−4.7
Gdansk	Bus	ZKM Gdańsk Sp. z o.o.	10	11	1
	Tram	ZKM Gdańsk Sp. z o.o.	23.5	24	0.5
Szczecin	Bus	SPA “Dąbie” Szczecin Sp. z o.o.	11	10	−1.0
	Tram	Tramwaje Szczecińskie Sp. z o.o.	24	19.3	−4.7
Bydgoszcz	Bus	MZK Sp. z o.o. Bydgoszcz	7	8	1
	Tram	MZK Sp. z o.o. Bydgoszcz	22.4	31.1	8.7
Lublin	Bus	MPK Lublin Sp. z o.o.	15	8	−7
	Trolleybus	MPK Lublin Sp. z o.o.	15	3	−12
KZK GOP Katowice	Bus	PKM Katowice Sp. z o.o.	n/a	12	n/a
	Tram	Tramwaje Śląskie S.A.	24.9	28.8	3.9

Source Own study on the basis of Ref. [8]

The revenue from sale of tickets, and thus also the decisions concerning prices, is also influenced by decisions taken by households. The decisions taken by the smallest units involved in economic activity, and their economic situation, are decisive for the development of trends in the entire economy of a given country. Table 6 presents the selected data and economic indicators, which influence the decisions of households, and which reflect the consequences of those decisions in the economy.

An average household in Poland has increasing monthly income at its disposal. In the period studied, that is from 2007 to 2014, the average monthly income per one person in the household increased by 44.6%. In the same period, the prices of fuel increased much less dynamically (Table 2). As can be concluded from Table 6 the amount of petrol, in liters, that can be purchased with an average gross salary increased by 29.8% in the years 2007–2014.

In the period analyzed, the price competitiveness of urban public transport, against individual transport, decreased significantly. Fares in urban public transport increased more dynamically than the price of fuel, and in 2014, one could purchase only 5% single full-fare bus tickets more than in 2007. Of course, the average cost of using personal vehicles exceeds by far the cost of fuel, as the costs include—among other things—depreciation, costs of periodic inspections, repairs, parking and garage, or the cost of insurance. Still, one should remember that marginal cost counts for the consumer, and the cost of fuel is taken into account by the consumer. Moreover, the advantage of motorized individual transport over urban public transport lies also in the comfort of traveling, the possibility of getting to the destination directly and quickly, as well as much greater sense of safety. This can be exemplified the best by dynamic growth the number of cars registered in Poland (in the years 2007–2014—increase by 37.1%). As the data from Table 6 indicate,

Table 6 Selected data and economic indicators that describe households in Poland in the years 2007 and 2014

Indicator	2007	2014	Change 2014/2007 (%)
Average monthly income available, in Polish zloty–zł (per 1 person in the household—total)	894.51	1293.32	44.6
The number of single full-fare bus tickets that can be purchased with average gross salary	1323	1389	5.0
How many liters of petrol (95-octane) may be purchased with average gross salary (l)	604.7	783.6	29.8
Price of a taxi ride, day tariff—for 5 km (zł)	13.55	16.19	19.5
Car ownership index (number of personal vehicles per 1000 inhabitants)	383	520	35.8
Registered personal vehicles, in thousand	14,589	20,004	37.1
Number of passengers transported by public transport, in million	4191.6	3858.8	−7.9

Source Own study on the basis of Ref. [9]

every other inhabitant of Poland has a car, which is not without influence upon the number of passengers using local public transport, which dropped in Poland by nearly 8% over the period analyzed.

Reduction in the number of passengers in local public transport and the decreased revenue from ticket sales make it necessary to limit the transport offer, or to obtain additional funding to cover the costs of organizing urban public transport. Obtaining additional financing results in the necessity of increasing the level of subsidizing by the municipality, or increasing the price of tickets.

The decision, made by the organizer of urban public transport, about the price of tickets, also requires taking into account the general relations that occur between price and demand for public transport services. Because one should take into account the price elasticity of demand, that is the change in demand response to the change of price. In line with the law of demand, price increase (with other conditions remaining unchanged and with the exception of non-typical goods) results in decreased demand. The price elasticity of demand decides about the price increase not being translated directly into increase of revenue from ticket sales, due to the drop in demand, caused by price increase. Depending on the location of the point along the curve of price elasticity of demand, demand will have a stronger or weaker reaction to price change, by 1%. Price elasticity of demand for urban public transport services, as in case of most foods and services in the economy, is less than −1, which entails that those foods and services have elastic demand, and that demand strongly reacts to price change (percent change of demand is greater than the price change that causes it) [11]. Thus, every increase of ticket prices will contribute only partly to the growth of revenue from ticket sales, particularly in the condition of high substitutability of services in urban public transport.

Conclusion

Urban transport is a substantial part of transport sector. From the point of view of the number of passengers transported, municipal economy, and the role it plays in the functioning of towns, it is also an important part of the entire economy. One should not forget that a vast majority of journeys, not only in Poland, but also worldwide, begins and ends in towns.

Besides the quality factors, an important element of the assessment of urban public transport are the prices of the services provided. Those prices are influenced by numerous factors, which may be classified as microeconomic and macroeconomic factors. By its nature, price depends upon costs, so the development of prices of resources is used in the process of providing those services. However, they are not the only factors influencing the entities that determine prices. It is visible that many policies are pursued in the process of price determination: social, development, spatial development or environmental protection policies, causing that the level of public financing in the urban public transport is high. It is also worth noting that other factors, different from material factors of production, are highly influential for the development of rates for transport services. They are mainly the investment projects, concerning the enhancement of service quality, e.g., passenger information systems.

There is a feedback between micro- and macroeconomic factors and prices of urban public transport services, which the above considerations have disclosed. The prices of services of urban public transport are influenced by decisions of entities and passengers, in which decisions in turn are taken on the basis of analysis of market prices, including prices of services. It is also worth noting that some microeconomic factors, the source of which are decisions of individual entities, form—in aggregated model—the macroeconomic trends.

Certain data have been gathered, and to make the analysis performed possible, they became the basis for drawing some initial conclusions, which would be the starting point for further studies. The relationships between micro- and macroenvironment factors and decisions concerning prices in the urban public transport are very complex and changing with time, which causes them to be difficult and complicated, requiring to apply mathematical tools and to construct models, which is connected with a wide range of research work, and with the time-consuming character. Nevertheless, extended studies concerning the factors that influence price development in urban public transport would be important indeed, not only from the theoretical perspective but also from application point of view.

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Forwarding in Contemporary Delivery Chain

Małgorzata Jarocka and Joanna Krupska

Abstract The main function of forwarder is performing actions indispensable to carry out transport process mainly related to organizing the load transport. The functions of forwarder as well as his tasks are still developing and adjusting to the needs and changes of the market. The changes are mainly related to the shape and complexity of delivery chain. This chapter is about the functions of forwarding in the contemporary delivery chains, especially scrutinizing the trend to use outsourcing.

Keywords Forwarding · Forwarder · Transport · Delivery · Companies · Logistics · Operator · Distribution

Introduction

Companies which exist on the dynamically changing market, more often than not, seek sources of their advantage over competing companies not in the product itself but in the way it is distributed, or in other words, in an efficient delivery chain. Delivery chain organization is related to carrying out logistics services, such as storing, transporting and forwarding.

Forwarder, as a load relocation coordinator, carries out a series of logistics actions with the aim of choosing the optimal means of transport so the commodity is relocated safely, in suitable time, at as low cost as possible.

The aim of this chapter was to present relations in forwarding and logistics, focusing on the function of forwarder as the coordinator and performer of the function of logistics service in delivery chain.

M. Jarocka (✉) · J. Krupska
Faculty of Economics, University of Gdańsk,
al. Armii Krajowej 119/121, 81-824 Sopot, Poland
e-mail: malgorzata.jarocka@ug.edu.pl

J. Krupska
e-mail: ekojs@ug.edu.pl

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The Scope of Actions Performed in Forwarding

In order to increase customer service efficiency in forwarding, modern tools and technology are used. However, the most important factor of efficient commodity relocation and sending is to coordinate law, economy and logistics all at the same time, so as the client is satisfied with forwarding service. It is only one of the functions forwarder has to carry out; nonetheless, it seems to be of the utmost importance. Forwarding includes any commercial activity based on relocating loads on private or physical person's order and carrying out a series of necessary additional activities related to the order [6]. Coordination of the process of relocating loads means delivery of goods to the customer in accordance with 7R rule: right product, right quantity, right condition, right place, right time, right customer and right price [7].

In Poland, no matter the size of loads, forwarding has to be based on the contract of carriage. Most of them are also using forwarding contract. The subject of forwarding contract is defined in the civil code as "sending a parcel; its reception; providing other services related to parcel delivery".

The scope of forwarding services is very broad. Forwarding plays more and more important role as a link between separate elements of the transportation process. The basic service provided by forwarding companies is coordinating transportation of goods in the country as well as abroad. In Poland, the area of activity comprises car, train, sea and air transport, and in the least percentage inland water transport. However, it is rare for transportation service to comprise only one branch. In particular, when complex (international and/or nonstandard such as oversized, mass, container, dangerous) orders are taken into consideration, the transportation service uses several transport branches.

Forwarder, who undertakes to send or receive delivery or provides other services related to its transportation with payment, is the coordinator of forwarding processes [4]. Transportation process includes a few aspects which are rather difficult to predict, such as the weather conditions, unpredictable events and customs queue longer than expected. Because of all this, forwarder's function is to prepare himself diligently to carry out the process. If forwarder carries out all the actions related to logistics customer service, he surpasses his standard tasks. The standard tasks of forwarder are as follows:

- suitable delivery time,
- product availability in the stock,
- delivery flexibility,
- delivery frequency,
- delivery reliability,
- delivery completeness,
- delivery accuracy,
- order convenience, and
- order documentation convenience.

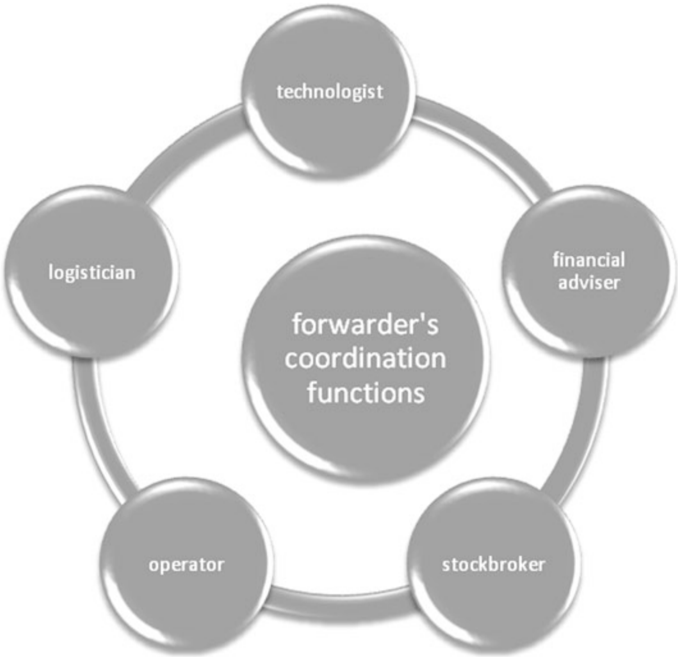

Fig. 1 Coordination functions of forwarder. *Source* [6]

While describing the contents of forwarding process, the coordination function of forwarders cannot be omitted. In the current economical conditions, forwarder should perform each of the five functions included in the chart below. They are reflected in particular stages of delivery chain (Fig. 1).

The most important tasks of the technologist forwarder include coordination of nonstandard load transport and organizing temporary storing services. Forwarder is also the operator of transport means and machinery so his function is to manage forwarding process in such a way as to use company's fixed assets in optimal and efficient way. The function of logistician forwarder is related to comprehensive conceptions of delivery chain management, that is, supplies, production, distribution and managing second-hand materials, waste, raw materials and by-products return [1]. For the administer of the load, forwarder is an important source of information about efficient and safe launch of the load in the international turnover via sea or air route. The function of stockbroker forwarder is related to organizing storage services.

Forwarding in Delivery Chains

In the current economical conditions, logistics management is indispensable for effective functioning of delivery chains. Logistics specialist should have several coordination skills, supply, storing, stock and transport control as well as taking into account suitable service for company's customers while keeping logistics' costs low.

The economical conditions and a growing competition on transport markets related to them force companies to adapt to the changing environment. In the search for different sources of advantage over competing companies, companies focus on the product as well as efficiency of activities in the scope of means of launching it in the market [7]. Companies adjust their activities to suppliers and recipients, in this way creating delivery chain.

A lot of definitions of delivery chain can be encountered in the literature [2]. This term is used to describe all activities related to flow and transformation of products and information: raw materials extraction to begin with, through all the stages of their transformation, ending with the delivery of goods to the client. The growth of competition is one of the many factors which influence the development and shape of contemporary delivery chains. Another very important factor is the pressure to reduce cost, which can be noted especially in American and European markets, where it is more and more popular to order production on the Asian market. An undeniable advantage of this idea is cost reduction; nevertheless, one should note the dangers stemming from this solution. A negative consequence, apart from the fact that abuse of the workers in factories in China, Thailand or Indonesia[1] has been recently voiced in the media, is impediment in delivery chain. Making the process of delivery more complex may be related to another factor shaping the development of delivery chains, namely the pressure related to stock reduction and shortening the time between order and delivery to the customer.

Outsourcing outside company's boundaries has been more common also in Polish companies. In the time of customer's growing expectations, the use of outsourcing has become necessary. Logistics processes are commissioned to outer subjects, especially when a company in question does not have necessary resources or certificates to carry out the services on its own.

3 PL, 4 PL and 5 PL Logistics Operator

Outsourcing is the basis on which services performed by 3 PL, 4 PL and 5 PL logistics partners have been made. The scope of logistics functions commissioned to outer companies may vary and include only transport organization as well as management of the entire delivery chain.

[1]Mainly in cloths and electronic business.

The basis of the above models is 1 PL (first-party logistics) and 2 PL (second-party logistics). The first model means that logistics services are performed by the producer himself, and the second model means that the producer (or trading company) commission only transportation or its part, while the company can still be the owner of the transport means.

Logistics service outsourcing has become the determinant of development of 3 PL (third-party logistics) logistics operators. 3 PL is a qualified operator which provides services which include transport as well as forwarding, storing and additionally it can provide services raising the value of the product, the so-called, value-added services. Using 3 PL reduces costs. In various companies, the use of the “third partner”, which can provide the below services, may vary:

- warehouse management,
- performing orders,
- stakes negotiations,
- the choice of carrier,
- transport management, and
- delivery monitoring.

Companies more and more often used 3 PL operators because it is a cost reducing tool for them as well as it increases complexity of their services by providing professional logistics services. 3 PL operators has become a part of delivery chains. In Poland, there have been an increasing number of subjects called 3 PL, Grupa Raben, Schenker, FM Logistic and among others.

The next stage of the evolution of outsourcing services was 4 PL (fourth-party logistics), which includes planning, coordination and control of delivery networks. 4 PL integrates resources, possibilities and its own and outer technology in order to design, build and carry out the entire delivery chain. The main functions of 4 PL integrator are as follows:

- 3 PL evaluation,
- negotiating contracts with suppliers of logistics service,
- monitoring operation activities,
- launching new informatics solutions, and
- human resources management.

So far, the highest stage of outsourcing services (of complexity level of logistics services) is 5 PL model (fifth-party logistics). Its function is to manage each of the subjects in a delivery chain as well as e-business. One can claim that 5 PL encompasses both 3 PL and 4 PL as well as controls all operations in delivery chain with the use of informatics technology.

In the time of internationalization of companies, most of the commodity flow is international. The phenomenon of outsourcing, implementation of modern technologies and communication means all favour this internationalization. All these factors influence the development of contemporary deliver chains, and it is becoming more and more complex and requires suitable management.

Partnership in Delivery Chains

Nowadays, there is a possibility of relocating almost everything (while acting in accordance with the law), so delivery chain management has to be efficient, which means it has to use technology and adapt to the changing conditions. The participants of the delivery chain should share information, planning process and taking risk in such a way as to guarantee each cell as many benefits as possible and to make the process of the product delivery chain efficient and profitable. An important aspect of the functioning of delivery chains are relationships between partners in all stages of delivery chains. The final cell of delivery chain is the customer; the management of delivery chains should depend on the customer's needs.

The term "partnership" is defined in economy as "shaping of the economic relationships between its cells on the basis of trust, sharing risk and benefits, leading to obtaining additional synergic effects and advantage over competition".[2] Partnership is mainly based on common business. Only logistics partnership makes cooperation strategic for all participants of delivery chain, from the producer to the client.

When considering aspect of managing relationship with the client in the functioning of delivery chain, every cell in delivery chain should be treated as a client. With this, we can say that:

- the producer is the client of parts and materials supplier,
- the distributor is the client of the producer,
- the trader is the client of the distributor,
- the consumer is the client of the trader, and
- supplier, producer, distributor and trader are clients of TSL sector companies.

Developing partnership relationships raise competitiveness of the companies participating in the international market. Forwarder is the link and integrator of the process happening in delivery chains. Coordination of tasks on each level of delivery chain allows to improve the process while maintaining partnership between companies.

Summary

An efficient delivery chain is a great benefit for a company. The most important benefits are lowering the cost, adapting to the market and shortening delivery time. Organization of delivery chain is related to carrying out logistics services, and because of this, the load relocation coordinator has to have broad know-how as well

[2]J. Witkowski, *Zarządzanie łańcuchem dostaw. Koncepcje, Procedury, Doświadczenia,* op.cit., p. 34.

as skills to adapt to changing conditions. This chapter has shown basic functions and features of forwarder, especially scrutinizing the functions which are indispensable to efficient management of delivery chain.

Economical conditions and the pressure to lower the costs and improve the efficiency related to them make companies seek new business models and perfect delivery chain. To treat logistics service, provider as a partner can be crucial in gaining and maintaining advantage over competition.

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How Transport and Logistics Operators Can Implement the Solutions of "Industry 4.0"

Wojciech Paprocki

Abstract The idea of Industry 4.0 was presented for the first time in 2011 by Henning Kagermann, former top manager of the SAP company. He suggested that different processes in production of goods can be coordinated in large-sized networks. One of the most important tools becomes the Internet of things (IoT). The implementation of IoT takes place not only in the production but also in the procedures which are used in the supply chains on the global market. Transport and logistics operators have started the development and implementation of IoT within their companies as well as outside of them. An important part of new solutions involves the data exchange between the transport vehicles and objects in their environment—particularly in public transport infrastructure which this paper addresses. Firstly, an overview is provided on multiple reports published by research institutes and market players. Secondly, this paper presents solutions that were implemented before 2016. The analysis provides a description of the challenge in modern transport systems and a discussion of possible actions for transport and logistics operators who aim to keep or improve their market position. Additionally, another part of the paper analyzes the impact on the market of transport and value-added services by the implementation of autonomous vehicles and the new generation of robots by transport and logistics operators. The main conclusion is the recommendation to promote closer cooperation between research institutes and market players as well as public authorities. It will be the best way to increase the efficiency of the development process of new technologies, which can be implemented by transport and logistics operators in the medium-term future.

Keyword Industry 4.0 · Logistics operators

W. Paprocki (✉)
Chair of Transport, Warsaw School of Economics, Warsaw, Poland
e-mail: wojciech.paprocki@sgh.waw.pl

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Introduction

Since 2011, Industry 4.0 has been a subject of discussion regarding the new direction of economic development worldwide. As H. Kagermann used this notion [1], there were only a few people outside the IT industry who understood the importance of a new standard emerging in virtual networks. Four years later, K. Schwab decided to position the Fourth Industrial Revolution as a topic for the World Economy Forum 20 [1] 6 [2]. It seems that the most intensive discussions about the new solutions, which have been already implemented or are in process of development, are taking place in the German industry and academia. The reason for this is that German managers fight to improve competitive advantages of their automotive industry and aim to maintain leadership in the world market. They threaten the development and implementation of new information and communication technologies (ICT), which have been developed in recent years in the USA as a chance to increase the efficiency of the production of cars, vans, busses, and heavy trucks. One has to consider that the level of complexity in the supply chains which serves the automotive industry acting globally has 10^{25} combinations of actions in the process of final product assembly [3]. The German managers are not alone. They are involved in competition with American and European peers as well as with Asian partners. They work together in the supply chains that are managed simultaneously by the shippers on the one side and by the transport and logistics operators on the other side. The service providers face the challenge of developing their procedures in the supply chain management according to the new rules, which are used as the most modern solutions of material planning, manufacturing, marketing and sales as well as distribution, in the era of Industry 4.0. Both the producers and logistics service providers have to learn new methods to capture the market when cloud technology allows the integration of goods and services producers with their customers in real time [4].

It is of main importance to remember that the symbol “4.0” should not be used unfoundedly. The way of thinking and doing in the new era can be considered “4.0” only in cases where the manner is radically changed in comparison with theory and praxis that made standards a few years ago [5]. Market research from 2015 confirmed that the top management of only half of German mid-sized companies has yet realized the importance of examining the way their leadership addresses this new era [6]. Further, it seems that only about 20% of German companies treat digital technologies as a key factor of successful market strategy [7]. As such, an overview of the German economy suggests that the digitalization of the industry, both in production and service sectors, is still a future direction for development and that now, in the middle of the second decade of the twenty-first century, one can observe only the first successful implementation cases of Industry 4.0.

The development and introduction of new business models and technological solutions which are labelled as Industry 4.0 becomes more and more popular in the contemporary economy. The transport and logistics operators develop and implement new solutions in the supply chain management and in the transport systems. Therefore, the main objective of this paper was to present and analyze the patterns of the new solutions, in particular those based on ICT development.

Logistics 4.0 as Reaction to Industry 4.0

Changes across the world are easier to understand if we define the global megatrends that are having a far-reaching impact on many industries. One of these megatrends is Industry 4.0, as part of complex new technologies [8]. The main goal of Industry 4.0 is to radically transform traditional procedures into smart procedures. In the past, standard solutions were prepared by people, and their task was to control all operations during the entire procedure. Nowadays, new solutions are prepared by people, as it was before, but the operations are carried out partly by self-controlling mechanisms. The key issue is the creation of disruptive technologies. The goal is to build up total connectivity inside of new open networks created in clouds where data exchange take places not only among the people but also among things without action of people. This new solution is called Machine to Machine—M2M—or wider Internet of things—IoT.

The IoT cannot be created as an island network inside of one organization. In the new era, as presented in Fig. 1, each producer can and has to be connected with an unlimited number of suppliers on one the side and with an unlimited number of customers on the other side [9]. In the new generation of the supply chains, the IoT connects users and devices representing at least three groups of market players. The first group contains shippers and consignees of goods. They are at the beginning or

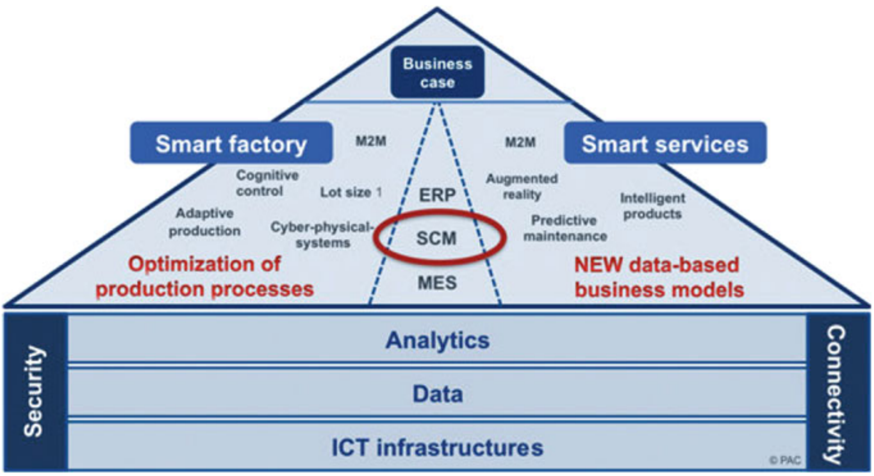

Fig. 1 Supply chain management (SCM) in the era of the Fourth Industrial Revolution. *Source* https://www.pac-online.com/scm-im-zeitalter-von-industrie-40 (7.02.2016)

at the end of each supply chain. On both ends of the entire supply chain, there are active people who use their hardware and software. The second group comprises people, hardware, and software that are employed or used by transport and logistics operators. The third group includes owners and/or infrastructure managers (e.g., IM of the public railway network in particular states) with their technical infrastructure: railroads with electric traction network and systems of traffic management, roads, takeoff runways in the airports, or warehouses. All of them manage their staff, technical equipment, and operations as well as the administration support using universal or dedicated software. Some of them have started to manage robots, which are *semi*-autonomous devices.

The new solution of Logistics 4.0 integrates these three groups of market players and additionally those public bodies which play the role of market regulator. The original improvement concerns the extension of the existing systems with implementation of the robots and the data exchange that runs autonomously among devices. The smart factory, as consignee, can create an order to the supplier of raw materials or spare parts, which are the subject of manufacturing or assembling. The order can be created by the smart factory's IT system without action of an employee, simply as a result of the automatic procedure [10]. In the supplier facility, incoming orders can be manually managed by automatic procedure. The IT system can send an order to a robot in the warehouse. Then, the robot carries out the picking order and packaging procedure and addresses the shipment to the loading ramp. The next step in Logistics 4.0 will be actions of the autonomous vehicle, which arrives to the ramp and picks up the shipment. In the following steps, the shipment will be transported to the place of delivery. In the smart factory, the shipment will be reloaded and transferred to the place where delivered goods will be used in the process of manufacturing or assembling. An alternative scenario utilizes the 3D-printer. It is a kind of robot which can be installed in the receiver's facility, yet it is controlled remotely by the suppliers. In this scenario, there is a significant difference in what becomes a subject of the physical movement. According to the traditional scheme, the good that is ordered for delivery is produced in the supplier's location, and the final product is shipped to the consignee. In the modern scheme, the subjects of the physical movement are raw materials which will be handled by the 3D printer. The transport of raw materials over any distance is easier than the transport of the final product. As a consequence, the implementation of a 3D printer can cause a significant reduction in the operating costs in the supply chains.

Every year there are new innovative solutions that can be implemented in the logistics industry. Each improvement brings new advantages. Since competition on the global market requests unending reduction of costs, it becomes more and more important to install new equipment which allows reductions in operating costs and investment of capital. The new generation of the reach trucks launched by Jungheinrich during the Hannover Fairs in 2016 provides a new opportunity to skip the installation of the cable network inside a warehouse. The new reach truck does not communicate anymore with devices located in the corridors among the racks and is able to observe its way using 3D cameras. This new generation of warehouse *semi*-autonomous equipment causes significant spending cuts [11].

The reduction in costs across the entire supply chain creates the biggest challenge in the global market. There are two topics to discuss. Firstly, the automatization is nothing new but in past decades it was implemented only inside of a factory or warehouse. The data exchange among the infrastructure (e.g., roads) on the one side and vehicles on the other side allows establishing automatic control of processes which also take place outside. An autonomous truck can be advised during its movement that the environment has just changed and the road in front of it has just been blocked. This difference is very significant. A human driver can react only when he observes something unexpected as the rule is “respond to what you have noticed in the visual line of sight.” The autonomous vehicle [12] is able to run beyond of the visual line of sight because its behavior can incorporate what is not in sight. It acts according to numerous signals, and most of them are provided as a data exchange among the devices without human control. Secondly, there is a question of quantity and quality of failure cases. The standard procedure in the supply chain is human-controlled to keep the time sequence of particular actions. The rule “just in time” means that each action has to be finished exactly on time, neither too early nor too late. This rule is violated by human mistakes which can be deliberate or accidental. The new solution eliminates both kinds of mistakes and allows a large number of actions at the same time, which cannot be controlled by a single person or even by a team [13].

The presented idea of automatic cooperation of robots and autonomous vehicles should be treated as a goal of development. Currently, the implementation of this idea has limitations due to low satisfaction of the job provided by technical devices. One of the biggest failures of the technical development in the last two decades is the still very limited capability of the FRID-technology. The printed barcodes continue to be used in the production and retail industries as well as in the logistics industry, while the implementation of chips has not become popular yet. The reason is that this technology has not brought the expected results in the supply chain. The managers of supply chains claim that the content of the shipments still has to be re-controlled by humans because the robots cannot do it properly. In some of the controlling procedures (e.g., on the ramp of retail shops), human sense organs are still viewed as sufficiently precise and reliable. The implementation of technical equipment and software there seems to be not efficient and effective enough yet.

Where and When Will the Autonomous Vehicle Replace the Truck Driver?

Heavy commercial vehicles are used to fulfill several kinds of transport tasks. Table 1 presents the description of particular services and conditions of work of these vehicles and their drivers.

Table 1 Transport services, characteristics of work of vehicles, and nature of driver's job

Type of service	Characteristics of work of vehicles	Nature of driver's job
Local transport in the loop inside of limited territory (e.g., transport of soil inside of a construction site)	Movement inside of the defined territory, partly off-road	Mostly routine actions
Local transport inside or outside of urban territory	Movement on streets and local roads that are used by different users: cars, busses, light and heavy commercial trucks, motors and bicycles as well as adult and child pedestrians; in some countries, this includes movements off-road	Complex actions in particular windows of time (peak hours) as well as partly routine actions
Medium- and long-range transport on the network of low-category roads	Movement on local and country roads that are used by different users: cars, busses, light and heavy commercial trucks, motors and bicycles as well as pedestrians; in some countries, this includes movements off-road	Complex actions in particular windows of time (peak hours) as well as partly routine actions
Medium- and long-range transport on the network of high-category roads	Movement on high-category roads; this activity is mostly extended on "first mile" and "last mile" distances where movement takes place on local and country roads of low category	Mostly routine actions including particular windows of time without any actions; fully passive presence of driver when only driving straight ahead on the highway

Transport operators are very interested in the implementation of autonomous vehicles in two of the above-defined cases: (i) local transport in the loop and (ii) medium- and long-range transport on the network of high-category roads. In these cases, the nature of the driver's job allows for its replacement by control systems that can manage vehicle movements. It means that the vehicles can be developed as *quasi*-autonomous vehicles that are able to control a part of their activities and are subject to interaction with the remote control system full time [14]. In both of these cases, it is possible to install some devices necessary to establish systems of communication between vehicle and infrastructure. There is experience in two cases. Inside of the construction site, there are temporarily installed mobile devices that exchange data with vehicles running there. On the highways in the USA, Germany, and some other countries, certain areas have already been equipped with devices that create the IoT and integrate it into the common network both for the vehicles and the infrastructure. In such cases, the infrastructure becomes intelligent and is described as a self-aware infrastructure [15]. The implementation of *quasi*-autonomous vehicles is possible if they work as a part of the complex transport system integrating both the vehicles and the territorially defined infrastructure. Such transport system will run under the permanent control of humans. The operator of such a system and its management will personally take responsibility in case of any failures. This type of transport system is very important due to the fact that common law regulation worldwide still requests that a human is responsible for any activities [16]. One can expect in the future that *quasi*-autonomous vehicles will replace trucks with drivers in these two cases described above [17].

In two other cases described in Table 1, the implementation of the *quasi*-autonomous vehicles seems to be much more difficult. Nobody has yet forecasted that IoT will cover the full territory of the Earth or even the full territory of particular countries, even into the third or fourth decade of the twenty-first century. It can happen in some regions, including very large metropolitan areas and the territory of small countries (e.g., Luxemburg). So long as there are technical barriers in the infrastructure, these are the only locations that could implement *fully* autonomous vehicles. Having vehicles equipped with self-managing systems supported by artificial intelligence, a human as a driver in a car or truck would be not be necessary anymore.

Producers of Cars and Trucks Become Competitors to the Logistics Service Providers

A big challenge for the existing transport operators (2PL) and logistics services operators (3PL) is the new strategy of the automotive industry that recognized that their final products are going to radically change their character. Traditionally, cars and trucks were treated as industrial final products that are used as transport means by commercial service providers. Nowadays, these products become connected cars and trucks. It is no longer their main functionality that they move people and goods. They are recorders, senders, and receivers of big data which has a value much higher than the value of traditional transport services. The automotive producers have understood that they can diversify and increase their revenue if they extend the offer. They have already realized that the data connectivity as a service can bring them new recurring revenues. Some of the producers have decided that a part of their output will be kept as the own fleet of producers who will start to use it as a tool of their own activity as a service provider on the multifunction service market. One of the advantages of this new offer will be that it becomes a transport solution for each different specific purpose. Conventionally, private consumers and the majority of the transport operators used to purchase vehicles which were able to carry out every transport order. Only a part of trucking companies followed another business policy and purchased specialized equipment, e.g., trucks or semitrailers with a tank for transport of liquid commodities. One of the advantages of this new offer will be a solution for each different, specific purpose.

An example of a new project is *CAR2SHARE cargo* prepared by Daimler Business Innovation [18]. The Courier Assist schema includes five services as follows:

- Smart Van,
- Smart Fleet Management,
- Smart Driver Management,
- Smart Administration, and
- Smart Tour Management.

Usually, there are three groups of partners who can take part in such a project. The first group is made of shippers who have to move their shipments. Due to the fact that each shipment can contain a different commodity, in particular cases different vans can be requested to match the specific patterns of a commodity. The second group comprises the classic service providers who carry out their transport services having their own drivers and using vehicles. Daimler or other automotive producers who traditionally offered cars, vans, or trucks as their products now belong to the project as new partners who offer transport capacity—and not any more transport means—only as their final products. The data exchange among all partners is the key factor. Each van can change the user every time, even several times during one day. Entrance to the van takes place using a code, which an employee receives from Daimler's *CAR2SHARE* management system and receives via Internet from his mobile device to the van. In this moment, he takes over the van that was used a few minutes ago by another driver from another company. The code is valid only during a fixed time window which was defined in the contract between the classic service provider and Daimler as the new service provider. During the working day, the same driver can use another van which is longer or higher than the first one, according to the new requirements described in the new order from the same or other shipper. In this project, the fleet used by the classic service provider becomes a virtual one. Every time such vehicle is available on request of the shipper. There are no more technical limits to carry out different orders. In this project, it is also possible to create a virtual team of drivers. The open question is how to recruit drivers who would carry out particular transport orders. All of them who are registered on the list of the "cloud staff" can and have to be continuously ready to get a new order and get into a van. Due to remote control of the permanent technical status of each van, it is possible to state without any doubt by whom and when any damages were made. The total process in this project is arranged by Daimler, including the full calculation and invoicing procedure that is automatically executed and booked into the accounting systems, for both the classic service provider and Daimler as the new service provider. In the *CAR2SHARE* project, it is also possible to optimize the utilization of the entire fleet. It happens in planning of tours which concern the movements both of the loaded and unloaded vans.

The Forecast for a Mixed System: Chances and Risks

The contemporary transport system contains both the very old technical solutions and the very modern virtual solutions. On the one side, in some countries, there are very old locomotives and (passenger or cargo) cars produced 50 years or more ago in operation in the railway industry. On the other side, the metropolitan traffic in several regions of the world is managed by the Uber company, which has nothing more to offer to millions of customers than a software and data exchange in the cloud. What will happen in the next 10–15 years?

It is likely that hybrid systems will find their future in the world. The standard cars and trucks produced using very poor technology are very simple to manage in operation and maintenance. The fleet of such cars and trucks will be kept for a long time in several regions. A tourist arriving in Cuba may observe the older cars and wonder how it is possible to maintain them without original spare parts. The answer is quite easy—in small workshops, they produce copies of the old spare parts or install similar spare parts to the original ones. This is still possible depending on how long the self-made old timers remain as products of the analog industry and they can run without any software. On the same streets of Habana, the newest limousines are used by diplomats. They belong to the most modern generation of connected cars which are able to park without direction of the driver, and in two to three years will be powered by hydrogen fuel cells [19]. In such cars, it is simply impossible to start the engine if the computer on board registers any failure in the operation system or outside of the car in the next environment. One can expect that in the supply chains, the modern digital technologies will become more and more popular. However, in some cases, it will be necessary to synchronize the old analog and new digital technologies.

The economy, which is more and more dominated by disruptive innovations, will evolve from two co-existing worlds where people live and work. In the former, people will try to continue the existence according the old rules. Some years ago one could say that such old world will remain in the South. The social movements which have come to light in the USA, Hong Kong, and Western Europe since the beginning of the current century shows that a significant group in the North does not accept the contemporary development [20]. The medium- and very-rich people belonging to this world are interested in having dinner in restaurants listed in the Michelin Guide because they request and expect the quality proved by professional inspectors using objective criteria. In the second world, people will create new requirements and adapt to them. There are people who are ready and able to change their mindsets and behaviors [21]. They are willing to achieve the level of the development where artificial intelligence will replace human creativity and diligence. They do not like to drive a car, and they expect to be moved by the *fully* autonomous car to a bar and back after consuming alcohol or drugs. They like to be admired in the popular bar confirmed by virtual San Pellegrino global ranking system, published in social media [22].

How Can These Two Worlds Coexist?

Even if one says that people from both of these worlds would like to coexist peacefully, there are some reasons why they will face some conflicts. The first of potential disputes is global climate policy [23]. Is it possible to eliminate the emission of CO_2 caused by human activity? Can such a goal be achieved without Industry 4.0? The second topic is criminal acts. If one wants to protect privacy, one cannot accept the permanent and omnipresent Big Brother practice. It means that individuals and even organized crime will use their (even limited) privacy to carry out criminal acts. In Industry 4.0, it is likely to see increased attacks on the networks, data bases, and applications. Hackers have already had success in blocking the software installed in advanced cars [24]. Open access to the method of storage in clouds creates an additional temptation for digital piracy [25].

Academics have a challenge to create the educational offerings for students who will soon enter school and expect successful careers. Regardless of the field of study, youth should learn the most modern digital technologies and the traditional humanities to be able to understand what is important to continue economic development and what is necessary to keep it sustainable. It is clear that the future of supply chains remain in their mixed character, but the question is how to manage the coexistence of the analog and digital worlds and not lose control of the balance of them.

Social movements have impact on the players who determinate the formal economic plans and manage public institutions. The public sector composes the infrastructure in each country. The open access to the network of roads, railways, waterways, etc. on the one side and to the network of electric energy lines and to the communication networks on the other side is a precondition to develop the modern supply chains where the most modern digital solutions can be efficiently implemented. Additionally, the public institutions have to act properly to ensure improvement of regulations that keep the activities of people and technical devices —including robots—on the national and international markets under control.

Conclusions

Transport and logistics operators take up the gauntlet of fundamental transformation of their activity in order to fulfill the challenge of the Fourth Industrial Revolution. The operators are surrounded by producers and entities involved in goods exchanges in the market which develop and introduce new network solutions, including the technology IoT and robots. The participants of the supply chain anticipate that the operators who serve them will use the same technologies and will adjust their business models to the changing demands of their customers.

A special challenge is the entry of new industrial enterprises, including startups of novel business profile which introduce disruptive innovations, on the traditional market of transport and logistics services. Rolling stock producers, including autonomous vehicles, keep a part of their final production for own uses and use new business models to offer services to the shippers instead of selling the final products to the shippers as well as to the transport operators, whereas before the era of Industry 4.0 the same shippers either made self-service or were served exclusively by transport and logistics operators.

A new way of proceeding of public infrastructure managers is expected in the era of the Fourth Industrial Revolution. Managers must create conditions for the development of integrated road networks, electric power transmission and electronic data exchange. Besides, they must adjust the created network to the autonomic proceeding within IoT.

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Self-regulatory Effectiveness of TSL Enterprises as an Indicator of Their Stratification Position in the Sector

Andrzej Letkiewicz and Beata Majecka

Abstract All of the enterprises which cooperate adapt different criteria for comparison of their achievements with the achievements of other participants of the market (revenues, costs, profit, employment). Consequently, an appearance of the market is created which is a sign of order of layers of different entities, striving to achieve different goals. One of those goals is to sustain the status quo on the market, which makes that status the primary goal of self-regulation. That goal can be described with an indicator of self-regulatory effectiveness. The indicator and its changes in the year 2014 has been analysed for the enterprises of the TSL sector shown in a published ranking. The analysis has proven that the enterprises with the highest efficiency or the highest share of the market were unable to achieve the best resource configuration. An optimal configuration, however, was achieved by an enterprise for which the growth of the self-regulatory effectiveness indicator had the value of 8906 points and was the last enterprise in the aforementioned ranking due to a low value of revenues and being a small enterprise. Ranking the enterprises according to the value of the growth of the self-regulatory effectiveness indicator creates an entirely different picture of the market.

Keywords Transport enterprise · Economic stratification of enterprises · Self-regulating · Self-regulating efficiency indicator

A. Letkiewicz (✉) · B. Majecka
Economics and Management of Transportation Companies,
Faculty of Economics, University of Gdańsk, Gdańsk, Poland
e-mail: ekoalt@univ.gda.pl

B. Majecka
e-mail: ekobma@ug.edu.pl

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Introduction

In the current functional conditions of the enterprises in the TSL branch, it becomes more and more important not only to have a good place among other entities but also to have a set of abilities, attributes of success which allow the enterprise the achieved position. As a result of the business processes in different enterprises, a complicated stratification structure of the TSL market appears, exemplified by the commonly known and published rankings of enterprises. However, in most cases, these rankings classify the enterprises according to the value of revenue which they had generated. They do not show the whole potential of the companies to sustain a certain position among other companies and to generate the revenues in the years to come.

The goal of the paper was to propose a method for measuring the self-regulatory skills of the enterprise (the self-regulatory effectiveness indicator), which lead to an achievement of a certain place on the market. As a result of ranking the TSL enterprises according to the value of growth of the proposed indicator, a different market picture is achieved, one which shows the ability of enterprises to achieve their long distance goals in fluctuating market conditions.

The methodological basis for the paper is as follows: the concepts of economic stratification of the enterprises and the theory of enterprises self-regulation.

Stratification of Enterprises as a Result of Achieving Market Goals

The purposefulness of the business activity of enterprises is their immanent characteristic. Every business entity strives to achieve its objectives and sets appoints different sets of goals—primary and secondary goals. The ability to reach those goals is the determined by the characteristics of the company itself as well as by the circumstances of its surroundings.

One of the most important factors determining the activity of the enterprises is their functioning in the market surroundings, which is a set of conditions, which, on the one hand stimulate the enterprises, but on the other hand create barriers for the achievement of their goals. The market is a place in which different enterprises allocate themselves, fighting constantly for their position, which is one of their main external goals. Therefore, the enterprise goals can be divided into two groups: the internal and the external (market) goals, and of the former ones the most important one is certainly to achieve a competitive position as good as possible under current circumstances and enterprise capabilities.

All of the enterprises participating in market competition can be perceived based on different references—among others their market share calculated as the overall turnover in the year. Business entities can also be presented and ranked based on different indicators (e.g. employment rate, value of motor vehicles). Regardless of the adopted classification criterion, the result of the analysis is a specific picture of a market. It is a representation of the stratification structure of the enterprises in the economy, which can be applied in a certain order of the layers of enterprises and is used to describe the events causing that order, while also being its consequence [2].

The stratification of the enterprises can therefore be seen in a twofold way. First of all, it is a static picture of the market which shows the different layers of business entities in certain relations with each other—it is then a basis for the knowledge of the enterprise position in the ranking (based on a certain criterion) as regards to the other enterprises. Second of all, the stratification is also itself the process of layering of the enterprises, that is the sequence of events in time, therefore, by its nature, a dynamic event.

The most important aspect of the stratification, regarding its usability, is the result of the conclusion that the position of the enterprise in the stratification order of the market is not random. On the contrary, it is the result of the unique characteristics of the entity (e.g. size, legal form, organisational form, ownership of the capital, market activity) but also the enterprise ability to perceive its surroundings and firmly adapt to its dynamics—the ability to self-regulate. Being in a certain layer is therefore the effect of a compilation of different characteristics of the enterprise. And even though the enterprises in the processes of achieving their goals are very individualised, a few groups of similarly behaving entities can be observed on the market. Based on the similarity of market behaviour, specific layers of enterprises are created. Since their market behaviour is similar, then, probably, their abilities to reach economic goals are also concurrent (not the same but comparable). On the basis of market behaviour observation and in consequence the processes of the creation of the stratification order of the market, enterprises can be ranked according to their ability to achieve market goals and therefore to survive in the long run.

If the market behaviour of the enterprise is positively verified by the environment, their ability to achieve long-term goals will be secured. However, for the market behaviour of the business entity to be appreciated in the market environment, it should possess a number of qualities. Most important of them is the ability to deal with the changes of the environment itself.

Self-regulation of the Enterprises as an Indicator of Their Ability to Compensate the Environment Changes

The overall awareness of the changes in the environments of the enterprises is common and beyond doubt in the current economic conditions. In the TSL sector, those changes are even more important because it is a result of the trade cycle changes among the current and potential contractors of haulage and the changes of the business conditions as regards the used materials, motor vehicles and workforce. Hence, the ability to compensate for the changes and to upkeep the effectiveness of goal achievement (which is the essence of self-regulation) through the adaptation to new conditions is necessary. That necessity is the result of two factors: the short-term goal of generating profit and the cumulated short term goal, identified in the long run through the increase in enterprise market value.

In the market dimension, from the functional point of view, the short-term goal is to strive to sustain the status quo on the market, making that state the first and foremost objective of self-regulation, which induces the understanding of self-regulation as an activity within the spectrum of the abilities of the enterprise to relate with its environment, based on the character. One of the main characteristics of a business entity is its ability to accept challenges and allocate the resources in a formerly unrecognised way. Entrepreneurial business entities accept in their functional philosophy the strive to seek new functional solutions, previously absent in other entities of the intra-organisational network thanks to which they adapt more successfully to the market conditions. In consequence, in the self-regulatory activities in the entrepreneurial companies, it results in changes within the system of partial equilibriums in the form of qualitative functional changes concern [1]:

- technology and technique;
- market (the search for new markets, fulfilment of new needs, use of new distribution channels);
- financial solutions (sources and mechanisms of financing, customer-entity financial relations, prices, equity relations);
- formal rules and structures;
- social system (recruitment, motivation, evaluation, promotion, culture, communication mechanisms, social initiatives, decision-making);
- and relations with the environment (marketing, promotion, public relations, lobbing).

Each of these areas can become a partial goal of the enterprise attributing to the primary goal, and each of them should be measured in a way which allows to determine the degree of its completion, including the profit. The formal measurement of the degree of goal completion is in most cases determined by the legal regulations—the accounting law and the taxation law which define the methodologies for profit calculation and evaluation of costs and revenues. All of these values, in their logic correct, become the basis for the construction of sector rankings. However, regarding the comparison of different enterprises, they become invalid, if only for the fact that in one ranking there are enterprises with a different scale of resources used to generate a certain value of revenue or profit.

Self-regulation is attributed to the effectiveness of goal completion—in the financial view those goals are revenues, costs and profits. They are the economic equivalent of used resources, and their relative configuration is important. The compensation of the changes within the financial self-regulation activities boils down to a search for such a configuration of the functional mechanism of the transport enterprise that allows for the best possible adaptation of the use of resources for revenue generation in the current market circumstances. The use of resources is evaluated in the form of the costs of the primary activity of the enterprise, in result becoming the basis for profit generation.

The Measurement of the Self-regulation Effectiveness of Enterprises

The measurement of the self-regulation efficiency of enterprises implicates the need to relate to a basic value, standardised in such a way that for all the enterprises the values are created according to the same methodology. It also requires a construction a measurement which then relativises the basic values positioning them on the basis of a relative value, which describes the relations describing the self-regulatory efficiency regardless of the scale of business activity. It is therefore needed to use a measurement which allows to describe the functional characteristics of an enterprise, while eliminating the influence of the revenues, costs and, in consequence, the profit.

By adapting the available business activity characteristics of transport enterprises, one can set the methodology for the measurement of self-regulatory effectiveness on revenues and profits generated by the enterprise. However, it is necessary to relativise those values through the effectiveness of activity in the form of the level of employment. It is a consequence of the characteristic of transport activity as a form of services. A useful measure in that matter might be the indicator of self-regulatory effectiveness (WSS), which takes into account the return on sales (effectiveness of financial self-regulation), efficacy of employment (effectiveness of operational self-regulation) and return on employment (effectiveness of economic self-regulation). Therefore, the formula for the indicator of self-regulatory effectiveness (WSS) is as follows:

$$\mathrm{WSS} = \frac{\frac{\mathrm{Zn}}{\mathrm{Ps}} \cdot \frac{\mathrm{Ps}}{\mathrm{Zatr}} \cdot \frac{\mathrm{Zn}}{\mathrm{Zatr}}}{\mathrm{Sop}} \quad (1)$$

where

- Zn—net profit,
- Ps—sales revenue,
- Zatr—employment,
- Sop—the degree of the sales revenue of the last enterprise in the sample; e.g., if the last enterprise has a sales revenue of around 1,000,000, then Sop is equal to one million.

Such an indicator does not have a reference value, nor does it have a border value. It is a relative measure and is therefore useful through the dynamic character of its analysis (changes of its value from one year to another), because of the fact that its growth shows the self-regulatory abilities of the enterprise and therefore allows to predict the long-term growth trend for the value of the entity.

Analysis of the Self-regulatory Effectiveness of the TSL Enterprises in Year 2014

Enterprises which were ranked in "Dziennik Gazeta Prawna" from 24 June 2015, nr 120 (4013) have been analysed—the ranking is shown in Table 1.

The ranking, shown in Table 1, allows to position the enterprises on the TSL market, according to the criteria shown in the head of the table (the basis for the segregation is the total value of revenue achieved in 2014). The natural conclusion is that the first enterprise (JAS-FBG S.A.) had the biggest share of the market in 2014. However, the effectiveness of business activity measured by the profit changes that picture completely—the first position is then occupied by SKAT Transport Sp. z o.o. Sp. k. (11,725,744 PLN), while the first position according to the profit dynamic belongs to an enterprise called No Limit with the 2014/13 dynamics on the level of 1125.85%. Those are still large enterprises, due to the fact that JAS-FBG S.A. employed 1018 people in 2014, SKAT Transport Sp. z o.o. Sp. k. employed 135 people and No Limit employed 371 people in the same year. The analysis of the dynamics of employment in these enterprises allows to observe that the entity with the largest revenue dynamics decreased their employment from 1148 employees to 1036 in 214, while the entity with the largest profit dynamics has increased its employment from 354 employees to 371 employees in 2014. The enterprise with the largest profit in 2014 (SKAT Transport Sp. z o.o. Sp. k.) has at the same time increased their employment from 109 to 135 employees. This leads to a question—Which of the enterprises has adapted the best to the changing economic conditions on the TSL market during that time frame?

To answer such a question, one has to revisit the listing in Table 1 and calculate the indicators of self-regulatory indicators for the years 2013 and 2014 for all the listed entities and then to calculate the value of change of that indicator from year to year (Table 2).

The analysis of the increase in the level of WSS that the aforementioned enterprises showing the largest market share or economic effectiveness were not the ones to have the best possible resource configuration for the functional equilibrium in 2014. Such a configuration of market activity and resource usage was achieved by the Albatros Cargo Sp. z o. o., for which the increase in WSS was on the level of 8906 points. It is especially interested when compared to the level of employment because that enterprise employed 6 workers in 2013 and 8 workers in 2014 which indicates a significant self-regulatory effectiveness. Arranging the enterprises according to the growth of the self-regulatory effectiveness indicator creates an entirely different picture of the market after all.

Table 1 Ranking of the TSL enterprises in 2014 according to their revenue

Name	Total revenue 2013	Total revenue 2014	Net profit 2013	Net profit 2014	Employment 2013	Employment 2014
JAS-FBG S.A.	447,214,000	457,265,000	6,086,000	7,808,000	950	1018
ERONTRANS	354,729,212	387,422,943	5,439,856	3,136,293	298	314
SKAT Transport Sp. z o.o. sp. k.	184,990,992	282,281,168	5,398,429	11,725,744	109	135
HellmannWordwide Logistics Sp. z o.o. sp. k.	254,294,000	280,525,000	1,126,000	1,033,000	410	391
Grupa Delta Trans	253,107,600	252,081,000	9,534,700	5,309,500	1148	1036
LINK Sp. z o. o.	220,176,170	247,844,431	5,030,073	5,092,203	504	531
CAT LC Polska Sp. z o.o.	202,044,000	209,214,000	2,370,000	2,370,000	266	282
Yusen Logistics (Polska) Sp. z o.o.	164,616,000	208,101,000	−275,000	1,077,000	178	205
MEXEM Sp. z o.o.	182,812,000	196,081,000	6,037,000	8,192,000	253	259
OMIDA Group	88,112,973	193,486,078	769,046	2,242,478	120	188
BATIM Transport Międzynarodowy i Spedycja	178,472,000	190,962,000	11,228,000	404,000	505	565
PPT PKS Gdańsk-Oliwa S.A.	162,868,849	180,486 579	2,776,186	2,372,011	148	164
SM LOGISTICS Sp. z o.o.	156,739,984	170,039,319	1,201,778	1,896,702	98	101
Eurogate Logistics Sp. z o.o.	99,502,000	117,176,000	878,000	1,701,000	57	68
No Limit	94,605, 000	103,279,000	147,000	1,655,000	354	371
Optima Sp. z o.o.	58,709,694	95,809,413	6,361,412	1,898,494	125	173
ZTE RADOM Sp. z o.o.	79,496,660	79,578,913	236,118	412,260	301	304
JURA POLSKA SP. Z O.O.	69,969,400	77,699,600	45,500	−261,600	29	33
Trans Logistyka–Olga Juchniewicz Sp. komandytowa	56,856,000	70,154,000	3,191,000	3,485,000	172	229
Botrans Sp. z o.o.	68,478,659	64,305,847	989,149	809,719	113	94
MAGTRANS	62,867,000	62,563,000	1,829,287	3,184,395	248	253
AsstrA Associated Traffic AG	84,354,000	58,677,000	1,133,000	187,000	77	80

(continued)

Table 1 (continued)

Name	Total revenue 2013	Total revenue 2014	Net profit 2013	Net profit 2014	Employment 2013	Employment 2014
SM Agroland Sp. z o.o.	48,281,824	48,172,666	842,979	622,275	33	35
INTERTRANSPORTSCENTRE-POLSKA Sp. z o.o.	34,227,322	36,932,883	1,426,238	1,501,991	18	19
NOX-POL Sp. z o.o.	27,149,655	35,817,308	185,385	385,414	87	100
Delphia Pisarska-Klinkosz, Klinkosz i Zagarów Spółka jawna	11,529,333	12,971,153	117,339	844,238	12	13
Transrem Sp. z o.o.	8,320,061	8,772,907	803,934	1,040,611	84	86
Albatros Cargo Sp. z o.o.	5,400,000	5,200,000	312,000	862,000	6	8

Source “Dziennik Gazeta Prawna”, 24.06.2015 nr 120 (4013)

Table 2 Ranking of TSL enterprises according to the dynamics of self-regulatory effectiveness indicator

Name	Self-regulatory effectiveness indicator		Change
	2013	2014	
Albatros Cargo Sp. z o.o.	2704.00	11,610.06	8906.06
SKAT Transport Sp. z o.o. sp. k.	2452.91	7544.20	5091.29
Delphia Pisarska-Klinkosz, Klinkosz i Zagarów spółka jawna	95.61	4217.38	4121.77
MEXEM Sp. z o.o.	569.38	1000.42	431.04
Eurogate Logistics Sp. z o.o.	237.27	625.74	388.47
SM LOGISTIC Sp. z o.o.	150.63	352.66	202.03
MAGTRANS	54.41	158.42	104.01
OMIDA Group	41.07	142.28	101.21
JURA POLSKA Sp. z o.o.	2.46	62.84	60.38
Transrem Sp z o.o.	91.60	146.41	54.82
Yusen Logistics (Polska) Sp. z o.o.	2.39	27.60	25.21
No Limit	0.17	19.90	19.73
JAS-FBG S.A.	41.04	58.83	17.79
NOX-POL Sp. z o.o.	4.54	14.85	10.31
ZTE RADOM Sp. z o.o.	0.62	1.84	1.22
Hellmann Wordwide Logistics Polska Sp. z o.o. sp. k.	7.54	6.98	−0.56
Botrans Sp. z o.o.	76.62	74.20	−2.42
LINK Sp. z o.o.	99.61	91.96	−7.64
CAT LC Polska Sp. z o.o.	79.38	70.63	−8.75
INTERTRANSPORTS CENTRE-POLSKA Sp. z o.o.	6278.26	6249.24	−29.01
Grupa Delta Trans	68.98	26.27	−42.72
Trans Logistyka-Olga Juchniewicz spółka komandytowa	344.19	231.60	−112.59
PPT PKS Gdansk-Oliwa S.A.	351.86	209.19	−142.67
AsstrA Associated Traffic AG	216.51	5.46	−211.05
ERONTRANS	333.23	99.76	−233.46
SM Agroland Sp. z o.o.	652.54	316.10	−336.43
BATIM Transport Międzynarodowy i Spedycja	494.34	0.51	−493.82
Optima Sp. z o.o.	2589.92	120.43	−2469.50

Source Own analysis

Conclusions

Stratification of the enterprises that is the process of the layering of the market is one of the possible methods for the description of the state of the market. The state of the TSL sector is constantly described through the publication of rankings in which enterprises are arranged according to the basic economic characteristics such as revenue, profit or employment. Using those rankings, one can also perform the stratification of the enterprises based on the changes of these values from year to year. However, such a description of the market and the comparison of different enterprises has one significant drawback, that is that the first places are always occupied by large enterprises with large potential, while the small enterprises, with small potential occupy the last places. The values of the economic categories generated by these groups of enterprises are beyond comparison, and while the dynamics of the levels show a bit different picture of the market, the stratification is still performed based one criterion. That leads to the inability to evaluate the enterprises according to their ability to adapt to changing market conditions—to self-regulate. The measure which layers the market according to the effectiveness of compensation of changes is the self-regulatory effectiveness indicator which describes in a relative way the characteristics of the achieved effect and the used resources. The indicator shows the effects of business activity while including the employment levels in the transport and haulage enterprises by bringing together the return on sales, the efficacy of employment and the effectiveness of employment. The use of the change in the value of the indicator, as calculated year by year (the value of WSS in 2014 minus the value of WSS in 2013) has shown during the research that the picture of the market and the layering of the enterprises is entirely different than when it is constructed according to the revenue, the profit or the employment. The enterprise which turned out to be the most effective one was an entity which was the smallest and therefore the last in the published ranking. It was characterised by a negative revenue dynamic, a significant profit dynamic and a small growth of employment. In conclusion, one has to state that the self-regulatory effectiveness indicator is a better criterion for the layering of the market because it allows to characterise the enterprises regardless of their economic potential in possession.

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The Use of Potential Models in Research on Transport Accessibility of Knowledge and Innovation Centers on the Example of Poland

Aleksandra Koźlak

Abstract In a knowledge-based economy, innovativeness is considered to be the main factor of regional development. Economic development on a regional and national scale is initiated in the urban agglomerations, in which there is a highest concentration level of knowledge, information, and tangible and intangible capital. The potential for innovation implementation is placed unevenly, which makes the spread of innovations and knowledge dependent on the transport accessibility of these places. The concept of transport accessibility and the possibilities for the use of potential models for the research on transport accessibility is presented in the article. It also covers the results of the research on the differences in transport accessibility of knowledge and innovation centers in different Polish regions which was based on the indicator of potential transport accessibility.

Keywords Transport accessibility · Potential models

Introduction

Modern socioeconomic development is based on knowledge and innovation introduction. Despite the extensive use of telecommunications technologies, spread of knowledge and innovation requires intensive personal contacts, which is achieved mostly through the connection between large city centers with fast public transport. New information and communications technologies are not pure substitutes of transport. Parts of knowledge in digital forms may be transferred over long distances with the use of information devices, but often there is no such possibility, and the need arises for infrastructure which would allow for direct human contact.

The increase in knowledge level and a fast spread of innovation requires regional cooperation of scientific activity and business centers with global economy centers,

A. Koźlak (✉)
Chair of Comparative Research of Transport Systems, Faculty of Economics,
University of Gdansk, Gdansk, Poland
e-mail: a.kozlak@univ.gda.pl

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and theses connections may only be achieved with developed air transport or with high-speed rail. On the other hand, the diffusion of knowledge from main centers in the region into secondary areas is connected with the necessity of improvement of the transport infrastructure state on regional and local level, so as to broaden the range radius [1].

The goal of the article is to present the results of the research on differences in transport accessibility of knowledge and innovation in different Polish regions, which was based on the indicator of potential transport accessibility. The level of accessibility assessed with the use of that method takes into account not only the quantitative and qualitative state of the transport system, but also the potential for innovation in different regions.

The Concept of Transport Accessibility and the Methods for Its Measurement

The notion of accessibility is not unambiguous, and in the literature, there are many concepts which are connected with it. The word accessibility is derived from words access and ability and means the ability to access something [2]. Therefore, in the general meaning, the concept of accessibility is used regarding the easiness for population of a certain area to reach access to different kinds of activities, such as work, education, healthcare, shops, and cultural areas. One of the first definitions of accessibility as regards the spatial planning was proposed by Hansen (1959), who defined accessibility as a possible potential for interaction happening [3]. The potential for interaction is dependent on the characteristics of the transport system (travel time or costs of reaching the destination) and the manners of land management (quality of potential destinations) [4]. Transport systems are planned in such a way to facilitate participation in different spatially spread activities, which it takes various amounts of time to reach. In many scientific articles, the reviews of current definitions and connected measurement methods are presented, as well as ideas for the improvement of these methods and examples of their practical use [5–7].

Regardless of the adapted definition, in the literature, there are certain main groups of components which are the integral elements of transport accessibility, two of which can be seen as primary: the spatial use component and the transport component. Geurs and Ritsema van Eck distinguish four components which constitute the transport accessibility [8]:

- land-use component,
- transportation component,
- temporal component,
- individual component.

The land-use component takes into account the different spatial allocation of possibilities and places in which the society can satisfy their various needs. This is also the component which is described as the attractiveness of the locations as a destination in the transport system. The transportation component, also called the resistance of the space, shows how hard it is to travel between two places with a certain transport branch, which is dependent both on the equipment of transport infrastructure and the quality of services provided by the transport system. The temporal component includes the differences of accessibility levels on account of the time of day, week, and year. These differences are crucial, especially due to the fact that in certain periods, the congestion affects the extension of travel time and decreases the transport accessibility of destination. In turn, the individual component takes into account the socioeconomic characteristics of the transport user and his mobility. Those are three factor groups: the needs (which are the result of age, life phase, family status, income, and education), abilities (a result of physical condition and availability of different transport branches), and chances (a result of the income level, the part of budget allocated to travel and education level) [9].

Therefore, the transport accessibility is a concept which is both relative and contextual, which is why its definition depends on the breadth and the objective of the research. The notion is used regarding the transport system and the spatial planning as well as the behavior of the enterprises and the households. Apart from that, it is a subjective concept—perceived differently by different people and entities based on their experience and assessment. The same location can be assessed as available for some and unavailable for others, if only for different times and costs of travel.

Due to the fact that there is no universal definition of transport accessibility, many various indicators with different theoretical basis and complexity levels have been used in the empirical research [10]. Based on the literature review, six main research approaches to assess the transport accessibility can be marked off [11]:

- infrastructure-based accessibility which is assessed with the use of infrastructure equipment indicators of a certain region, e.g., the quantity and quality of spot and linear objects of transport infrastructure, that is, for example, the density of road and rail network or the capacity of airports;
- distance-based accessibility, in which the distance can be viewed as the physical distance (Euclidean), the real physical distance (e.g., the road distance), temporal (travel time) or economic (travel cost) between the origin point and the destination or collection of journey destinations, e.g., the total travel time to the ten largest European cities;
- cumulative accessibility or izochronic accessibility which is measured by an assessment of the set of journey destinations available in a given time, within a certain cost or travel effort, e.g., the number of citizens available within one hour, the number of high schools available within half an hour;
- potential accessibility measured by the possibility of an interaction between the travel origin and the set of travel destinations based on an assumption that the attractiveness of the destination is diminished by the extension of travel time or cost;

- person-based accessibility which takes individual preferences into account, analyzing the transport accessibility on an individual level, for example, the activities in which a certain person can participate within a certain time. That type of measures, based on behaviorism, was created in the time-space geography of Hagerstrand [12]. These measures include the temporal and spatial restrictions of human capabilities to function in a certain environment, such as the place and time of obligatory activities, the amount of free time and speed of travel available in the transport system;
- utility-based accessibility which analyzes the economic benefits which are the result of the access to spatially dispersed activity places. The transport accessibility is interpreted as a result of the choice made by the user of the transport system so as to maximize the utility out of the set of all possible solutions, which can all fulfill the same needs. This sort of transport accessibility measurement is connected with the transport demand modeling and the utility theory.

The further part of the article is concentrated on the modeling of potential accessibility, which was used to investigate the transport accessibility of knowledge and innovation centers in Poland. The use of potential model in the analysis of socioeconomic development level of regions was limited to two of its forms: the income potential and the population model, rarely regarding the market, work, or education services.

Potential Model in the Research on Transport Accessibility

The potential model belongs to the class of gravity models which are more and more used in the socioeconomic research. The essence of the potential model is based on the hypothesis that the mutual effects of two areas are directly proportional to their mass measured by, for example, their industrial production levels, economic potential, innovativeness level, population, and inversely proportional to their distance from each other. The notion of spatial potential is grasped in analogy to the potential of gravity field [13]. The potential determines the intensity of relations between the regions. It is a dependent variable not only of the size of the regions or the intensity of certain characteristics, but also their location regarding one another, that is their distance. The region as such might have a small internal potential but use the potential of other regions due to a beneficiary location in the regional system [14].

The use of potential models in scientific papers concentrating on the regional research on European countries has become common in the 1980s and 1990s of the twentieth century. The earliest research may be attributed to Keeble et al. [15], who used the potential for regional income as a basis of the availability of business activity and proceeded to use it investigate the changes of regional diversification of the European Union. On the other hand, Vickerman et al. [16] have assessed the differences in regional availability of regions on a European scale based on the distribution of human potential and tried to establish the relations between the changes of accessibility and the economic development [14].

So far, the most complex research on transport accessibility for Europe was performed in the ESPON programme. The effect of the research was the calculation of indicators and the construction of maps of potential transport accessibility including the minimal travel time between the administrative type NUTS 3 units. The potential transport accessibility of an area has been established based on the economic and social potential, to which there is an easy access by transport routes of different transport branches. The indicator of potential transport accessibility specifies the number of attractive destinations which can be reached (or the population) weighed by the negative effect of travel time or cost [17].

In Poland, the research on the potential transport accessibility had been developed within the framework of economic geography before they were developed in economy. The Poznań center was famous for that research, from which Chojnicki [18], Czyż [19] and Ratajczak [20, 21] origin. In that center, the gravity and potential model was widely used for the research on transport accessibility so as to investigate the accessibility of cities and countries. An increased interest in the research on transport accessibility is visible in the recent years, which is undoubtedly a result of the Polish accession into the EU and a greater concern attributed to the problems of convergence and regional development. Broad research on the potential transport availability is conducted in the Institute of Geography and Spatial Organization of the Polish Academy of Sciences.

An Assessment of the Transport Accessibility of Knowledge and Innovation Centers in Poland

A methodology of the calculation of potential accessibility indicator was used so as to investigate the differences in transport accessibility of knowledge and innovation centers in Poland. The main assumption of the model is that the travel time between scientific centers of the high tier from different regions determines their access to knowledge and innovation. The indicator of potential transport accessibility determines the level of innovation potential which can be reached weighed by the negative effect of the travel time. A modified formula for the potential transport accessibility has been used in which, due to nature of the research, the internal potential of the region has been used.

$$A_i = P_i \exp(-\beta t_{ii}) + \sum_j P_j \exp(-\beta t_{ij}) \quad (1)$$

where

- A_i—access of the ith region to knowledge and innovation centers,
- P_i—innovative potential of the ith region,
- t_{ii}—travel time in the ith region,
- P_j—innovative potential of the jth region,
- t_{ij}—travel time between the ith region and the jth knowledge and innovation center,
- β—the parameter which determines the sensitivity to the travel time increase in the transport user.

In this view, the transport accessibility of the regions increases with the growth of innovative potential and decreases with the travel time increase. The transport accessibility of the knowledge and innovation centers is therefore determined with the use of variables, where

- the level of innovative potential is represented by the variable: the value of expenditure on R&D activity in year 2014 in a certain voivodeship[1];
- the travel time to different scientific centers has been established as the shortest possible travel time by road, rail, or air transport from the voivode city of the region.[2]

The β coefficient has been set at the level of 0.005 by analogy to the ESPON projects. Such a value means that for the travel time of zero minutes between the regions (which is not possible in reality but has been assumed in the region for the access to the internal potential of the region), the innovative potential in the destination region will be fully included into the indicator of potential accessibility in the region of origin. For the travel time of a bit over two hours, the weight is 0.5, and if the travel time extends to over five hours, the weight drops to 0.2. The data used to calculate the indicator of the potential transport accessibility is shown in Table 1.

The model of potential transport accessibility is not easy to interpret as it does not have any identifiable units. This is why, for clarity of the results, they are shown in a relative manner, i.e., regarding the average value of the whole research area, considering the average value as 100%. The values of potential transport accessibility of knowledge and innovation centers have allowed to group the voivodeships which are similar to each other regarding that indicator. The results of the research are graphically shown in the Fig. 1.

[1]The amount of expenditures on R&D has a high correlation with other variables which characterize a potential of knowledge and innovation, for example, a number of scientific workers, a participation in EU framework programs, and a number of students and graduates of high schools.

[2]In the air, transport has been imputed travel time between airports and city centers and 60 min necessary for check-in in domestic voyages.

Table 1 Value of R&D expenditures in year 2014 (in mln PLN) and the matrix of shortest travel times (in minutes) by road, rail, or air transport used to research the accessibility to knowledge and innovation centers in Poland

Voivodeship	R&D expenditures	Dolnośląskie	Kujawsko-Pomorskie	Lubelskie	Lubuskie	Łódzkie	Małopolskie	Mazowieckie	Opolskie	Podkarpackie	Podlaskie	Pomorskie	Śląskie	Świętokrzyskie	Warmińsko-Mazurskie	Wielkopolskie	Zachodnio pomorskie
Dolnośląskie	1 070.1		219	387	139	166	162	144	43	242	375	299	115	255	397	117	272
Kujawsko-Pomorskie	255.6	223		330	198	146	338	186	299	413	352	79	312	269	185	83	224
Lubelskie	690.7	384	330		403	232	239	133	341	149	234	308	279	145	281	318	473
Lubuskie	68.1	139	196	403		206	290	174	195	368	390	289	241	403	259	87	157
Łódzkie	703.7	166	146	232	206		181	67	169	285	256	206	154	129	235	126	288
Małopolskie	1 850.3	162	334	239	290	182		139	120	98	313	235	56	86	316	238	267
Mazowieckie	6 487.2	144	185	132	174	86	139		175	143	143	144	138	149	147	137	181
Opolskie	122.3	42	293	343	195	169	120	174		204	334	343	76	203	405	164	330
Podkarpackie	931.0	242	413	148	368	285	98	143	204		393	243	138	156	427	236	205
Podlaskie	233.4	408	350	234	413	256	320	143	365	393		316	296	315	213	336	498
Pomorskie	1 031.7	314	82	300	288	206	235	144	376	243	309		307	338	135	168	261
Śląskie	1 218.1	115	312	319	241	154	56	141	76	138	328	307		118	332	255	294
Świętokrzyskie	140.5	216	269	149	403	129	91	149	171	156	315	338	116		312	251	413
Warmińsko-Mazurskie	126.1	394	187	270	354	229	339	150	405	427	210	131	326	312		231	395
Wielkopolskie	1 059.3	124	84	317	93	126	238	137	175	236	302	167	238	251	234		140
Zachodniopomorskie	179.9	276	224	477	157	288	267	181	330	205	514	261	294	413	343	139	

The sums of travel times in rows and columns may differ, because the travel times by rail transport are often different in opposite directions. Travel times from a certain region are in the columns

Source Own elaboration on the base [22–25]

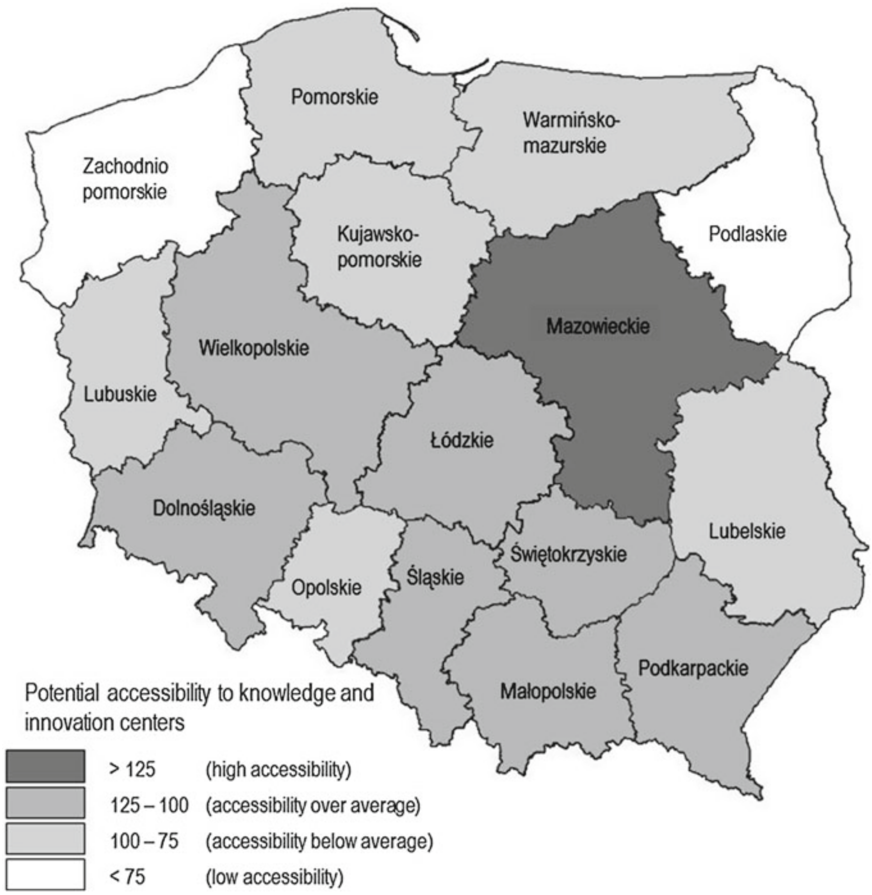

Fig. 1 Map of potential accessibility to knowledge and innovation centers in Poland. *Source* Own elaboration

The areas in which the innovative potential of the knowledge-based economy is concentrated are metropolises and metropolitan areas. The internal potential of the region and the travel time to other largest metropolises has the prevailing effect on the transport accessibility level of the regions.

The expenditures on R&D in Poland are very unevenly dispersed, and the Mazowieckie Voivodeship is significantly dominant (40.1% of the national scale in 2014). The Małopolskie Voivodeship is also significant and has a participation level of 11.4%. The following voivodeships for which the participation levels are about 6–7% are as follows: Śląskie Voivodeship, Wielkopolskie Voivodeship, and Pomorskie Voivodeship.

It is worth mentioning that in the abovementioned regions, the potential transport accessibility to knowledge and innovation centers is above the country average (except for the Pomorskie Voivodeship). The Pomorskie Voivodeship is characterized by a below average accessibility to knowledge and innovation despite the fact that the Tricity Metropolis is the region. In the voivodeship, the R&D expenditures are over 1 bln PLN, just as in the Dolnośląskie and Wielkopolskie Voivodeships, but the travel time to other research centers is relatively long due to a peripheral location in the country. On the other hand, the Łódzkie and Świętokrzyskie Voivodeships have lower R&D expenditures but benefit from the vicinity of regions which invest more. The lowest transport accessibilities are shown by the Zachodniopomorskie and Podlaske Voivodeships in which low R&D developments are accompanied by a long travel time to most important metropolises.

Summary

Under the conditions of knowledge-based economies, innovativeness is considered to be the most important factor of regional development. Therefore, much of the scientific research is concentrated on the ability to increase the level of innovativeness and the diffusion of knowledge and innovation. Modern development processes occur to a high extent in the system of enterprises, research institutes, public administration, and people initiatives network. That is why the development of the economy starts in the areas in which there is a highest level of concentration knowledge, information, and intangible and tangible capital. Furthermore, the spread of knowledge and innovation from the main areas of their development to the regions which are located further away will depend highly on the quality and effectiveness of the transport system.

Transport determines the knowledge transfer and the diffusion on innovations. That statement holds both for the passenger transport which allows the share of unstructuralized knowledge during personal contacts and for the cargo transport which allows the transport of, for example, books, documentation and data carriers. Apart from that, transport, despite the development of telecommunications technologies, determines the willingness to cooperate between the enterprises and between the enterprises and R&D entities. Decent transport accessibility is a key factor here.

In the article, the broad possibilities for the use of potential models for the research on transport accessibility were presented. The model was then used to analyze the diversity of transport accessibility to knowledge and innovation centers in Poland. The research has shown that there are significant differences in that regard. It is mostly the result of the concentration on R&D expenditures in scarce metropolises and the differences in the communication of different regions with these metropolises. Further activity concentrated on the improvement of the innovativeness of all the regions should take the transport factor into account.

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Assessment of Selected Elements of Logistic Customer Service for Management in Transport Enterprises —The Multiple Discriminant Analysis

Marta Kadłubek and Aneta Włodarczyk

Abstract The aim of the paper is the assessment of selected elements of logistic customer service for management as perceived by the recipients of services on example of commercial cargo motor transport enterprises. The surveys of the logistic service level as perceived by the recipients of the services of Polish Silesian Province's commercial cargo motor transport enterprises, carried out using the Servqual method, enabled the quality assessment of the logistic service elements of business entities included in the test sample. Considering the results of classification of the most significant logistic customer service elements at the enterprises under study, an attempt was made to examine the effect of logistic customer service element quality on service correctness, service timeliness, service completeness, service provision promptness, technological advancement of the fleet, and service availability. For the determination of the above-mentioned significance, the multiple discriminant analysis was employed. The computations were made using the *STATISTICA 10.0* package.

Keywords Logistic customer service · Commercial cargo motor transport enterprises · Servqual method · Multiple discriminant analysis

Introduction

The term of logistic customer service is formulated, i.e., by Ballou [1], Florez-Lopez and Ramon-Jeronimo [2], Kempny [3], Kisperska-Moroń and Krzyżaniak [4], and Lambert et al. [5], as the abilities or skills to assemble the customer's requirements and expectations, predominantly in terms of the time and place of delivery, though using all obtainable varieties of logistic activities,

M. Kadłubek (✉) · A. Włodarczyk
Faculty of Management, Czestochowa University of Technology, Czestochowa, Poland
e-mail: martakadlubek@wp.pl

A. Włodarczyk
e-mail: aneta.w@zim.pcz.pl

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including transport, storage, and management of inventory and information. Many authors frequently transfer the idea of logistic customer service to the very principles and objectives of logistic management [6], which are most temporarily articulated in the definition of "seven Rs" [7]. Because all of the logistic activities have the consequence on the customer receiving accurate product or service, in its appropriate condition, in the exact time and space, and at reasonable costs; therefore, looking for the right service is accompanied by managing logistic activities in such an approach, as to attain the crucial level of customer satisfaction at the lowest possible costs [8, 9]. Subsequently, the elements of logistic customer service are placed on a measurable level, as evaluated from the perspective of the recipients of offered products or services [10].

Simultaneously, such a scrupulous framework of analysis of the logistic service matter appears as appropriate from the viewpoint of the theme issue of the paper. The aim of the paper is the assessment of selected elements of logistic customer service for management as perceived by the recipients of services on example of commercial cargo motor transport enterprises. Considering the results of classification of the most significant logistic customer service elements at the enterprises under study, an attempt was made to examine the effect of logistic customer service element quality. For the determination of the above-mentioned significance, the multiple discriminant analysis was employed.

Acquiring the Research Material

The elements of logistic customer service of the Silesian Province's commercial cargo motor transport enterprises [11–13] under study are placed on a measurable level [14], as evaluated from the perspective of the recipients of offered transport services [15–17]. The measurement of the logistic customer service level, as found at the entities examined [18], was made using the Servqual method [19–21].

Carrying out the examination of the level of logistic service rendered by business entities included in the test sample required the assessment of the level of customers' expectations toward particular elements of this service and the formation of perception of the service level provided at the entities examined. The determination of the average level of discrepancy between the customers' expectations and experiences in particular aspects of logistic service quality made it possible to do the quality assessment of distinguished categories of logistic service and those of its attributes, in which a quality loss occurs. Thus, the difference between the expectation fulfillment level and the customers' perception of the service was examined, whereby the fifth gap of the Servqual method was defined.

The questionnaire used in the study was constructed based on 22 logistic customer service determinants. The questionnaire form was composed of two sections: The first section illustrated the expectations of service recipients toward the logistic service, while the second section included items intended for the scoring of services rendered by a given service provider. Using the seven-point Likert scale, clients were asked to assign weights to the respective statements: 1 meant that the respondent totally disagreed with a given item, while 7—that he or she totally agreed with it.

Questionnaire forms were filled by 294 customers of the 147 Silesian Province's commercial cargo motor transport enterprises examined, i.e., two customers of each enterprise. Questionnaire forms were handed over directly to 38 respondents indicated as the customers of 19 enterprises, while with the remaining customers of 128 entities examined, telephone surveys were carried out.

Selection of Statistical Methods

The surveys of the logistic service level as perceived by the recipients of the services of Silesian Province's commercial cargo motor transport enterprises, carried out using the Servqual method, enabled the quality assessment of the logistic service elements of business entities included in the test sample. Considering the average level of discrepancy between the expectations and experiences of 294 service recipients in respect of 22 logistic service elements, based on the acquired initial data, an attempt was made to examine the significance of the quality of logistic customer service elements for those 6 elements that had been identified by the examined entities' customers as the most important. Considering the results of classification of the most significant logistic customer service elements at the enterprises under study, an attempt was made to examine the effect of logistic customer service element quality on service correctness, service timeliness, service completeness, service provision promptness, technological advancement of the fleet, and service availability.

In view of the ordinal nature of the scores of service recipients' expectations and experiences and the differences between their levels, the use of linear regression-relying methods at the next stage is arguable. Attempts to use such a method ended practically in failure, since the fitting of potential equations estimated on the assumption of the best possible adjusted value of the determination coefficient R^2, though being statistically significant, in 6 out of 7 cases did not exceed the threshold of 0.5, and in the best presentation, the fitting was as low as 54.7%.

For the determination of the above-mentioned significance, the multiple discriminant analysis was employed. In discriminant models, "*in the space of k-dimensional inhomogeneous random vectors of finite values of mathematical expectations, variances and covariances, hyperplanes can be passed, which will divide this space into subspaces of more homogeneous vectors*" [22]. The sample consists of several p-dimensional normal distributions with expected value vectors, x_1, x_2,...x_n, and the same covariance matrix, S. The discriminant function is $a^T x$, where, for the two-dimensional system, we take on the vector maximizing the expression [23]:

$$t^2(a) = \frac{\left[a^{\mathrm{T}}(\bar{x}_1 - \bar{x}_2)\right]^2 \frac{N_1 N_2}{N_1 + N_2}}{a^{\mathrm{T}}\mathrm{Sa}} \tag{1}$$

where $a^{\mathrm{T}}\mathrm{Sa} = 1$.

The vector a is the solution of the homogeneous system of equations:

$$\left[\frac{N_1 N_2}{N_1 + N_2}(\bar{x}_1 - \bar{x}_2)(\bar{x}_1 - \bar{x}_2)^{\mathrm{T}} - \lambda S\right] a = 0 \tag{2}$$

where

$$\lambda = \max_a t^2(a) = \frac{N_1 N_2}{N_1 + N_2}(\bar{x}_1 - \bar{x}_2)^{\mathrm{T}} S^{-1}(\bar{x}_1 - \bar{x}_2) = T^2 \tag{3}$$

The rank of the matrix of this system is equal to $p - 1$, which defines the following form of linear discriminant function:

$$y = (\bar{x}_1 - \bar{x}_2)^{\mathrm{T}} S^{-1} x \tag{4}$$

In view of the comparable variance of the observed variables, in the next step, the estimation of the discriminant function was made.

In determining the coefficients of a discriminant function, the aim is to maximize the ratio of the intergroup variability of the input data to their intragroup variability [24]. As the criterion, the Anderson classification statistics was employed [25]:

$$W = (\bar{x}_1 - \bar{x}_2)^{\mathrm{T}} S^{-1} x - 0.5 \cdot (\bar{x}_1 - \bar{x}_2)^{\mathrm{T}} S^{-1}(\bar{x}_1 + \bar{x}_2) \tag{5}$$

where we classify x into population 1 (with low rated scores) when $W < 0$ and into population 2 (with high rated scores), when $W > 0$.

As the criterion of division of the endogenous variable, arbitrary values of scores for particular variables (X_2, X_3, X_4, X_5, X_6, X_{14}) were proposed in such a manner that the first group is $X_i < -3$; the second is: $-3 \leq X_i < 0$; the third is: $0 \leq X_i < 3$; and the fourth group is: $X_i \geq 3$. Respective values were assigned to individual values, classifying them into groups 1, 2, 3, 4. For each assessment of X_i scores separately, individual assessment values were determined, and then, classification into groups was done. The dependent variables are, respectively,

- X_2—availability of the services of the transport enterprises examined,
- X_3—timeliness of the services of the transport enterprises examined,
- X_4—correctness of the services of the transport enterprises examined,
- X_5—completeness of the services of the transport enterprises examined,
- X_6—promptness of delivery of the services of the transport enterprises examined, and
- X_{14}—technological advancement of the fleet of the transport enterprises examined.

The test sample consisted of 294 complete questionnaire forms filled by the recipients of the services rendered by the entities under study, based on which the classification was made. Sixteen input variables were proposed, with six presentations for the above-mentioned potential output (diagnostic) variables. Such broad diagnostic formulation was due to, on the one hand, by the pioneering nature of the study and, as a consequence, the difficulty in defining uniquely the results possible to be obtained.

The independent variables are, respectively,

- X_1—inquiry response time in the transport enterprises examined,
- X_7—extensiveness of the services of the transport enterprises examined,
- X_8—geographic coverage of the services of the transport enterprises examined,
- X_9—terminal protection in the transport enterprises examined,
- X_{10}—location of the infrastructure of the transport enterprises examined,
- X_{11}—equipment range of the infrastructure of the transport enterprises examined,
- X_{10}—informatization of the infrastructure of the transport enterprises examined,
- X_{13}—meeting the environmental requirements by the infrastructure of the transport enterprises examined,
- X_{15}—age of the fleet of the transport enterprises examined,
- X_{16}—meeting the environmental requirements by the fleet of the transport enterprises examined,
- X_{17}—claims and complaints received by the transport enterprises examined,
- X_{18}—monitoring of the services of the transport enterprises examined,
- X_{19}—round-the-clock servicing offered by the transport enterprises examined,
- X_{20}—competencies and expertise of the logistic consultancy of the transport enterprises examined,
- X_{21}—flexibility of the logistic consultancy of the transport enterprises examined,
- X_{22}—reliability of the logistic consultancy of the transport enterprises examined.

In the proposed discriminant functions, the influence of all independent variables in the first presentation (variables X_1, $X_7 - \mathrm{X}_{13}$, $\mathrm{X}_{15} - \mathrm{X}_{22}$) is taken into account.

At the beginning, the assumption was made that at least, the first k discriminant variables were significant, and the hypothesis of the significance of the last $s - k$ discriminant variables was put to the test. The verifying statistics is Wilks' lambda in the following form [26]:

$$\Lambda = \prod_{l=k+1}^{s} \frac{1}{1 + \lambda_l} \tag{6}$$

It assumes values within the range from w 1 (no discrimination power) to 0 (excellent discrimination power) [27]. This statistics, on the assumption of the zero hypothesis being true, has an asymptotic chi-square distribution in the form of [25]:

$$\chi_k^2 = \left(n - \frac{s+z}{2} - 1\right)\ln\Lambda_k \quad (7)$$

and the following numbers of freedom:

$$\mathrm{d}f = (m-k)(n-k-1) \quad (8)$$

The analysis was carried out stepwise in the following manner, on the assumption that the level of significance for individual parameters had to be lower than 0.05. The procedure in the stepwise discriminant analysis is analogous to the procedure in the case of the stepwise regression method. In the case of progressive stepwise regression, those variables were successively added to the model's independent variable set, which had a significant influence on the dependent (forecast) variable [25].

The computations were made using the *STATISTICA 10.0* package.

Analysis of the Examination Results

The first of the presented discriminant functions indicates an influence of the independent variables on the second dependent variable, i.e., X_2—availability of the services of the transport enterprises examined.

To illustrate the properties of the presented function, the following result tables are enclosed.

According to the data in Table 1, the discrimination of the assessment types by the variables being already present in the model, in spite of being relatively high, is significant ($\Lambda = 0.53999$, $F = 12.810$, $p < 0.0000$). The value of Wilk's lambda has decreased (from 0.5995 to 0.5957) after inputting the last variable to the model, which indicates an increase in its discrimination power. The elimination F value for the independent values is, however, high, and the critical level of significance adopted for all variables, $p < 0.05$, very clearly indicates a significant contribution of the whole group of scores to the discrimination. Tolerance values different from unit and values of R^2 different from zero have also appeared in the table. For example, a tolerance value of 0.8535 and R^2 amounting to 0.1465 for the variable X_9 mean that 85.35% of the information brought in by this variable is not duplicated by the other two variables being already present in the model.

The presented results confirm the significant but equalized importance of all input variables in the model.

The results presented in Table 2 confirm that the variable X_{22} has the greatest influence on the discrimination of the variable X_2, and the distances of subsequent variables from one another differ distinctly. The variables X_9, X_{17}, and X_{20} remain strong determinants, while the others, despite their significance, have a much smaller weight. Of the two functions proposed at the beginning, the first one was

Table 1 Characteristics of variables—a summary of the discriminant function analysis for the variable X_2

Var.	Wilks' lambda	Part. Wilks	Elim. F (4,21)	p level	Toler.	1-toler. (R-square)
Var22	0.6107	0.8842	18.5986	0.0000	0.8486	0.1514
Var9	0.5803	0.9306	10.5925	0.0000	0.8535	0.1465
Var10	0.5842	0.9243	11.6279	0.0000	0.9224	0.0776
Var17	0.5822	0.9275	11.1010	0.0000	0.9403	0.0597
Var20	0.5797	0.9314	10.4524	0.0000	0.8767	0.1233
Var13	0.5608	0.9628	5.4817	0.0046	0.9035	0.0965
Var7	0.5573	0.9690	4.5425	0.0114	0.8014	0.1986
Var18	0.5569	0.9696	4.4492	0.0125	0.9376	0.0624

Source Author's elaboration using the *STATISTICA 10.0* package

Table 2 Values of the standardized and raw discrimination function coefficients for the variable X_2

Variables	Standardized values		Raw values	
	First function	Second function	First function	Second function
Var22	0.5497	−0.3864	0.4954	−0.3482
Var9	0.4458	0.0216	0.3752	0.0182
Var10	−0.3296	−0.6603	−0.2202	−0.4410
Var17	0.4003	−0.3662	0.3731	−0.3414
Var20	0.4335	0.1254	0.3568	0.1032
Var13	−0.2783	0.3309	−0.1857	0.2208
Var7	0.2592	0.3602	0.2539	0.3528
Var18	0.2793	0.0750	0.1730	0.0464
Constant	–	–	1.8987	−0.0703
Eigenvalue	0.6921	0.0944	0.6921	0.0944
Accumulated proportion	0.8800	1.0000	0.8800	1.0000

Source Author's elaboration using the *STATISTICA 10.0* package

Table 3 Results of the significance test of discriminant variables for the variable X_2

	Eigenvalue	Canonical R	Wilks' lambda	Chi-square	df	p level
0	0.6921	0.6395	0.5400	177.1565	16	0.0000
1	0.0944	0.2937	0.9137	25.9399	7	0.0005

Source Author's elaboration using the *STATISTICA 10.0* package

chosen due to its distinctly highest eigenvalue. This is also confirmed by the chi-square test results, included in Table 3.

In Table 3, both functions are characterized by a suitably high significance.

Table 4 Numerical assessment of the proposed functions for the variable X_2

	First function	Second function
G_1:1	0.1967	1.1100
G_2:2	0.5208	−0.0381
G_3:3	−0.8993	−0.0191

Source Author's elaboration using the *STATISTICA 10.0* package

Table 5 Values of the coefficients of correlation (factor loadings) of the input variables with the discriminant variables for the variable X_2

Var.	First function	Second function
Var22	0.5760	−0.3453
Var9	0.4589	0.1550
Var10	−0.3097	−0.5888
Var17	0.2422	−0.3938
Var20	0.4489	0.1516
Var13	−0.0568	0.4524
Var7	0.1400	0.4226
Var18	0.1183	0.1248

Source Author's elaboration using the *STATISTICA 10.0* package

Table 6 Classification accuracy matrix for the assessment of enterprises for the variable X_2

	Percent	G_1:1	G_2:2	G_3:3
G_1:1	25.0000	2	4	2
G_2:2	86.6667	3	156	21
G_3:3	74.5283	0	27	79
Total	80.6122	5	187	102

Source Author's elaboration using the *STATISTICA 10.0* package

The successive columns of Table 4 obtained contain the mean values of discriminant variables for each enterprise type (with very good logistic servicing, good logistic servicing, poor logistic servicing, and very poor logistic servicing). The differences between the mean values of the discriminant variable for assessments are significantly greater, especially for the second and third categories. The first discriminant function distinguishes all assessments and does this in an ordered manner, while for the remaining ones, they are relatively close to one another or divided in an unintelligible manner. The mean value of the first discriminant function is not similar for any assessments.

According to Table 5, it can be stated that the variable X_2 represents primarily the discrimination values of the input value X_{22} (in the first model). In the second approach, the variable X_{10} would have been taken into account.

As follows from Table 6, in the case of the variable X_2, more than 80% of the enterprises have been correctly classified to the assessment scores. A quite good result was obtained for good scores; however, due to the moderate representation, the risk of failure is fairly high here. A much more satisfactory is the result for the poor group: an accuracy of 86.67%—this is a very numerous group. The totally negative scores, on the other hand, are characterized by relatively low accuracy.

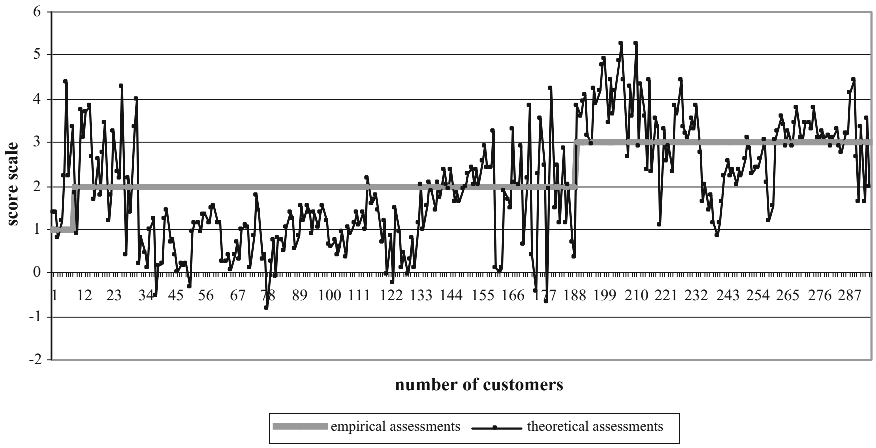

Fig. 1 Theoretical and empirical values determined for the variable X_2. *Source* Author's elaboration

Table 7 Classification accuracy matrix for the assessment of enterprises for the variable X_3

	Percent	G_1:1	G_2:2	G_3:3
G_1:1	32.1429	9	19	0
G_2:2	94.0367	5	205	8
G_3:3	16.6667	1	39	8
Total	75.5102	15	263	16

Source Author's elaboration using the *STATISTICA 10.0* package

This model has turned out to be quite restrictive. As many as 74.52% of positive assessments were accurate; on the other hand, only 25% were assessed incorrectly. Therefore, for the positive assessment, it can be stated that it is in the 3/4 of cases correct. In contrast, the definitely negative assessment, based on the indicated model, may not be binding.

The simulation (theoretical) values and empirical values determined for the variable X_2 are presented in Fig. 1. The estimated theoretical values are clearly more sensitive to the smallest fluctuations of input data. The first part of the plot—responsible for the worst scores—is the most diversified in terms of assessment, while the values of the second group (situated below the theoretical plot) show the best fitting.

In a similar way, the examination of the influence of independent variables on the remaining dependent variables was performed. The results are presented below.

The second of the presented discriminant functions indicates an influence of the independent variables on the third dependent variable, i.e., X_3—timeliness of the services of the transport enterprises examined.

According to the results in Table 7, using the second discriminant function, 75.5% of the enterprises have been correctly classified in respect of the known

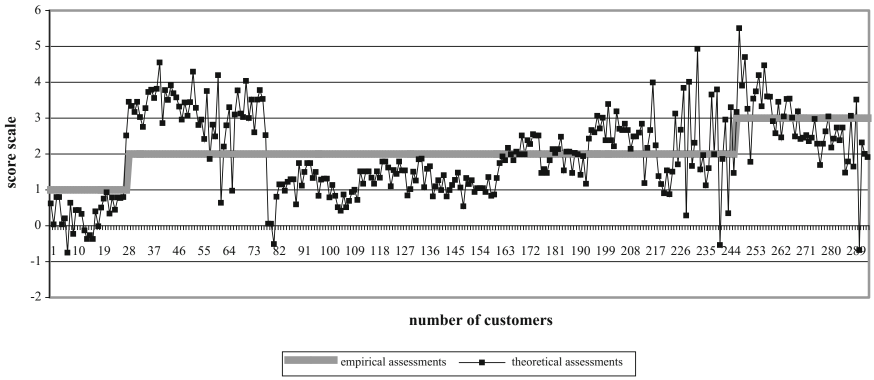

Fig. 2 Theoretical and empirical values determined for the variable X_3. *Source* Author's elaboration

Table 8 Classification accuracy matrix for the assessment of enterprises for the variable X_4

	Percent	G_1:1	G_2:2	G_3:3
G_1:1	40.0000	8	12	0
G_2:2	86.8932	5	179	22
G_3:3	41.1765	1	39	28
Total	73.1293	14	230	50

Source Author's elaboration using the *STATISTICA 10.0* package

assessment scores. The highest accuracy was achieved for enterprises assessed as poor (94.04%), which made up the largest group.

The simulation (theoretical) and empirical values determined for the variable X_3 are represented in Fig. 2. The presented plot highlights the observation groups being closer to the expected assessments (oscillating around a given assessment) and distinctly divergent (clearly distant from a given assessment). The scatter around the theoretical values shows more distinctly the diversity of the sample and the individual character of activities of particular entities. Despite some generalization of their doings—which has been done by defining the individual features—their intensity and different configurations have resulted in different assessments.

The third of the presented discriminant functions indicates an influence of the independent variables on the fourth dependent variable, i.e., X_4—correctness of the services of the transport enterprises examined.

As presented in Table 8, using the second discriminant function, 73.1% of the enterprises have been correctly classified in respect of the known assessment scores. The highest accuracy was achieved for enterprises assessed as poor (86.89%). This result is lower than that in the previous presentations; however, the accuracy in the two preceding categories exceeded 405 samples, thus improving the assessment of the whole function. The negative (poor and very poor) assessments are characterized by the total accuracy at a level above 90%. So, the model is optimistic, since

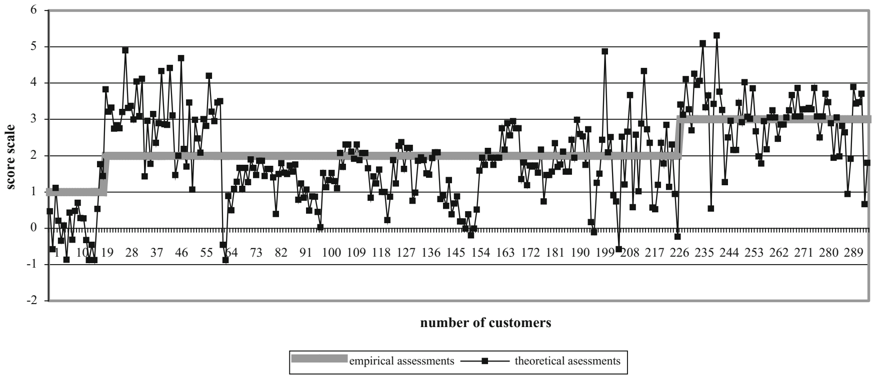

Fig. 3 Theoretical and empirical values determined for the variable X_4. *Source* Author's elaboration

Table 9 Classification accuracy matrix for the assessment of enterprises for the variable X_5

	Percent	G_1:1	G_2:2	G_3:3
G_1:1	44.4444	4	5	0
G_2:2	90.4110	7	198	14
G_3:3	40.9091	0	39	27
Total	77.8912	11	242	41

Source Author's elaboration using the *STATISTICA 10.0* package

the hitting of a negative score is highly probable, while a positive score is likely to be largely overestimated.

The simulation (theoretical) and empirical values determined for the variable X_4 are represented in Fig. 3. In the case of the variable, $X_{4,}$ in spite of good fitting, also visible in Fig. 3, deviations from the correct assessment were not avoided, after all. This is evidenced by the values less than 0 in the presented plot. Obviously, some of the positive values are wrong, too, but the size of the mistake is much smaller. Perhaps, several repetitions of this type of survey (e.g., on a larger group of customers) would have provided better fitting of the discriminant function.

The fourth of the presented discriminant functions indicates an influence of the independent variables on the fifth dependent variable, i.e., X_4—completeness of the services of the transport enterprises examined.

As Table 9 shows, using the discriminant function described here, 77.9% of the enterprises have been correctly classified in respect of the known assessment scores. This is a result slightly better than the previous ones, as can be seen in both the second group of scores (an accuracy of 90.4%) and the first group (an accuracy of 44.4%). The highest accuracy was achieved for enterprises assessed negatively (93.9%), so the results qualify the function as optimistic.

The simulation (theoretical) and empirical values determined for the variable X_5 are represented in Fig. 4. The next graphical illustration indicates a fairly high level of fitting of the discrimination results to the actual results. The function treating the

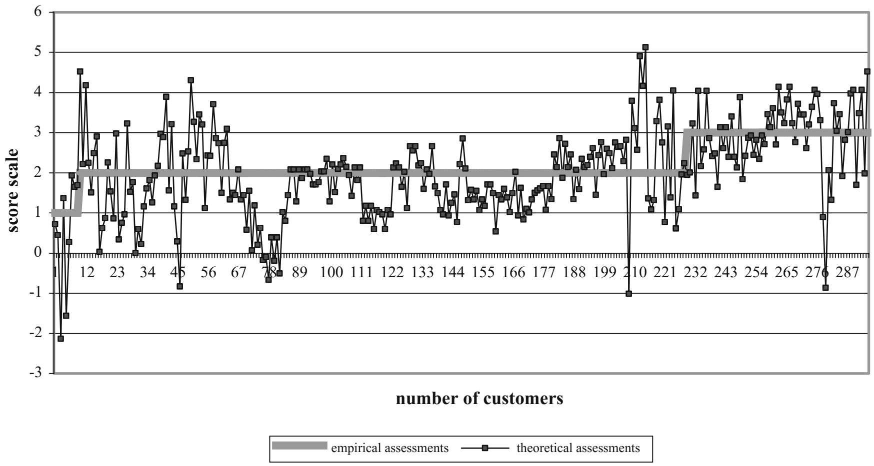

Fig. 4 Theoretical and empirical values determined for the variable X_5. *Source* Author's elaboration

Table 10 Classification accuracy matrix for the assessment of enterprises for the variable X_6

	Percent of hits	G_1:1	G_2:2	G_3:3	G_4:4
G_1:1	–	0	0	2	0
G_2:2	85.0267	0	159	26	2
G_3:3	28.1553	0	73	29	1
G_4:4	50.0000	0	1	0	1
Total	64.2857	0	233	57	4

Source Author's elaboration using the *STATISTICA 10.0* package

variable X_5 as a criterion seems, based on the illustration, to be one of the better in this presentation.

The fifth of the presented discriminant functions indicates an influence of the independent variables on the sixth dependent variable, i.e., X_6—promptness of delivery of the services of the transport enterprises examined.

According to Table 10, 64.3% of enterprises have been correctly classified into the assessment scores. The best results were obtained for poor scores, for which an accuracy of 85.03% occurs. Much less satisfactory is the result for the very good group—an accuracy of 50% (which is largely due to the small size of this group). The results for the very poor and good groups are even unsatisfactory. The indicated model seems to be one of the weaker from the proposed models.

The simulation (theoretical) and empirical values determined for the variable X_6 are shown in Fig. 5. The presented plot only confirms the results given in Table 10. The sequence of theoretical assessments for particular observations in each fragment of the plot, sometimes distinctly and, what is worse, in a multidirectional manner, deviates from the actual assessments. So, with the data resources

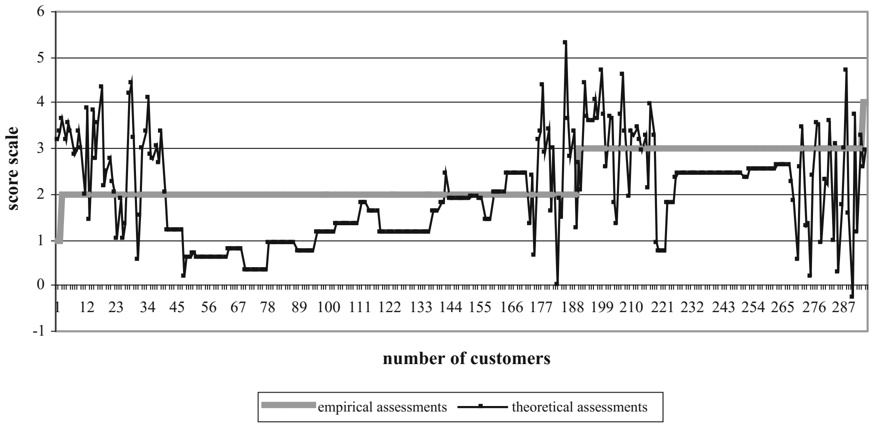

Fig. 5 Theoretical and empirical values determined for the variable X_6. *Source* Author's elaboration

Table 11 Classification accuracy matrix for the assessment of enterprises for the variable X_{14}

	Percent	G_1:0	G_2:1	G_3:2
G_1:0	66.6667	6	1	2
G_2:1	93.6759	3	237	13
G_3:2	53.1250	2	13	17
Total	88.4354	11	251	32

Source Author's elaboration using the *STATISTICA 10.0* package

possessed, the variable X_6 should not constitute the tool for the assessment of entrepreneurs' behavior.

The sixth of the presented discriminant functions indicates an influence of the independent variables on the third dependent variable, i.e., X_{14}—technological advancement of the fleet of the transport enterprises examined.

The function presented in Table 11 appears to be the best of the ones presented so far. The accuracy of its assessments is as high as 88.44%. In any of the groups, the accuracy of its assessments exceeds 50%, and for the enterprises scored as poor, it amounts to as much as 93.68%.

The simulation (theoretical) and empirical values determined for the variable X_{14} are shown in Fig. 6. When looking at the plot, one may get an impression that its good fitting is largely owing to the stretching of the scores of the second category in the empirical results.

The results of all the six prepared discriminant models for six independent variables are summarized in Table 12, indicating the frequency of occurrence of the independent variables in these models.

In Table 12, the "+" sign indicates the occurrence of individual independent variables in the discriminant models discussed earlier, reflecting these variables being considered in the discrimination of the dependent variables displayed.

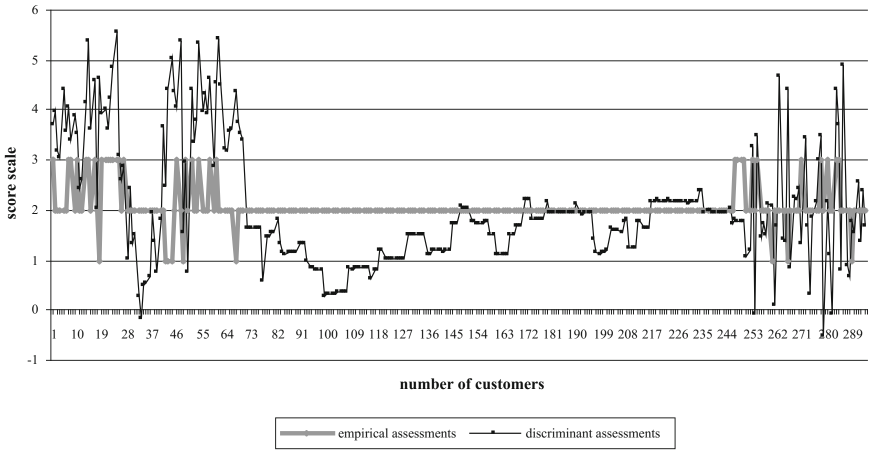

Fig. 6 Theoretical and empirical values determined for the variable X_{14}. *Source* Author's elaboration

Table 12 Frequency of occurrence of individual variables in the discriminant models examined

Independent variables	Dependent variables						Frequency
	X_2	X_3	X_4	X_5	X_6	X_{14}	
X_1	–	–	–	+	+	+	3
X_7	+	–	+	+	–	+	4
X_8	–	+	+	+	–	–	3
X_9	+	+	+	+	–	–	4
X_{10}	+	–	+	–	–	–	2
X_{11}	–	–	–	–	–	–	–
X_{12}	–	–	–	–	–	+	1
X_{13}	+	–	–	+	+	+	4
X_{15}	–	–	+	–	–	+	2
X_{16}	–	–	–	+	–	–	1
X_{17}	+	+	+	–	–	+	4
X_{18}	+	–	–	–	–	–	1
X_{19}	–	–	–	+	–	–	1
X_{20}	+	+	–	+	+	+	5
X_{21}	–	–	–	–	–	–	–
X_{22}	+	+	+	+	+	+	6

Source Author's elaboration

The "–" sign indicates the fact of individual independent variables not being considered in the discrimination of the dependent variables. On the basis of the results in Table 12 and the power of action of the indicated independent variables on the dependent variables, as observed on the presented models, the following conclusions have been drawn.

Conclusions

The most frequent influence on the dependent variable is exhibited by the independent variable X_{22}, i.e., the reliability of the logistic consultancy. This determinant, as the only one, occurred in all of the estimated equations, and what is more, in four out of the six, it was the strongest in the group. The significance of the reliability of the logistic consultancy is, therefore, in the light of the performed examination, prominent, especially for the availability (X_2), timeliness (X_3), correctness (X_4) and the promptness (X_6) of services in the perception of the recipients of the commercial cargo motor transport enterprises' services.

Not much lower frequency of occurrence in the presented discriminant models was noted for the independent variable X_{20}, that is, the competencies and expertise of the logistic consultancy of the transport enterprises examined. Considering X_{20} in the discrimination of all dependent variables, except for X_4, i.e., the correctness of services, constitutes a reinforcement of the weight of logistic consultancy quality for the service recipients, especially in the sphere of the availability (X_2), timeliness (X_3), completeness (X_5), the promptness of delivery (X_6) of the services, and the technological advancement of the fleet (X_{14}) of the transport enterprises examined.

A relatively high frequency of occurrence in the estimated discriminant models was shown by the variables: X_7—extensiveness of the services, X_9—protection of the terminal in the entities examined, X_{13}—meeting the environmental requirements by the infrastructure, and X_{17}—claims and complaints, which were four times considered in the discrimination of the displayed dependent variables. Considering the demonstrated power of action of the independent variables on the dependent variables, particularly great significance was ascribed to the independent variable X_9. This category not only occurred frequently in the examination, namely 4 times, but also was placed second or third in terms of its influence on the availability, timeliness, correctness, and completeness of the services offered by the entities under examination. A similarly high position was achieved by the independent variable X_1, i.e., inquiry response time, which influenced chiefly the timeliness, promptness of delivery, and completeness of services. The customers appreciate also the geographic coverage of the services offered (the independent variable X_8), most strongly influencing the timeliness, correctness, and completeness of the services.

At the same time, no statistically significant importance of the independent variable X_{11}, i.e., the range of the infrastructure equipment, and the independent variable X_{21}, i.e., the flexibility of the logistic consultancy, for the dependent variables discussed was found in any of the models. These categories do not play, therefore, any significant role in shaping the most important elements of logistic customer services in the perception of the recipients of the examined entities' services. Not much more significant importance for the dependent variables is shown by the independent variables: X_{12}—informatization of the infrastructure, X_{18}—monitoring of services, and X_{19}—round-the-clock servicing. These variables only occurred in one equation, thus playing a marginal role. Similarly, in one model, the independent variable X_{16} occurred, indicating the importance of meeting the environmental requirements by the fleet of the entities examined, but its role in exerting influence of the dependent variable X_5, i.e., the completeness of services, turned out to be the strongest.

Due to the small values of the obtained statistical measures, all conclusions contained in this discussion are rather hypothetical in character, while the generalizations formulated on their basis can be regarded as interesting research propositions constituting premises for undertaking further basic research.

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Dynamic Optimization Model for Planning of Supply, Production, and Transportation of Perishable Product

Mykhaylo Postan and Ludmila Filina-Dawidowicz

Abstract In this article, the dynamic optimization model for planning of raw materials supply, production of perishable finished product, and its transportation to destinations is proposed. It is assumed that the additional investments intended for decreasing raw materials and finished perishable product's deterioration during its warehousing are provided. The above model is based on the Wagner–Whitin model in the inventory control theory and classical transportation problem. The objective was to maximize the total profit of supply chain over the given planning horizon. Two cases are considered in detail: (1) Demand at destinations is given and fixed and (2) demand is random with known probability densities.

Keywords Supply · Production · Transportation · Perishable finished product · Planning · Dynamic optimization · Control of deterioration

Introduction

During the last decade in the theory of logistics and its applications, the great attention was paid to the problem of perishable product flow control that was inspired by food production/transportation growth. Due to the importance of this problem, even special direction was formed in logistics, the so-called cold logistics which studies the warehousing/transportation problems of perishable items taking into account the special regimes of their storage [1–3].

Due to the report presented by the Food and Agriculture Organization (FAO) of the United Nations [4], roughly one-third of the food produced for human consumption in the world gets lost or wasted (approximately 1.3 billion tonnes every

M. Postan
Odessa National Maritime University, Odessa, Ukraine
e-mail: postan@ukr.net

L. Filina-Dawidowicz (✉)
West Pomeranian University of Technology, Szczecin, Poland
e-mail: lufilina@zut.edu.pl

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year). These processes are observed throughout all stages of the supply chain, from the initial production up to the final consumption. These losses are high both in industrialized and in developing countries. More than 40% of the food losses take place at post-harvest and processing levels in developing countries. In industrialized countries, the majority of food losses occur at retail and consumer levels (more than 40% of overall losses). The weight percentages of food production losses and waste for different regions and stages of supply chain for selected commodity groups are presented in Fig. 1.

It is well known that inventory control theory plays an important role in logistical applications. Indeed, integrated logistical management first of all is intended for the development of optimal supply plan, work in process, and production plans, as well as optimal transportation plans for perishable finished product delivery to destination. At the same time, the known models from inventory control theory cannot be applied to the "cold logistics" practices immediately. In many real situations arising in logistical management, it is needed to adopt and generalize the classical models of inventory control theory for the case of deterioration of

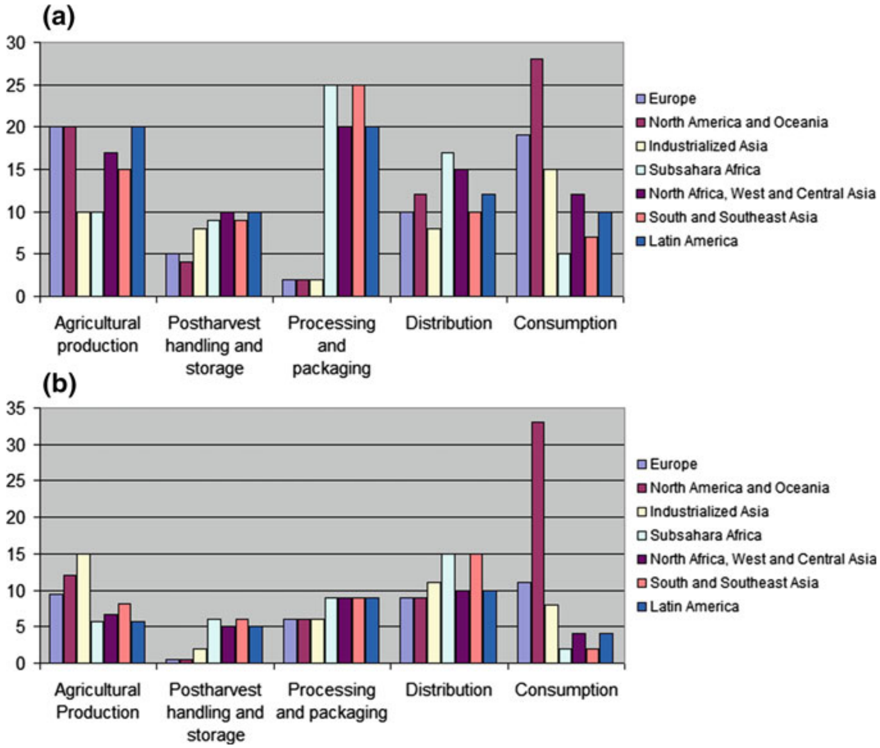

Fig. 1 The weight percentages of food production losses and waste in different world regions for selected commodity groups. *Source* Own elaboration on the basis of [4], where **a** Fruits and vegetables, **b** Fish and seafood

perishable materials and finished product under prolonged warehousing. Deterioration can deal with product spoilage, physical depletion, gradual loss of qualitative properties of materials with the passage of time, and above all storage conditions' changing [5, 6]. It is natural to suppose that the volume of perishable product deterioration depends on the technical characteristics of refrigerating equipment and corresponding cost directed to the supporting of special warehousing regimes.

In the studies [7–9], the simple models for optimal lot sizing of perishable product based on the generalization of the classical Wilson model were studied. However, in the cited works, the possibility of warehousing regime control was not considered. In the studies [10, 11], the models were proposed for optimal planning of integrated logistic chain functioning including supply of materials, manufacturing of perishable finished product, and its delivery at points of destination based on the generalization of the Wagner–Whitin model from the inventory control theory. The aim of this paper is to further develop this approach and proposal of dynamic optimization model for the case of perishable material and finished perishable product coming through the logistic chain taking into account the control of deterioration process at warehouses. This idea was firstly mentioned in our previous works [12, 13].

Description of Mathematical Model for the Case of Fixed Demand

Let us consider a plant that produces the K types of perishable finished product subjected to deterioration under storage at the plant's warehouse. To manufacture these products, the R kinds of material and complete set are used which are subjected to deterioration during their storage, as well. It is assumed that the matrix

$$A = \|a_{rk}\| \quad , k = 1, 2, \ldots, K; \; r = 1, 2, \ldots, R,$$

of technological coefficients is given, where a_{rk} is the amount of the rth kind of material needed for the manufacturing of the kth type of perishable finished product's unit.

A plant purchases all kinds of materials from the R suppliers. The finished perishable products must be shipped to the N destinations. The planning horizon is T (time is measured in discrete units). The total demand for the kth type of perishable finished product at the nth destination over the period T is known and is equal to $d_{kn} > 0$ (it may be determined, for example, in the result of market's analysis). Taking into account the given demand, plant purchases the materials and manufactures the products (Fig. 2).

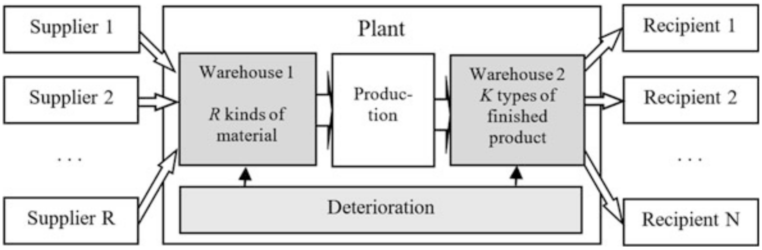

Fig. 2 The part of logistic chain of perishable product. *Source* Own research

In addition, we make the following assumptions:

- The market of materials is unlimited.
- All ordering of materials and delivering of finished perishable products occur at the start of each period. Inventories of materials are charged on the amount on hand in the end of each period.
- The lead time is zero; that is, an order arrives as soon as it is placed.
- The time of transportation of any amount of perishable finished product to any destination does not depend on this amount.
- The production equipment is absolutely reliable.
- The capacities of production lines of plant are limited only by the capacities of warehouses for the storage of materials and finished perishable products.

Similarly as in the article [10] for better understanding, we introduce the following designations:

- Let x_{rt} be the amount of the rth kind of material ordered and purchased in period t, for t = 1, 2,…, T.
- Let y_{kt} be the amount of the kth type of perishable finished product which plant plans for output in the end of period t, for t = 1, 2,…, T.
- Let z_{knt} be the amount of the kth type of perishable finished product planned for delivery to the nth destination in the end of period t, for t = 1, 2,…, T.
- Let s_{knt} be the sale unit price of the kth type of perishable finished product shipped to the nth destination in period t, for t = 1, 2,…, T.
- Let p_{rt} be the per-unit order cost and K_{rt} be the fixed order cost for the rth kind of material ordered in period t, for t = 1, 2,…, T.
- Let e_{kt} be the per-unit production cost of the kth type of perishable finished product in period t, for t = 1, 2,…, T.
- Let c_{knt} be the cost of transportation of the unit of the kth type of perishable finished product from the plant to the nth destination in period t, for t = 1, 2,…, T.
- Let $h_{1rt}(h_{2kt})$ be the holding cost per unit of the rth kind of material (of the kth type of perishable finished product) in period t, for t = 1, 2,…, T.
- Let C_1 (C_2) be the warehouse's capacity for the storage of materials (perishable finished products).

- Let $q_{1r}(q_{2k})$ be the initial inventory level of the rth kind of material (of the rth type of perishable finished product). It is assumed that

$$\sum_{r=1}^{R} q_{1r} \le C_1, \quad \sum_{k=1}^{K} q_{2k} \le C_2.$$

- Let $I_{1rt}(I_{2kt})$ be the inventory level of the rth kind of material (of the kth type of perishable finished product) in the end of period t, for t = 1, 2,…, T.
- Let $0 \le \beta_{1r}, \beta_{2k} \le 1$ be the coefficients describing the deterioration of the rth kind of material and the kth kind of perishable finished product during their storage at warehouses correspondingly.
- It is assumed that during the delivery of material to a plant and delivery of perishable finished product at destinations, they do not subject to any deterioration.

To avoid the trivial situations, we suppose that

$$\sum_{n=1}^{N} d_{kn} > q_{2k}, \quad k = 1, 2, \ldots, K.$$

It is obvious that the following inventory-balanced equations are valid:

$$I_{1rt} = (1 - \beta_{1r}) I_{1r,t-1} + x_{rt} - \sum_{k=1}^{K} a_{rk} y_{kt}, \quad r = 1, 2, \ldots, R, \tag{1}$$

$$I_{2kt} = (1 - \beta_{2k}) I_{2k,t-1} + y_{kt} - \sum_{n=1}^{N} z_{knj}, \quad k = 1, 2, \ldots, K; \; t = 1, 2, \ldots, T, \tag{2}$$

where $I_{1r0} = q_{1_r}, I_{2k0} = q_{2k}$.

From (1) and (2), it follows the relations

$$I_{1rt} = (1 - \beta_{1r})^t \left[q_{1r} + \sum_{j=1}^{t} \left(x_{rj} - \sum_{k=1}^{K} a_{rk} y_{kj} \right) / (1 - \beta_{1r})^{t-j} \right], \quad r = 1, 2, \ldots, R, \tag{3}$$

$$I_{2kt} = (1 - \beta_{2k})^t \left[q_{2k} + \sum_{j=1}^{t} \left(y_{kj} - \sum_{n=1}^{N} z_{knj} \right) / (1 - \beta_{2k})^{t-j} \right], \quad k = 1, 2, \ldots, K. \tag{4}$$

Since

$$\sum_{r=1}^{R} I_{1rt} \le C_1, \ \sum_{k=1}^{K} I_{2kt} \le C_2, \quad t = 1, 2, \ldots, T,$$

then from (3) and (4), we obtain

$$\sum_{r=1}^{R}(1-\beta_{1r})^t q_{1r} + \sum_{r=1}^{R}\sum_{j=1}^{t}(1-\beta_{1r})^{-j}x_{rj} - \sum_{j=1}^{t}\sum_{r=1}^{R}\sum_{k=1}^{K}(1-\beta_{1r})^{-j}a_{rk}y_{kj} \le C_1, \tag{5}$$

$$\sum_{k=1}^{K}(1-\beta_{2k})^t q_{2k} + \sum_{k=1}^{K}\sum_{j=1}^{t}(1-\beta_{2k})^{-j}y_{kj} - \sum_{k=1}^{K}\sum_{n=1}^{N}\sum_{j=1}^{t}(1-\beta_{2k})^{-j}z_{knj} \le C_2. \tag{6}$$

On the other hand, in period t, it cannot be consumed the rth material and delivered the kth product in amounts more than inventory levels $I_{1,r,t-1}$ and $I_{2,k,t-1}$ correspondingly in the end of period $t-1$, that is,

$$\sum_{k=1}^{K} a_{rk}y_{kt} \le I_{1r,t-1}, \quad r = 1, 2, \ldots, R,$$
$$\sum_{n=1}^{N} z_{knt} \le I_{2k,t-1}, \quad k = 1, 2, \ldots, K,$$

Therefore, from (5) and (6) we get

$$\begin{aligned}\sum_{k=1}^{K} a_{rk}y_{rt} + \sum_{j=1}^{t-1}\sum_{k=1}^{K} a_{rk}y_{kj}(1-\beta_{1r})^j &\le q_{1r}(1-\beta_{1r})^{t-1} \\ &+ \sum_{j=1}^{t-1} x_{rj}(1-\beta_{1r})^j, \quad r = 1, 2, \ldots, R,\end{aligned} \tag{7}$$

$$\begin{aligned}\sum_{n=1}^{N} z_{knt} + \sum_{j=1}^{t-1}\sum_{n=1}^{N} z_{knj}(1-\beta_{2k})^j &\le q_{2k}(1-\beta_{2k})^{t-1} \\ &+ \sum_{j=1}^{t-1} y_{kj}(1-\beta_{2k})^{t-1}, \quad k = 1, 2, \ldots, K; \ t = 1, 2, \ldots, T.\end{aligned} \tag{8}$$

At last, the perishable finished product of the kth kind must be delivered at the nth destination in amount d_{kn} over the planning horizon, that is,

$$\sum_{t=1}^{T} z_{knt} = d_{kn}, \quad n = 1,2,\ldots,N;\ k = 1,2,\ldots,K. \tag{9}$$

In the model described above, the coefficients of materials and finished perishable product deterioration β_{1r}, β_{2k} may be considered as control variables, as well. Indeed, generally speaking, they may depend on the power of refrigerating equipment of plant or, in value expression, on this equipment price. Denote V_1 and V_2 the values of refrigerating equipment at warehouses for material and finished product correspondingly. It is natural to suppose that $\beta_{1r}(V_1), \beta_{2k}(V_2)$ are the non-increasing functions of their variables satisfying the following conditions:

$$\begin{aligned} \beta_{1r}(\infty) = 0, \quad \beta_{2k}(\infty) = 0, \\ \beta_{1r}(0) = 1, \quad \beta_{2k}(0) = 1. \end{aligned} \tag{10}$$

The simplest dependencies of such kind, for example, are

$$\beta_{1r}(V_1) = \frac{\beta_{1r}}{(1+\mu_{1r}V_1)^{\alpha_r}}, \quad \beta_{2k}(V_2) = \frac{\beta_{2k}}{(1+\mu_{2k}V_2)^{\gamma_k}}, \tag{11}$$

where $\mu_{1r}, \mu_{2k}, \alpha_r, \gamma_k$ are the positive coefficients determined by the methods of mathematical statistics; β_{1r}, β_{2k} are the deteriorating coefficients reflecting the basic deterioration without additional cost for its reduction.

Note that according to the above designations, the expressions $p_{rt}\beta_{1r}I_{1rt}$ and $s_{knt}\beta_{2k}I_{2kt}$ give the meaning of economic losses caused by the deterioration of the rth kind of materials and the kth kind of finished perishable product during their storage in period t correspondingly.

Expression for the total profit of all integrated logistical chain (i.e., objective function) taking into account the cost for the control of refrigerating regimes is

$$\begin{aligned} P = \sum_{t=1}^{T} \Bigg\{ & \sum_{n=1}^{N} \sum_{k=1}^{K} p_{knt} z_{knt} \\ & - \sum_{k=1}^{K} \Bigg[e_{kt} y_{kt} + (h_{2kt} + s_{knt}\beta_{2k}) \big((1-\beta_{2k})^t q_{2k}. \\ & + \sum_{j=1}^{t} (1-\beta_{2k})^{-j} y_{kt} - \sum_{n=1}^{N} \sum_{j=1}^{t} (1-\beta_{2k})^{-j} z_{knj} \big) \Bigg] \\ & - \sum_{r=1}^{R} \Bigg[p_{rt} x_{rt} + K_{rt}\delta(x_{rt}) + (h_{1rt} + p_{rt}\beta_{1r}) \big((1-\beta_{1r})^{-j} q_{1r}. \\ & + \sum_{j=1}^{t} (1-\beta_{1r})^{-j} x_{rj} - \sum_{k=1}^{K} \sum_{j=1}^{t} (1-\beta_{2r})^{-j} a_{rk} y_{kt} \big) \Bigg] \Bigg\} - V_1 - V_2, \end{aligned} \tag{12}$$

where $p_{knt} = s_{knt} - c_{knt}; \delta(x) = 1,$ if $x > 0, \delta(0) = 0.$

The optimization problem may be now formulated by the following way: It is needed to find out the nonnegative values of variables $x_{rt}, y_{kt}, z_{knt}, V_1, V_2$, satisfying the conditions (5)–(9), (11) and maximizing the function (12). This optimization problem may be solved by the method of dynamic programming [14]. The other method of solving is based on the method proposed in the work [15]. This method allows us to eliminate from consideration the non-differentiable term $K_{rt}\delta(x_{rt})$ entering the function (12) by the introduction of additional variables.

Model with Random Demand for Finished Perishable Product

Given in Section "Description of Mathematical Model for the Case of Fixed Demand" model of optimal planning of supply, manufacturing and delivery of finished perishable product is based on supposition that total demand at each destination is known and fixed. It may be generalized for the case of random demand with the help of method proposed by Williams [16].

Let us assume that now $d_{kn}(\omega)$ are the continuous and mutually independent random variables with the given probability densities $\phi_{kn}(d)$. Put

$$u_{kn} = \sum_{t=1}^{T} z_{knt}, \tag{13}$$

where u_{kn} is the amount of finished perishable product of the kth kind planned for delivery at the nth destination before the realization of random demand $d_{kn}(\omega)$. After its realization, two cases may arise:

(a) $u_{kn} < d_{kn}(\omega)$,
that is, demand will not be met;

(b) $u_{kn} > d_{kn}(\omega)$,
that is, there will be necessity for the storage of perishable finished product of the kth kind surplus at the nth destination.

It is assumed that both types of risks belong to the final consumer of perishable finished product. In other words, we will suppose that all manufactured products are sold. Denote π_{kn} the penalty for the deficit of the kth kind of perishable finished product at the nth destination, and denote h_{3kn} the cost for the storage of the kth kind of perishable finished product's unit at the nth destination. Then, the average total profit of integrated logistic system over the planning horizon is

$$\overline{P} = P - \sum_{k=1}^{K} \sum_{n=1}^{N} \left\{ \pi_{kn} \int_{0}^{u_{kn}} (u_{kn} - w)\varphi_{kn}(w)\mathrm{d}w + h_{3kn} \int_{u_{kn}}^{\infty} (w - u_{kn})\varphi_{kn}(w)\mathrm{d}w \right\}, \quad (14)$$

where P is determined by the expression (12).

Thus, the nonlinear optimization problem should be formulated as follows: Maximize the function (14) under conditions (5)–(9), (11), (13), and taking into account the nonnegativity of all variables. This problem may be solved by the method of dynamic programming, as well.

Conclusions

In this chapter, we proposed the approach to modeling and optimization of integrated logistic system functioning for the case of perishable materials and finished perishable goods which are based on the inventory control theory application. The main idea of our approach is coordination among supply firm, plant, and transport companies at the stage of their joint plan development over the finite planning horizon. Our approach allows us to increase the total profit of logistic system due to additional expenses directed to the reduction of deterioration of perishable goods. The calculated results may be useful for logistic operators and other participants of logistic cold chain (e.g., warehouse operators and transport companies). The proposed optimization models are relatively simple and may be implemented in practice with the standard software. In order to make calculations, it is necessary to collect the relevant data and to create appropriate databases. The results obtained will be used as the basis for our further investigation and research in the field of "cold logistics."

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Grounds and Challenges for Implementing a Circular Economy in the European Road Transport Sector

Monika Paradowska

Abstract Environmental challenges, especially in the form of resource depletion, pollution and greenhouse gas emission, are very important challenges for the socio-economic development. For this reason, the concept of a circular economy has been developed and is being implemented in different areas. In 2015, the European Union adopted the Circular Economy Package consisting of an "EU Action Plan for the Circular Economy", presenting a set of actions aimed at achieving objectives of the circular economy in Europe. The goal of the paper is to describe and discuss key challenges facing implementation of the concept of the circular economy in the European road transport sector. First, the concept of a circular economy is explained. Then, the European Circular Economy Package is presented, and selected aspects of a circular economy in the transport sector are described. Current and planned actions in the transport sector are discussed in terms of their accuracy and efficiency for achieving a circular economy.

Keywords Circular economy · Circular economy package · Road transport sector

Introduction

The need for more sustainable development seems to be inevitable in the today's world [1, 2]. Overproduction and overconsumption based on linear business models (*take–make–waste* or *take–make–dispose*) [3] result mostly from striving to welfare and well-being and are one of the most important reasons for inefficient use of resources. This in turn causes depreciation of natural capital (including non-renewable resources) and reduced natural capital restoration. Negative socio-economic effects of such situation are more and more visible all over the world. For example, in the economic sphere, there are increasing demands for

M. Paradowska (✉)
Faculty of Economics, Chair of Economic Geography and Spatial Economics, University of Opole, Opole, Poland
e-mail: mparadowska@uni.opole.pl

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resources versus decreasing resource supply, as well as price volatility in some resource markets [4]. Lack of intervention in the "business-as-usual" scheme in the long term can lead to insufficient natural capital for sustaining human lives (freshwater, food, fresh air, etc.), especially in the face of predicted world population growth and increased consumption resulting from socio-economic development. On the other hand, an increasing problem is waste (over)generation. Direct and indirect costs of waste utilisation (e.g. landfills or waste incinerators), e.g. in the form of additional soil and air pollution or inefficient resource usage, are borne by whole societies and businesses [5]. In other words, though the linear model of production and consumption allowed many countries to achieve a high level of socio-economic development, welfare, well-being and happiness for their inhabitants, it causes many negative effects in environmental, social and economic spheres. Moreover, the consequences of a linear economy threaten our further development, as well as cause many distortions on markets, in social life and even in relations between countries and nations due to unequal access to different resources.

An answer to the above-mentioned problems is a circular economy, involving a new approach to the use of resource and requiring changes in behaviour of consumers and companies. The main aim of a circular economy is elimination of waste, by the way of inter alia efficient resource use and by keeping value in products as long as possible [5]. This paper elaborates key issues related to introducing a circular economy in the European road transport sector, with main focus on individual motorisation. The European Union, aware of the need for more efficient use of resources, as well as for reduction of waste, adopted in 2015 the Circular Economy Package consisting of an "EU Action Plan for the Circular Economy" [6]. Many actions impact the road transport sector, considered a "black sheep" in terms of generation of waste and negative externalities, which lead to a decrease in socio-economic welfare for current and future generations. First, the concept of a circular economy is explained. Then, the European Circular Economy Package is presented, and selected aspects of a circular economy in the transport sector are described. Current and planned actions in the transport sector are discussed in terms of their accuracy and efficiency for achieving a circular economy.

Developing Circular Economy in the European Union

The Concept of a Circular Economy

A circular economy is a pretty "new" concept, though it has arisen from existing ones, such as sustainable development and reverse logistics, and it is strictly related to their premises and assumptions. One can say that a circular economy is a way for (more) sustainable development in terms of resource use, environmental protection and a required change in people's behaviour towards sustainability. There is no one and commonly used definition of a circular economy, what results mainly from the fact that the concept is still being developed by different organisations, institutions, companies, etc., both in terms of theory and practice.

According to the European Commission, "[c]ircular economy systems keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has reached the end of its life, so that they can be productively used again and again and hence create further value" [5]. Similarly, the Ellen MacArthur Foundation underlines that "the circular economy aims to keep products and materials in use for as long as possible, recirculating them when necessary, aiming towards zero leakage from the system as waste. A key principle is 'tight circles'—recirculating products and materials with little change for fast return to productive use with minimal energy expenditure" [7].

To reach the goals of a circular economy, there should be focus on creating and sustaining value of a product in each phase of a life cycle, from the primary concept, design and raw materials extraction to recycling (see Fig. 1). The above-presented citations highlight key features of a circular product, namely the longevity (durability) and lack of waste after the last stage of a life cycle. The "tight cycles" mean that the best way is to reuse a product with a minimal input of energy and resources (this is presented as cascades in Fig. 2). The tightest cycle has the highest value, and the least tight cycle has the lowest value. These effects can be achieved in particular thanks to (see, e.g., [4, 8]):

- product maintenance (the tightest cycle),
- product reuse/redistribution,

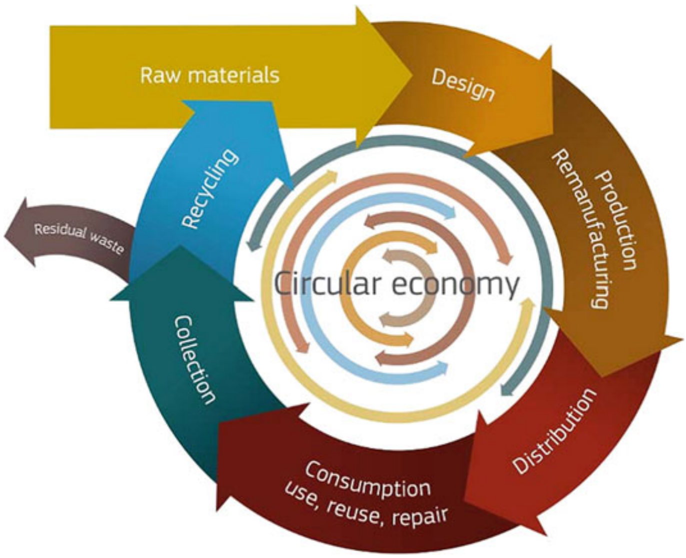

Fig. 1 Concept of the circular economy. *Source* [5]

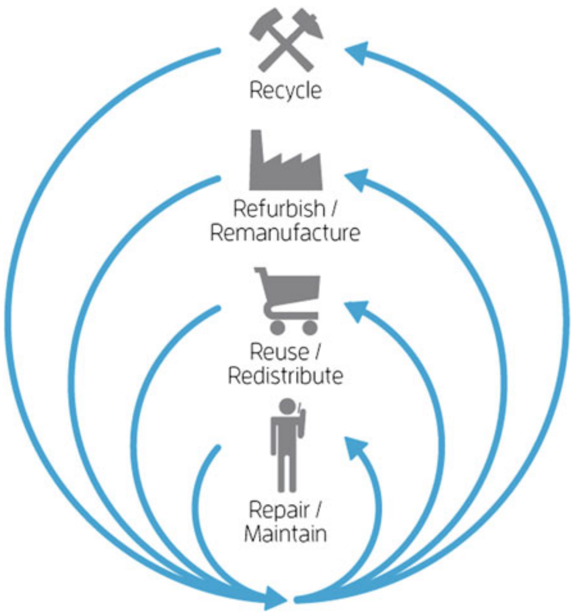

Fig. 2 Cycles of a circular product. *Source* Fairphone, https://www.fairphone.com/projects/circular-economy/

- product refurbishment/remanufacture,
- product recycling, and
- reprocessing of technical nutrients.

According to the Ellen MacArthur Foundation [4], there are three main principles of the circular economy to introduce: (i) "Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows—for example, replacing fossil fuels with renewable energy or returning nutrients to ecosystems"; (ii) "Optimise resource yields by circulating products, components, and materials in use at the highest utility at all times in both technical and biological cycles—for example, sharing or looping products and extending product lifetimes"; (iii) "Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use". On the other hand, Accenture [3] presents 5 core business models enabling an organisation to operate in a more circular way and to manufacture more circular products. The models were distinguished based on an analysis of over 120 case studies. They are briefly presented in Table 1 and Fig. 3.

The 5 models are to a large extent a continuation of models which have been already developed, e.g. within the concept of sustainable business or reverse logistics. Moreover, each of them enables to introduce circularity mostly in one or

Table 1 Five business models driving the circular economy

Business model	Brief description
Circular supplies	The model is based on supplying fully renewable, recyclable or biodegradable resource inputs that underpin circular production and consumption systems. It is most powerful for companies dealing with scarce commodities or ones with a major environmental footprint
Resource recovery	Recovery of embedded value at the end of one product life cycle to feed into another promotes return chains and transforms waste into value through innovative recycling and upcycling services. Solutions range from industrial symbiosis to integrated closed-loop recycling and Cradle-to-Cradle® designs where disposed products can be reprocessed into new. This model […] is a good fit for companies that produce large volumes of by-product or where waste material from products can be reclaimed and reprocessed cost effectively
Product life extension	The model allows companies to extend the lifecycle of products and assets. Values that would otherwise be lost through wasted materials are instead maintained or even improved by repairing, upgrading, remanufacturing or remarketing products. This model is appropriate for most capital-intensive B2B segments (such as industrial equipment) and B2C companies that serve markets where pre-owned products (or "recommerce") are common or whose new releases of a product typically generate only partial additional performance benefits for customers over the previous version
Sharing platforms	The model promotes a platform for collaboration among product users, either individuals or organisations. These facilitate the sharing of overcapacity or underutilisation, increasing productivity and user value creation. This model, which helps maximise utilisation, could benefit companies whose products and assets have a low utilisation or ownership rate
Product as a service	The model provides an alternative to the traditional model of "buy and own". Products are used by one or many customers through a lease or pay-for-use arrangement. This model would be attractive to companies whose products' cost of operation share is high and that have a skill advantage relative to their customers in managing maintenance of products

Source Adapted from Circular Advantage. Innovative Business Models and Technologies to Create Value in a World without Limits to Growth. Accenture (2014), pp. 13–14, https://www.accenture.com/us-en/insight-circular-advantage-innovative-business-models-value-growth.aspx

two phases of a product's life cycle. For this reason, a mixture of models, more innovative products and approaches, and involvement of each actor in supply chains would be required. The shift towards a circular economy can be considered and conducted more as an evolution, though the environmental and socio-economic challenges, contemporary technological progress and socio-economic development make it possible to implement some revolutionary solutions (see, e.g., [9]).

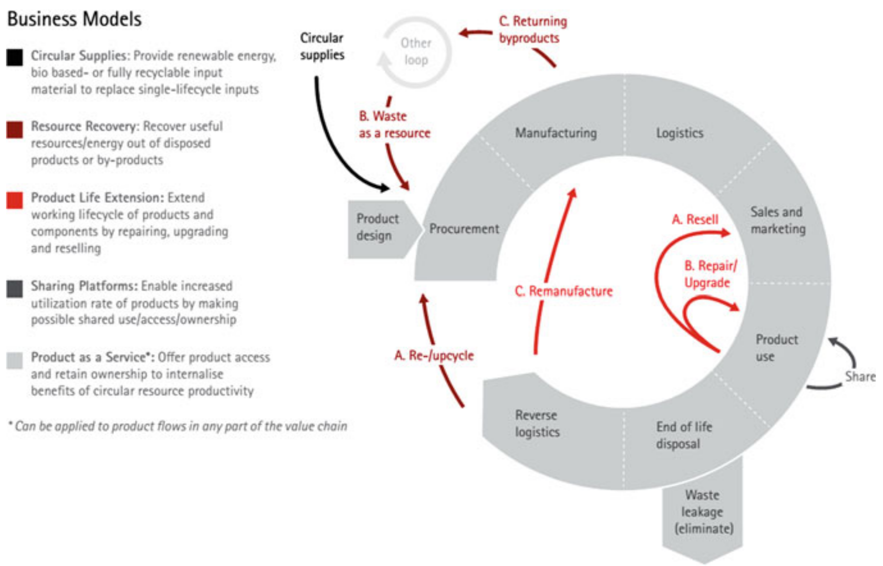

Fig. 3 5 business models driving the circular economy. *Source* [3, p. 12]

Introducing Circular Economy in the EU

For decades, the EU and its member countries have introduced law regulations to ensure a careful use of natural resources, to minimise adverse environmental impacts of production and consumption and to protect biodiversity and natural habitats. Though the beginning of the EU's environmental policy is dated for the early 1970s, the focus on developing a circular economy in Europe is a matter of the second decade of the twenty-first century, and it is strictly related to the Europe 2020 Strategy for smart, sustainable and inclusive growth [10] and related documents (especially the communication "A resource-efficient Europe—Flagship initiative under the Europe 2020 Strategy" from 2011 [11]). First meaningful document under the initiative of the "Circular Economy Strategy" was the communication "Towards a circular economy: a zero waste programme for Europe" [5, 12], adopted by the European Commission in July 2014 and accompanied by communications on sustainable buildings, green employment, SMEs and a legislative proposal for the review of waste legislation (see [13–16]). The Communication presented inter alia key reasons for developing a circular economy in Europe, examples of instruments addressed to different actors representing the supply- and demand-side, as well as suggestions for further, required actions and initiatives of the EU to boost circularity in Europe. It was a kind of a signal of intensification of works towards a Circular Economy Package and a framework for a substantive strategy aimed at transforming Europe into a more competitive, resource-efficient economy. What is worthy to mention is that in December 2014, the Commission decided to withdraw its legislative proposal on waste [16] and to start a new review process of the EU waste legislation. Effects of the review were presented in late 2015, together with the Circular Economy Package.

In May 2015, an indicative road map was provided by the EU [17], which was a working document including inter alia directions of required changes towards a circular economy in Europe. Moreover, it could be considered an open invitation to a discussion on building the Circular Economy Strategy in Europe, as the Commission launched a public consultation on the subject from the 28 May until the 20 August 2015 [18]. In the consultation process, an important event was a one-day Stakeholder Conference on Circular Economy “Closing the Loop—Circular Economy: boosting business, reducing waste”, which was held on 25 June 2015 in Brussels and attracted about 700 delegates.

Finally, the eagerly awaited Circular Economy Package was adopted by the Commission on 2 December 2015. The Package consists of an “EU Action Plan for the Circular Economy”, the annex to the action plan [19] and revised legislative proposals on waste [20]. The primary goals of a circular economy, in the form of improved resource efficiency, as well as reduced waste and pollution in the life cycle of a product, inspired the whole bundle of rules and initiatives indicated in the documents.

The action plan presents measures covering the whole life cycle of a product, including product design and production processes, consumption and waste management and the market for secondary raw materials and water reuse. A timetable with horizon to 2017 was drafted in the annex for specified actions in all these areas. Moreover, a timetable for sectorial actions (for food, waste food, critical raw materials, construction and demolition, biomass and bio-based materials, innovation and investments, as well as for monitoring) was planned as well.

Within the Circular Economy Package, the following legislative proposals on waste have been adopted [20]:

- Proposal for a Directive of the European Parliament and of the Council amending Directive 2008/98/EC on waste (COM/2015/0595 final—2015/0275 (COD)) with an annex,
- Proposal for a Directive of the European Parliament and of the Council amending Directive amending Directive 94/62/EC on packaging and packaging waste (COM/2015/0596 final—2015/0276 (COD)) with an annex,
- Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste (COM/2015/0594 final—2015/0274 (COD)),
- Proposal for a Directive of the European Parliament and of the Council amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators and 2012/19/EU on waste electrical and electronic equipment (COM/2015/0593 final—2015/0272 (COD)),

- Commission Staff Working Document—Additional analysis to complement the impact assessment SWD (2014) 208 supporting the review of EU waste management targets and
- Commission Staff Working Document—Implementation Plan.

In the revised legislative proposals on waste, clear targets were set, aimed at reduction of waste. Key elements of the revised waste proposals include [21]:

- "a common EU target for recycling 65% of municipal waste by 2030,
- a common EU target for recycling 75% of packaging waste by 2030,
- a binding landfill target to reduce landfill to maximum of 10% of all waste by 2030,
- a ban on landfilling of separately collected waste,
- promotion of economic instruments to discourage landfilling,
- simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU,
- concrete measures to promote reuse and stimulate industrial symbiosis—turning one industry's by-product into another industry's raw material and
- economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles)".

All actions foreseen in the Circular Economy Package are more or less connected with existing programmes, initiatives, documents and strategies in the EU. In addition, the transition to a circular economy has a strong and diverse funding base within the current EU's financial mechanisms. An important financial support will be provided by the European Structural and Investment Funds (ESIF), which includes 5.5 billion EUR for waste management. 650 million EUR will be provided under Horizon 2020, and many investments in the circular economy will be financed at national levels [22].

The EU expects many direct and indirect benefits from introducing a circular economy in Europe. Positive outcomes should be visible not only in environmental, but also in social and economic spheres. For example, according to different studies, a circular economy could lead to an 11% increase in European GDP by 2030 and an 27% increase by 2050, compared with 4 and 15% in the current development scenario [4]. Additional economic benefits could be, for example, incomes from new, "circular" technologies, additional value created by new, "circular" markets and savings resulting from lower prices of resources, lower costs of landfilling, more efficient use of resources, better energy efficiency, higher employment, reduced spending on preventing and mitigating pollution, etc. Multiple benefits and value added should be created in the long term for companies (see, e.g., [23, 24]). Job creation, including so-called green jobs in a circular economy, is considered a positive effect in both economic and social lives. In addition, social benefits embrace lower prices of consumer products resulting from cheaper resources, as well as reduced environmental pollution leading to a better quality of life (see, e.g., [25]). Moreover, a circular economy would support independence from imported resources for Europe. Now, the EU imports around 60% of consumed fossil fuels and metal resources [4].

Background of and Actions Towards a Circular Economy in the European Transport Sector

Reasons for Developing a Circular Economy in the Road Transport Sector

Road transport is currently the most attractive and popular mode of transport in Europe. According to EUROSTAT [26], in 2013, the share of road transport accounted for almost 50% of the total freight transport and for almost 72% of inland freight transport in the EU (in tkm). Modal split of passenger transport in the EU-28 was far more adverse in 2013 in terms of its possible negative environmental and socio-economic impact, with almost 82% share of passenger cars, 9.2% share of buses, 7.4% share of railways and 1.7% share of tram and metro (in pkm). Though the mobility sector in general and the automotive sector in particular are of great importance for growth and development in the EU[1] (see, e.g., [4]), and a lot of effort has been made to make this sector more sustainable, in the whole life cycle of motor vehicles, there are still a great share of resources used, including non-renewable resources, huge waste generation, emissions of greenhouse gases and pollutants and other negative effects. Some examples of reasons for developing a circular approach in the road transport are presented in Fig. 4 and in Table 2.

Examples presented in Table 2 provide a general overview of some problems related to production and usage of road vehicles, especially of passenger cars, in terms of a circular economy. In reality, a wider view should be taken. For example, road transport is strictly dependent on road infrastructure. Thus, actions towards a circular economy in road transportation should embrace, e.g. construction and maintenance of roads, parking space, and traffic lights as well. On the other hand, due to globalisation, different raw materials, car parts, etc., necessary to assemble a car are extracted and/or produced in different regions of the world and then transported to one place. Similarly, produced cars need to be distributed to retailers. All these transportation processes contribute to consumption of energy and resources and generate emissions. This paper considers a circular economy in the road transport sector only in a narrow sense.

[1]According to the European Automobile Manufacturers' Association—ACEA [27], some 12.1 million people (5.6% of the EU employed population) work in the automobile industry, including 3.1 million jobs in automotive manufacturing—10.4% of EU's manufacturing employment. Moreover, in the EU-15, motor vehicles account for 396 billion EUR in tax contribution. The sector annually invests 41.5 billion EUR in R&D in Europe, what makes it the largest private contributor to the development of knowledge and innovation.

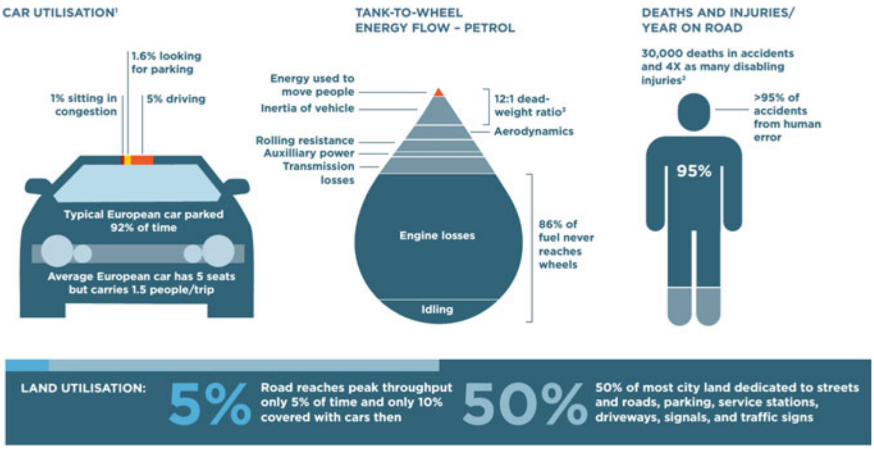

Fig. 4 Structural waste in the mobility system. *Source* [4, p. 19]

Actions Towards a Circular Economy in the Road Transport in the EU

First of all, developing a circular economy in the road transport requires numerous actions at different levels and in different areas. Changes seem to be necessary in consumer behaviour, in activities of companies (including shifts in production towards more "circular" products), in policies, technologies, etc. According to the MacArthur Foundation [4], there are six levers that could transform the contemporary European mobility systems (see Table 3). Cooperation between numerous stakeholders of more sustainable transport, including car producers, original equipment manufacturers (OEMs) and software providers, is expected to lead to an "integrated, automated, multimodal, on-demand mobility system", with sharing, electrification, automation, a materials evolution and the system-level integration of transport modes as key drivers for a circular economy [4].

The EU's actions towards a circular economy in the road transport sector have not been started by launching the Circular Economy Package. Since transition in the automobile sector is of great importance in terms of striving for (more) sustainable development and building a circular economy, the EU addressed some of related problems in earlier documents. Examples can be above-mentioned directives on waste and the Directive 2000/53/EC on end-of-life vehicles [35]. Though the concept of a circular economy has been developed dynamically for the last several years, the Directive 2000/53/EC is of great importance in terms of introducing basic assumptions of a circular economy in the automotive industry. It takes many aspects of circularity into consideration, and especially the following ones [36]:

- "Vehicle and equipment manufacturers must factor in the dismantling, reuse and recovery of the vehicles when designing and producing their products. They

Table 2 Examples of reasons for developing a circular economy in the road transport sector in Europe

Phase of the life cycle	Examples of challenges and reasons for the circular economy
Design	– Design of new road vehicles, especially passenger cars, is still determined not only by the need for improved resource efficiency and reduced emissions, but by features of demand and requirements of future users as well [28]. An example can be large vehicles used by inhabitants in cities or requirements for high-standard equipment in new cars. However, the attractiveness of large-engine cars has decreased, mostly due to governmental regulations in the EU member states (e.g. higher taxes and/or additional fees dependent on the size of engine) [29]
Raw materials extraction and production of road vehicles	– Car manufacturing requires numerous non-renewable resources, such as iron ore for steel, aluminium, petroleum (used in plastics production and for polyester for cloth seats and headliners), copper, platinum and palladium, rubber for tires, lead, nickel or lithium for batteries and many others for different car parts (see, e.g., [30, 31]). Producing new cars leads to an increase in demand for these resources, both from the primary (i.e. from mining) and secondary (i.e. from recycling) markets. For example, mobility (not just the road transport) is responsible for around 7% of resource consumption in Europe [30], and the automotive sector itself represents 8.5% of European demand for plastics [32] – Raw materials extraction and production processes contribute to emissions of greenhouse gases and pollutants. For example, according to TERM 2009 [33], 23% of CO_2 emissions generated during a life cycle of a passenger car results from the production of fuels and vehicles and from disposal of used vehicles – Energy is needed not only to run vehicles, but to manufacture different parts and to assemble a car. For example, according to UNESCO [31], it takes 20 000 MJ to produce one average passenger car
Use	– An average EU's citizen uses his/her car in a very inefficient way, because the car is parked for 92% of its lifetime, and only 1.5 from 5 available seats are used (see Fig. 4) [4] – Less than 20% of the energy from petroleum is used to keep a car moving [4, 31], and only 1/13 of that energy is used to transport people [4] – Road congestion is one of the most vital problems in many European cities. However, even in peak hours, cars cover only 5% of an average road in the EU [4] – On average, 50% of space in European cities is devoted to road infrastructure [4]

(continued)

Table 2 (continued)

Phase of the life cycle	Examples of challenges and reasons for the circular economy
Collection and recycling	– Extraction of many resources is still cheaper than collecting and recycling end-of-life vehicles (ELVs) in Europe [4] – Annually, there are around 8–9 million tonnes (Mt) of ELV waste generated in the EU [34] – The number of ELVs in Europe is increasing, from around 12.7 million in 2005 to around 14 million in 2014 [34] – Many old cars, which are close to the end of their lives, are being sold to the member states from Eastern Europe [29]

Source Own elaboration based on: Growth within: a circular economy vision for a competitive Europe. Ellen MacArthur Foundation (2015), http://www.ellenmacarthurfoundation.org/publications; Nilsson, M.: Paving the Road to Sustainable Transport: Governance and Innovation in Low-carbon Vehicles. Routledge (2012), p. 21; Passenger cars in the EU. EUROSTAT. Statistics explained (2015), http://ec.europa.eu/eurostat/statistics-explained/index.php/Passenger_cars_in_the_EU#Passenger_cars_with_small_petrol_engines_more_common_than_medium-sized_and_large_engines_in_the_majority_of_Member_States; Overconsumption? Our use of the world's natural resources. Sustainable Europe Research Institute (SERI), Austria and GLOBAL 2000 (Friends of the Earth Austria) (2009), p. 22, https://www.foe.co.uk/sites/default/files/downloads/overconsumption.pdf; UNESCO Module 1: Cars and energy. UNESCO education, http://portal.unesco.org/education/es/file_download.php/a01355752c9e869a63cc5651084cfa30Cars+and+energy.pdf; Plastics—the Facts 2014/2015. An analysis of European plastics production, demand and waste data. Plastics Europe (2015), p. 7, http://www.plasticseurope.org/documents/document/20150227150049-final_plastics_the_facts_2014_2015_260215.pdf; Towards a resource-efficient transport system—TERM 2009. EEA Report No. 2/2010. European Environmental Agency (EEA) (2010), http://www.eea.europa.eu/publications/towards-a-resource-efficient-transport-system; **Commission Staff Working Document "Ex-post evaluation of Five Waste Stream Directives Accompanying the document Proposal for a Directive of the European Parliament and of the Council reviewing the targets in Directives 2008/98/EC on waste, 94/62/EC on packaging and packaging waste, and 1999/31/EC on the landfill of waste, amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EC on waste electrical and electronic equipment" [**SWD(2014) 209 final**]**

have to ensure that new vehicles are: (i) reusable and/or recyclable to a minimum of 85% by weight per vehicle; (ii) reusable and/or recoverable to a minimum of 95% by weight per vehicle.

- They may not use hazardous substances such as lead, mercury, cadmium and hexavalent chromium.
- Manufacturers, importers and distributors, must provide systems to collect ELVs and, where technically feasible, used parts from repaired passenger cars.
- Owners of ELVs delivered for waste treatment receive a certificate of destruction. This is necessary to deregister the vehicle.

Table 3 Six levers at work in mobility

Lever	Examples of solutions
Regenerate	Regenerate and restore natural capital, e.g. by powering vehicles by renewable energy or reclaiming land used for transport infrastructure
Share	Keep product loop speed low and maximise product utilisation, e.g. by car-sharing and ride-sharing, reusing vehicles or by prolonging durability of vehicles and car parts, providing software upgrades, modularity/interchangeability or maintenance services for customers
Optimise	Optimise system performance, e.g. by increasing efficiency in the whole value chain or improving intelligent solutions in vehicles
Loop	Keep components and materials in closed loops and prioritise inner loops, e.g. by remanufacturing end-of-life products or by recycling
Virtualise	Deliver utility virtually, e.g. by developing technology of autonomous cars and direct virtualisation of materials, or by virtual travels (element of rationalising transport demand)
Exchange	Select resource input wisely, e.g. by direct (better performing materials) and indirect (new products, e.g. transport means and technologies) substitution of materials and resources

Source Growth within: a circular economy vision for a competitive Europe. Ellen MacArthur Foundation (2015), p. 55, http://www.ellenmacarthurfoundation.org/publications

- Producers meet all, or a significant part, of the costs involved in the delivery to a waste treatment centre. There is no expense for the vehicle's owner except rare cases where the engine is missing or the ELV is full of waste.
- Waste treatment centres must apply for a permit or register with the competent authorities.
- ELVs are first stripped before further treatment takes place. Hazardous materials and components are removed and separated. Attention is given to the potential reuse, recovery or recycling of the waste.
- The legislation applies to passenger vehicles and small trucks but not to big trucks, vintage vehicles and special use vehicles".

A significant breakthrough has been initiated by adopting the Strategy Europe 2020 in 2010 [10] and related documents, i.e. communications on a resource-efficient Europe [11, 37], and the White Paper "**Roadmap to a Single European Transport Area**" in 2011 [38]. While in the Strategy Europe 2020 the greatest pressure is put on "modernising and decarbonising transport sector" by the way of inter alia technological progress leading to an improved resource efficiency and reduced emissions of greenhouse gases and pollutants [10], the two other documents present some wider list of actions enabling realisation of goals of a circular economy in the road transport sector. For example, in the communication on a resource-efficient Europe, there is the need underlined for building "a vision for a low-carbon, resource-efficient, secure and competitive transport system by 2050 that removes all obstacles to the internal market for transport, promotes clean technologies and modernises transport networks" [11]. Problems of changes in behaviour of producers and consumers are raised in this document as well.

Moreover, it is assumed that an important tool is "getting prices right", i.e. making prices reflect all social costs of producing goods and providing services, inter alia in the transport sector. Reducing emissions by around 60% by 2050 in the transport sector is one of the priorities among environmental goals. Finally, in a possible "high-end variation" of development trends, a vision of "Successful transformation towards demand management, 'getting prices right' and accelerated technological innovation, enabling widespread electrification" by 2050 [11] in the transport sector is presented.

In the White Paper on Transport, analogous directions of actions are highlighted. According to the document, "transport has to use less and cleaner energy, better exploit a modern infrastructure and reduce its negative impact on the environment and key natural assets like water, land and ecosystems" [38]. Further development of technologies as well as "more sustainable behaviour" is indicated as key means to achieve this scenario. Though the White Paper includes a general action plan of changes in the transport sector, in reality there are no detailed actions towards a circular economy presented. Moreover, a significant focus is on different issues related to positive external effects of transport for the European society and economy and to other socio-economic aspects, such as safety in all transport modes, but especially in the road transport, security and quality of employment in transport, support for the European single market, and social cohesion or support for the economic growth within the EU. The meaning of the automotive industry for the competitive position and economic performance of the EU is stressed as well [38]. The White Paper was followed by the European transport technology strategy [39] adopted in 2012, focused on technology and innovations as main tools towards resource-efficient, low-emission and user-oriented integrated transport.

Both in the communication on a zero waste programme for Europe [5] and in the EU Action Plan for the Circular Economy [6], there are no detailed actions presented regarding the road transport sector, except for some examples of recycling waste from ELVs. However, solutions ensuring a shift towards more circular products and required behaviour of companies and consumers, which are included in the action plan, play a crucial role in terms of changes towards a circular economy in the road transport. Improved product design, enabling easy reparation, remanufacturing and then disassembling vehicles, aimed at better resource efficiency while producing and using vehicles, and at increasing share of materials recycled from ELVs, are expected to be a significant step in the transition to a circular economy. Moreover, in the annex to the action plan [19], there are planned actions listed which will have impact on the road transport sector, for example ecodesign work plan 2015–2017 aimed at developing ecodesign requirements on durability, reparability and recyclability of products, guidance for Best Available Techniques reference documents (BREFs), improving EMAS and developing the pilot programme on environmental technologies verification, action on Green Public Requirements, and developing quality standards for secondary raw materials, especially for plastics, some actions regarding critical raw materials and some other initiatives. It seems obvious that detailed actions in the road transport sector require involvement of different stakeholders, a systems approach and development of many tools, necessary, for example, to measure environmental impact of manufacturing and using vehicles, to change consumer behaviour or simply to make different actors in supply chains more engaged in a circular economy.

Similarly, the EU's proposals for new directives amending existing waste directives do not provide more detailed information on possible solutions in the road transport sector. For example, the only amendment suggested for the Directive 2000/53/EC on ELVs [35] regards resigning from reports that each member state was obliged to submit to the European Commission every three years. Instead of the reports, member states shall report data concerning the implementation of article 7 (1): "Member States shall take the necessary measures to encourage the reuse of components which are suitable for reuse, the recovery of components which cannot be reused and the giving of preference to recycling when environmentally viable, without prejudice to requirements regarding the safety of vehicles and environmental requirements such as air emissions and noise control" [35]. On the other hand, the proposal for a directive amending Directive 2008/98/EC on waste provides, for example, incentives to: the application of the waste hierarchy, minimum operating requirements for extended producer responsibility, Best Available Techniques reference documents and similar instruments for most industrial and extractive waste, an industry-oriented approach, and to taking by each member state appropriate measures to prevent waste generation and monitoring and assessing progress in the implementation of such measures [40]. Other directions of actions embrace, for example, development of infrastructure and appropriate tools for waste management, especially in "less advanced" member states, to reach the targets within the deadlines, as well as the development of monitoring and quality reporting [41]. Finally, there are different analytical tools suggested for an impact assessment of suggested changes in waste management [42].

Numerous actions and initiatives described in above-mentioned documents are planned to be supported, funded and/or conducted within existing European programmes and initiatives, for example under the Horizon 2020 work programme 2016–2017. It includes a key initiative "Industry 2020 in the circular economy" with over 650 million EUR for innovative demonstration projects aimed at reaching goals of a circular economy [5, 6].

Challenges for and Barriers to Implementing a Circular Economy in the European Road Transport

Due to huge amount of waste, inefficient resource use and economic and social costs related to waste utilisation resulting from ELVs, the EU adopted the Directive on ELVs in 2000. However, actions need to be taken in each phase of a life cycle of a vehicle. Though many of such actions have been developed by numerous stakeholders at different levels, one can say that the focus is more on different goals of sustainable transport development, such as reducing negative transport

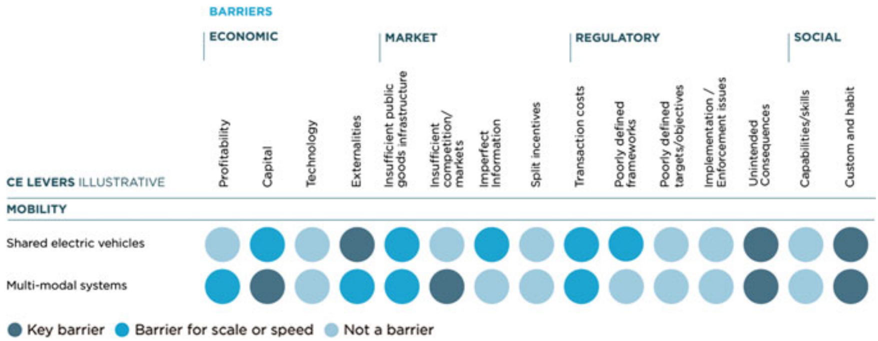

Fig. 5 Key barriers to the implementation of a circular economy in the mobility system. *Source* [4, p. 21]

externalities at local levels or CO_2 emissions in the European dimension, with little concern on coordinated policy towards a circular economy (see [42, 43]). This is because goals of sustainable transport development, though they seem to be the same in general, can differ depending on a stakeholder. Thus, hell-bent and purposive position of the EU to develop framework for a circular economy at the European level can be considered a necessary solution, if assumed objectives shall be realised. On the other hand, complexity of the road transport sector, interdependence and correlation between numerous actors and stakeholders in each phase of a vehicle life cycle create many different barriers and challenges while developing a circular economy, especially that these actors and stakeholders predominantly follow their own, split interests and goals. For this reason, a step towards a more advanced systems approach, involving all stakeholders [43], can be supported by the EU's actions, although many challenges, often even unpredicted, still exist. Figure 5 presents key barriers to implementing a circular economy in European mobility systems according to the MacArthur Foundation.

Though the model presented in Fig. 5 concerns two example solutions, i.e. electric cars and multimodal systems, it can be a basis for a wider discussion. According to the MacArthur Foundation [4], significant economic challenges for developing a circular economy in the European road transport sector regard capital needed to ensure changes, as well as unpriced externalities resulting from road transport. However, capital, externalities and profitability are considered barriers to scale or speed of changes as well. As different studies show (see, e.g., [4, 5, 37]), a circular economy provides economic, social and environmental benefits, and thus, it is a more profitable system than a linear business model. A question can be raised, why "traditional" linear business models are still so attractive both for producers and consumers, though they lead to wastage and losses of (environmental, social and economic) capital, and they are inefficient and uneconomical? An answer to this question is complex. First of all, in reality, the market mechanism, considered the most optimal system for the allocation of resources, does not provide enough incentives to improved resource efficiency based on a circular economy. At least, it has not provided enough incentives so far, because of easy accessibility of relatively cheap natural resources all over the world. This adverse phenomenon, as well as negative externalities, is the consequences of market failures and imperfections, which are supposed to be corrected by proper government policy. But, as experience shows, the government policy can be incorrect as well, and it can create, e.g., incentives for inefficient resource use or it can lead to an increase in externalities in the long term.

For instance, in a situation, when different resources used to manufacture a vehicle are cheap and easily available (e.g. they can be imported to the EU from all over the world), what is the incentive to improved resource efficiency? It can happen that car manufacturers strive to lower costs of production, and for this reason, they develop resource-efficient technologies. But in a typical market economy, that would probably happen in case of rather rare and expensive resources. In addition, in the today's globalised economies aimed at economic growth, the demand for non-renewable resources, including metals and petroleum, is increasing, what causes that supply of recycled resources is too low and people are still mining [44]. Moreover, not all recycled materials are cheaper than newly extracted resources. Recycled aluminium generates significant environmental and economic benefits and is cheaper than extracted aluminium, but, for example, it is still cheaper to produce some new petroleum-based, especially plastic, products than to use recycled plastics [45]. Economic profitability of recycling depends on many factors, such as availability of resources and costs of mining, differences between costs of landfilling versus costs of collecting and separating waste, what in turn depends on the level of development of required infrastructure, companies and institutions, etc. In other words, recycling needs its own developed market, and if incentives to creating such a market are weak, intervention of government is needed, what in turn usually requires an involvement of strong institutions [46]. For this reason, reaching the recycling targets set in the EU Circular Economy Package is considered difficult, particularly for less advanced member states [40]. And still, there are not always enough market incentives to recover materials from end-of-life vehicles. For this reason, the EU's regulations on waste from ELVs are of great importance for correcting the market. Similarly, the EU's plans of creating minimum operating requirements for extended producer responsibility and Best Available Techniques reference documents are expected to give incentives for producers to developed more resource-efficient technologies aimed not only at cost cuttings, but at required effects in each phase of a life cycle of a vehicle in terms of implementing a circular economy.

But what if there are government policy failures in terms of developing a circular economy? For example, a huge amount of European funds was spent on constructing road infrastructure in "new" member states that accessed the EU in 2004 and in later years. The main goal was to promote positive external effects of transport, e.g. to support the single European market, facilitate trade and improve the mobility of factors of production. Since in the EU-15 the road transport was responsible for the biggest share of freight and passenger transport, and the road infrastructure in the new member states was poor, these investments seemed to be reasonable. But, as a result, road transport became easier, more comfortable and attractive, what in turn led to increased demand for road vehicles, particularly for private cars. Moreover, *removal* of *administrative barriers to import cheaper used cars from Western Europe caused the problem of a large number of old vehicles and of ELVs in Eastern Europe, i.e. in these "less advanced" member states. According to EUROSTAT* [29]*, the biggest share of vehicles which are ten or more years old is in Lithuania (85%), Poland (75%), Latvia (72%) and Estonia (64%). For sure, after 15 years of membership in the EU, there is a visible improvement in the level of welfare in these countries, consisting, for example, of higher incomes for companies and households, better accessibility of different products and services or in increased motorisation rate.*[2] *What is interesting is that the number of authorised ELVs facilities in Estonia fell from 70 in 2005 to 32 in 2008 and in Poland from 670 in 2005 to 557 in 2007 (there are no data available for Lithuania and Latvia)* [47]. *In 2014, the EU took Poland to the EU Court of Justice because of insufficient law regulations and improper implementation of the EU's legislation on ELVs* [48]. *As it can be noticed, though the EU provides some legislative framework for a circular economy, lack of appropriate institutions, facilities, companies and regulations (i.e. a properly developed market) impedes implementation of some key solutions. It could be another argument in the discussion on the environmental quality as a luxury good and another example of Engel's law (see* [49]*).*

The above example of "shifting problems and responsibility on environment" [50] *from high developed to poorer countries, even if justified by market mechanism and striving for improved well-being and quality of life,*[3] *is not the only one. For instance, according to official statistics, in 2008 there were more than 892 thousands of used vehicles exported out of the EU, from which 33.4% were sold to Africa, 11.7% to Belarus, 9.9% to Russia and 8.7% to Kazakhstan* [47]. *The problem of used car markets in medium- or low-developed countries can cause difficulties with implementing a circular economy in the road transport sector not only within the EU, but at a supracontinental level as well. This, in turn, could lead to a situation, when a circular economy could be a kind of a club good for the European member states, without eliminating resource inefficiency and emissions in a global scale. In addition, it could lead to a further increase in inequities between rich and poor countries. This problem is strongly related to unpredicted and unintended consequences of different actions, like it was with the case of biofuels. Biofuels were expected to make the road transport sector more environmentally friendly, to boost the European economy as well as to make Europe less*

[2]In 2004–2013, the motorisation rate (number of cars per one thousand inhabitants) increased: in Lithuania from 392 to 615 (third position in the EU!), in Poland from 314 to 504, in Latvia from 305 to only 317 and in Estonia from 451 to 474 [29].

[3]In medium-developed countries in Eastern Europe, an own car is associated with a better quality of life, as it usually enables more comfortable possibilities of traveling than public transport (author's own unpublished study based on interviews with citizens from Poland, Lithuania, Ukraine and Czech Republic).

dependent on imported resources [51]. *However, it turned out that the global costs of stimulating supply and demand for biofuels for European cars were much higher than the benefits (see, e.g.,* [52, 53]*). Thus, potential current and future, direct and indirect costs and benefits of different actions aimed at a circular economy in the EU's road transport sector should be thoroughly investigated, in order to provide a reliable cost–benefit analysis. This task is very difficult (one can even say that it is impossible), because of the complexity of the road transport sector in Europe, its interrelations and relations to actors form the whole world due to globalisation.*

The European Automobile Manufacturers' Association (ACEA) underlines advantageous outcomes of vehicle producers' actions in terms of improved resource efficiency. For example, a wide variety of car parts is remanufactured, what enabled to use up to 80% less energy, 88% less water and more than 90% less chemicals when compared to new parts. In general, the overall waste generated while manufacturing cars has been reduced by 70% thanks to the circular approach. Other actions taken by automobile manufacturers in Europe embrace, for example, extending the lifetime of a vehicle, prolonging maintenance services for customers or improving fuel efficiency and reducing CO_2 emissions in order to reach some of goals of a circular economy in the use phase [54]. On the other hand, ACEA raises some doubts regarding the EU's directions of actions towards a circular economy. For example, it would be impossible to set a reporting obligation on resource use for all companies providing resources and car parts in value chains involved in manufacturing road vehicles in Europe, because the majority of these companies are located in different parts of the world, whereas establishing such an obligation only for European companies would seriously harm their competitive position due to additional administrative and bureaucratic burdens. Moreover, ACEA criticises the main indicator used to measure the resource productivity target[4] and argues that it cannot represent a holistic approach required in a circular economy. Finally, ACEA underlines that inter alia these actions suggested by the EU will probably lead to a deteriorated performance of European companies in the automotive industry, as it will be cheaper to import many resources [27]. One could ask, why there is a tendency at the EU level to implement different instruments aimed at changes in the behaviour of producers to achieve a circular economy, and less attention is paid to the consumer behaviour. Incentives for consumers in the use phase are often created and implemented by central governments (e.g. taxes related to buying and using a car) and by local authorities (e.g. parking policy and green zones). If consumers would pay a bigger share of costs resulting from the necessity of recycling ELVs,

[4]Gross domestic product divided by raw material consumption is considered by the EU the best available indicator for resource productivity, as it relates to all sectors in the economy and shows the amount of resources used and simultaneously the relative decoupling of gross domestic product from raw material consumption (see [55, 56]).

maybe there would be some economic incentives created to not buy and use a car. On the other hand, it could lead to some unintended effects. For example, higher costs could be paid by citizens in the "less advanced" countries, who often cannot afford new, more resource-efficient vehicles. Second, if people would pay more for a car due to the necessity of recycling it in the end-of-life phase, some of them could resign from the individual motorisation, what would be disadvantageous for the European automotive industry, with all negative socio-economic consequences of such situation. And finally, revenues from taxes and charges resulting from buying and using cars account for an essential share of budget revenues in some countries, both at local and at central levels.

Problems related to imperfect market mechanism and market failures, insufficient or inefficient government regulations as well as unintended consequences of some actions are of great importance in terms of consumer behaviour and the use phase of road vehicles. First of all, a circular economy requires not only a bigger share of recycled materials used while manufacturing a car or improved ecodesign aimed at, e.g., better resource efficiency while using it, but some basic changes in the way people use products as well. Car-sharing and a shift from "owning" to "using" cars are something more than required. However, since European cars are parked for 92% of the time [4], it seems obvious that rationality and profitability are not the main determinants of consumer behaviour among the majority of car drivers in the EU. Or, in other words, there are many other benefits of owning a car which are preferred to economic savings, resource efficiency or improved environmental quality. These benefits can be, for example, an immediate access to a car, a feeling of independence and privacy, etc. For example, 96% of the EU's citizens argue that there should be focus on a better use of resources in Europe, but only 21% have leased or rented a product instead of buying it, and only 27% have been involved in a sharing economy [4]. In this situation, a question could be asked whether the policy on pricing negative transport externalities would lead to required changes in the behaviour of car users or whether it would simply lead to an increase in tax revenues due to poor price elasticity of demand for private cars. However, as effects of some policy measures at local levels show, a shift is possible from private cars to public transportation, cycling and walking, if a set of integrated policy measures is developed and implemented (see, e.g., [57–59]). Thus, wouldn't it be better to resign from cars as the dominant transport mean and to use more environmentally friendly and resource-efficient transport modes and means? If properly planned and implemented, such a solution could result in a much better resource efficiency for Europe and it could lead to a significant reduction in emissions. However, due to the path dependence, it seems to be impossible, as the role of the automotive industry is too important for the European economy and for the society, and the road transport is considered the highest developed transport mode, generating, besides increasing negative externalities, numerous positive external effects for the socio-economic development.

Conclusion

The EU's Circular Economy Package seems to be an essential step towards more sustainable development, as the market mechanism does not provide enough incentives to an optimal and efficient use of resources, and due to externalities, pollution and greenhouse gases, emissions exist. An inter- and supranational approach to a circular economy in the road transport sector is likely to be more effective, because globalisation and internationalisation make domestic companies interrelated, and international, globalised supply chains predominant on the automotive market. However, there is hardly any chance that actions undertaken only in the EU member states would create a global approach, which would be the most appropriate for a transition to a real circular economy, based on effective use of resources, and elimination of waste and emissions in the whole life cycle of a vehicle. Moreover, it could lead to a situation that a circular economy in the road transport sector would become a kind of a club good for Europe.[5] On the other hand, there is a risk that due to non-exhaustive cost—benefit analyses and/or unintended consequences, some actions towards a circular economy in the road transportation could potentially lead to a deteriorated performance and decreased global competitiveness of European companies in the automotive sector and in related sectors.

Moreover, the EU has provided a very general framework for a circular economy so far, which needs to be developed at the European level and which requires—according to the principle of subsidiarity—development of national and local policies aimed at introducing a circular economy in the road transport sector. Since some member states with a very high share of old cars are still facing difficulties with the proper implementation of the directive on ELVs, there is a question whether all EU countries will be able to effectively implement some other laws and regulations on a circular economy. This relates especially to the use of vehicles. Regulations at the European level are likely to have expected impact on companies, but in many situations, local and/or national regulations are more effective and efficient in terms of required changes in consumer behaviour. And these changes are of great importance as well. At this point, it should be stated that a circular economy in the road transport sector, though certainly more sustainable than linear business models, raises some doubts on all-encompassing resource efficiency, reduction in waste and in emissions of pollutants and greenhouse gases. Even if the majority of people across the Europe would use more energy- and resource-efficient cars produced with cleaner technologies, it could be still more energy- and resource-consuming and would generate more pollution than, for example, travelling by public transport, cycling or walking. Thus, the question is not only about market imperfections causing negative externalities or inefficient use of resources, but on inefficient and non-optimal allocation of resources between different

[5]This is more likely for only some elements of a circular economy, because there are global supply chains in the European automotive industry.

transport modes, what puts further obstacles in the path to *sustainable development*, even if a circular economy in the road transport sector is implemented.

Due to the path dependence, Europe still follows a car-based pattern of people's mobility. A large share of the European society associates car with a better quality of life and with improved welfare and well-being. The automotive industry is crucial for employment, R&D and innovations in Europe, for the competitive advantage of the EU—simply: for the European economy. Nevertheless, actions towards a circular economy in the European road transport sector play an important role for improved resource efficiency and reduced emission. But a question can be raised whether we are on a right way while looking for complex and systems solutions aimed at sustainable development, especially in terms of possible unwanted and unintended consequences of actions within the policy on circular economy, which are difficult to predict.

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Promotion of Environmentally Friendly Transport Behaviour Using a Multicriterial Multimodal Trip Planner as a Means to Support Reduction of External Costs

Grzegorz Sierpiński

Abstract In this chapter, it has been proposed that a multimodal trip planner should be used to promote appropriate (i.e. environmentally friendly) transport-related behaviours reflected in the choice of travelling modes and routes which enable reduction of negative environmental effects of transport. The trip planner discussed in the paper is an outcome of works conducted under the international Green Travelling project implemented within the framework of the ERANET Transport III programme. The paper also provides an example of the GT Planner application which enabled comparing different routes in the aspect of time, distance and two environment-related parameters for three travelling modes (passenger car, public transport and the Park&Ride system). The testing ground used in the research was the area of Biscay (Basque Country, Spain).

Keywords Multimodal trip planner · Sustainable transport · Environmental costs · Climate change index · Disability-adjusted life year index · Transport modes · Green travelling

Introduction

As regards the matter of increasing the mobility of travellers, one may often observe intensifying problems connected not only with congestion, but also with other forms of negative environmental impact of transport, such as emission of harmful substances. These problems are particularly evident in dense transport networks. The negative impacts exerted by transport, whose effects are both social and

G. Sierpiński (✉)
Faculty of Transport, Silesian University of Technology, Katowice, Poland
e-mail: grzegorz.sierpinski@polsl.pl

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environmental in nature, form a particularly long list. As the automotive industry develops and the availability of passenger cars increases, the problems caused by limited capacity of transport networks also grow all around the world. Transport, including individual transport, is very land-consuming, whereas options of further expansion of the transport network, especially in heavily urbanised areas have practically been exhausted. Another negative transport-related phenomenon is the impact on natural environment through emission of harmful substances and noise. It is increasingly often that people choose the comfort of using one's own car which, apart from alienation, contributes to ineffective utilisation of urban space. While travelling to work or school on everyday basis, it is typical that only the driver uses the given passenger car.

Reduction of external costs of transport (including its environmental and social impact) is one of the challenges with which the institutions responsible for developing the twenty-first century transport systems are faced. Changes in this respect are possible through various undertakings. Seeking solutions to the above problems, on account of their complex nature, requires application of diversified remedial actions. In line with the EU guidelines (including [1]), all such changes should follow the principles of sustainable development. As regards transport, the foregoing applies to actions targeting the pursuit of balance in the modal split of transport, on the one hand, and on the other hand, strong emphasis is placed on the development of technologies reducing the negative environmental impact of transport as well as on the necessity of limiting energy consumption [2, 3]. In this respect, one may refer to numerous investment-related and organisational activities mainly aimed at promotion of travelling in a more eco-friendly manner (such as separating bus lanes, building biking routes, organising urban bicycle rental facilities, organising change points and P&R systems, introducing congestion fees and passenger car traffic-free zones.) (read more about this subject in e.g. [4–10]). Nevertheless, besides the foregoing, one must not disregard the activities intended to exert a direct impact on travellers' behaviours, such as promotion of desirable travelling forms (including [11, 12]).

The purpose of this article is to discuss the option of supporting the reduction of external costs of transport (in this case, part of environment-related costs) through application of a dedicated multimodal trip planner (GT Planner) developed as one of outcomes of the Green Travelling project implemented under the ERANET Transport III programme. The trip planner in question, besides the basic criteria applied to search for the quickest and the shortest route, has been enhanced with a number of complementary features, including the criteria directly reflected in the environment-related costs.

The article mainly concentrates on comparing characteristics of different travelling modes for an actual research area, highlighting the possibilities of reducing the negative impact of individual travelling on the environment. What has also been taken into consideration is multimodal travelling which may be planned using the tool in question.

Environmentally Friendly Transport and Multimodal Trip Planner

Changes in transport systems targeting reduction of emission of harmful substances and noise, and by that means also fostering more eco-friendly solutions, particularly with regard to urban areas, must not be limited to the "hard" (i.e. infrastructural) instruments only. Behaviours of travellers comprise a particularly important element in the process of appropriately shaping the future of transport systems. Therefore, education and broader understanding of the problem among travellers are so important.

With regard to transport, flow of information between the transport system and its users is of particular importance. The said flow should ensure that travellers' needs are appropriately defined and should support travelling persons in making decisions about the route and the forms of travelling. In the making of the travel-related choice, a transport system user defines such aspects as the given means of transport (alternatively a chain of transfers/several means of transport), the route, the travel commencement time as well as the points of start and destination. The support for making the foregoing choice is delivered through a multitude of increasingly popular trip planners.

An example of such solutions is GT Planner (Fig. 1) developed under implementation of an international project entitled "A platform to analyse and foster the use of Green Travelling options (GREEN_TRAVELLING)" co-financed under the ERANET Transport III Future Travelling programme. The institutions involved in the project represented three countries: Saitec, Factor CO_2 and DeustoTech from the Basque Country, the Silesian University of Technology from Poland and Mantis from Turkey. The aforementioned support is available through transfer of information about possible alternatives towards travellers' common behaviours (habits). People often travel in a specific manner, because they are not familiar enough with

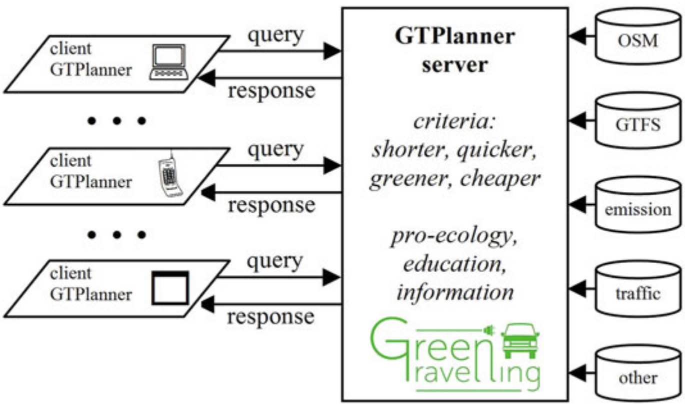

Fig. 1 Functional diagram of GT Planner. *Source* Own research

transport options offered by the municipality (convenient connections by means of public transport, travelling distances etc.). They are also unaware of the comparison between one's own car and public transport in terms of travelling times. As regards the latter aspect, support for a trip planning tool appears to be particularly important, since travellers can be educated through its practical application.

The planner discussed in the paper makes use of a number of databases (Fig. 1) offering such information as, for example the current status of the transport system (using open source maps—OSM), public transport timetables (to be elaborated in the next section), information about the current traffic situation in individual sections of the transport network and topographic features. As a part of the route planning functionality, four main criteria have been implemented, namely minimisation of travelling time, distance, costs and environmental impact. At the same time, 11 travel types (among others: walk only, bike only, electric car, walk and public transport, walk and urban bike rental, walk and urban car rental, walk and Park&Ride etc. [13]) as well as the "all" mode have been defined.

GT Planner may be used not only by travellers, but also (owing to yet another tool to be developed under the project in question) by local authorities for purposes of simulation of the impact exerted by the transport solutions being currently implemented on travellers' behaviours. A wider description of the tool as well as of the available travelling options including the additional parameterisation capability has been provided in [13, 14].

Environmental Costs and "Greener" Criteria of Travel Optimisation

Following the definition provided in [15], external costs are those which do not encumber the person who generates them, but others. The foregoing may be complemented with a statement that external costs of transport apply to a situation when the user does not cover all the costs (including those connected with natural environment, congestion and accidents) or does not receive all the related benefits [16]. External costs include, for instance, the aforementioned congestion costs, costs of accidents and selected costs linked with transport infrastructure [17]. The environmental costs are particularly important among the foregoing. Environmental effects constitute a large group of phenomena triggered by the negative impact exerted by transport on the environment. This group includes [18]: emission of all kinds of air polluting substances, climate changes, ecosystem transformations and noise. The reports being published usually follow a global perception of the problem by estimating the collective negative outcome of transport activities (although presented in a breakdown). These reports send a clear message to regional or local authorities, informing them about changes to environmental costs in time (in examples: [15, 19, 20]).

In this article, the individual aspect is the focal point, where it is the preparation of the information to be addressed directly to a traveller that matters particularly. It is assumed to trigger a change in the latter's travelling behaviour. There are numerous ready-made calculators supporting the process of estimating the negative effect of transport on the environment (e.g. [21–23]). Some of them are limited to determination of the CO_2 emission only, whereas other makes it possible to estimate the emission of further substances as well, including NO_x and SO_2. These calculators are limited in functionality on account of the necessity to specify the distance one is about to travel with the given means of transport [23] or to define the start and the destination point from a complete list [21]. As regards the estimation of the negative environmental impact of transport (in this case, individual travels), GT Planner is a combination of traditional emission-based calculators featuring a trip planning optimisation tool.

Originally, more than a dozen emission indicators were identified [24], including the ones most frequently mentioned in European and international publications (including in [1, 15, 25–27]): CO (Carbon monoxide), HC (Hydrocarbons), NO_x (Nitrogen oxide), PM (Particle matters), CO_2 (Carbon dioxide), Pb (Lead), SO_2 (Sulphur dioxide), CH_4 (Methane), Benzene, N_2O (Nitrous oxide), NH_3 (Ammonia), NO_2 (Nitrogen dioxide) and PN (Particle number), as well as FC (Fuel consumption) and WH (Energy consumption in the case of electric cars). Social surveys imply that a traveller will be more easily convinced to using eco-friendly means of transport by reporting the given result in a more discernible (comprehensible) unit of measure. On account of the clear social message the GT Planner being prepared under the project is assumed to deliver, a decision was ultimately made to identify two collective measures defining the impact of the given travel on the environment. For that purpose, dependences between the above emission indicators and final measures were established. The emission models built are based on the approach presented in HBEFA (Handbuch für Emissionsfaktoren) [28]. Consequently, it was decided that an indicator connected with climate change (CC), considered as a measure comprising global warming (in degrees Celsius) caused by emissions, as well as the disability-adjusted life year (DALY) should be applied [24]. The former reflects the environmental costs, and the latter the social ones. It should also be noted that GT Planner can be used for planning of individual travels, and therefore, the results obtained are currently not large values [expressed with a metric prefix *atto* meaning 10 * exp(−18)], still they make it possible to gradually change travellers' behaviours in small steps by increasing their awareness in this respect.

The impact results depend on five major parameters (1):

$$\mathrm{CC\ or\ DALY} = f(\mathrm{VT},\ \mathrm{RT},\ G,\ S,\ T) \tag{1}$$

where

VT—vehicle type, RT—road type, G—gradient [degree], S—speed [km/h], T—traffic.

A reference was made between the vehicle types (VT), for public transport, and the existing options classified under the OSM (Open Street Map) standard, and then, they were complemented with categories of vehicles used in individual travelling. The planner does not entail transport with lorries, since the Green Travelling project applies to passenger transport only. It should also be noted that bicycle and urban car rental systems as well as electric cars were taken into account in this respect.

Road types, similarly to vehicle types, are directly derived from those defined under the OSM (since GT Planner is assumed to be a universal tool making use of commonly available data as much as possible). Therefore, more than a dozen road types were included.

The gradient determines topographic features of the land, and it is estimated based on the information contained in such databases as the National Elevation Dataset [29] or the Shuttle Radar Topography Mission [30].

Another two parameters are related to speed with reference to organisational limitations, i.e. the permissible driving speed (*S*) and the traffic flow indicator (*T*), and are estimated based on the current average running speed of vehicles using individual sections of the transport network. Parameter *T* was limited to four options: free flow, heavy, saturated and stop and go [24].

Assuming that one can define set *R* of routes between the points of start and destination in the transport network for the given forms of travelling, where each route is described by numerous parameters, including those resulting from calculations performed in the planner (2):

$$R = \{r_i : r_i(t, d, c, \mathrm{CC}, \mathrm{DALY}), \quad i = 1, 2, \ldots, n\}, \tag{2}$$

where

t—total time, *d*—total distance, *c*—total cost, CC and DALY—coefficient as above.

The above concept proposed for calculating environmental and social costs has been implemented in GT Planner as one of optimisation criteria, where the objective function is to obtain minimum values of CC and DALY (depending on the chosen criterion) (3):

$$Z = \min_{\mathrm{CC\ or\ DALY}} (r_1, r_2, \ldots, r_n) \tag{3}$$

The planner client may choose whether the optimisation is to apply to CC or DALY. By application of algorithm *A**, GT Planner determines the most optimum travelling route for the chosen means of transport [14]. Finding the solution (i.e. establishing the optimum route) consists in searching though the transport network and the public transport system. The planner user may obtain (depending on the selected options) the following:

- One result for the chosen means of transport which, even if a passenger car has been chosen, translates into relevant reduction of the negative environmental impact of the travel.

- Multiple results, i.e. routes close to the optimum one for the chosen means of transport which makes it possible to compare several routes for the given means of transport and make a subjective choice of the most friendly one.
- Multiple results, i.e. routes close to the optimum one for multiple means of transport, which makes it possible to obtain a full set of information and a collation of environmental effects caused by individual travelling modes.

In the latter case, one should bear in mind that even choosing a "worse" solution than the optimum one will be more environmentally friendly than the travelling mode (route/means of transport) practiced so far. Some examples of such calculations have been provided in the next section.

Each time the planner returns a breakdown of results, four values are provided to characterise the given result (trip), i.e. time, distance, costs and CC or DALY. Besides delivering the foregoing information, every route is displayed with accuracy similar to that of navigation systems.

Case Study—Examples from Bilbao (Spain)

In order to demonstrate the functionality of GT Planner in terms of determination of environmental effects, Biscay (Basque Country, Spain) was chosen. This area is one of the testing grounds covered by the Green Travelling project (others being Silesian Voivodeship in Poland and Çankaya, Ankara in Turkey). It features an efficient transport system offering a multitude of public transport options (underground, tram, railway, buses) as well as bicycle rental services. One of the possible ways to integrate the transport system was to introduce a shared card enabling payments to be made when using every means of transport.

In the course of investigations, calculations were conducted for several set points of travel start and destination entailing the use of three forms of travelling: the car, the Park&Ride system and public transport. The analyses conducted under the research disregarded extremely eco-friendly travelling modes, such as walking and biking (using one's own or rented bicycle) on account of the length of routes. The travel start and destination points constituted centrodes for the transport districts defined within the territory of Biscay. Routes were set using four optimisation criteria (quicker—time minimisation, shorter—distance minimisation, greener—minimisation of environmental costs in two modes: CC minimisation and DALY minimisation). Since some of the results obtained depend directly on the date and time of the travel commencement (public transport timetable), the article has been limited to a single example for morning hours on a working day. It provides a travel report concerning the route connecting Santurtzi and Getxo. Values contained in Tables 1, 2 and 3 are, respectively, the ratio between the resulting parameters for the given route according to the given optimisation criterion and a travel made by following the *quicker* criterion. The reference to the quickest travel stems from the fact that travellers usually consider travelling time to be the most significant

Table 1 Ratio between results obtained for individual criteria and values of the "quicker" criterion—results obtained for a car travel

Trip parameter	"Shorter"	"Greener" for CC	"Greener" for DALY
Time	1.722	1.405	1.638
Distance	0.960	0.997	1.074
CC	1.063	0.887	0.925
DALY	0.861	0.851	0.727

Source Own research

Table 2 Ratio between results obtained for individual criteria and values of the "quicker" criterion—results obtained for travelling with public transport

Trip parameter	"Shorter"	"Greener" for CC	"Greener" for DALY
Time	1.009	1.719	1.108
Distance	0.734	0.829	1.230
CC	1.355	0.426	0.574
DALY	1.344	0.597	0.388

Source Own research

Table 3 Ratio between results obtained for individual criteria and values of the "quicker" criterion—results obtained for travel using the Park&Ride system

Trip parameter	"Shorter"	"Greener" for CC	"Greener" for DALY
Time	1.809	2.210	1.107
Distance	0.734	0.762	1.136
CC	1.295	0.390	0.596
DALY	1.423	0.381	0.120

Source Own research

measure of quality, and they often make a choice of both the means of transport and the course of the travelling route based on such grounds (according to [31] and own research).

When using a passenger car (Table 1), making a trip along the route defined as being 21.3% more eco-friendly (against parameter CC) lengthened the travelling time by ca. 40%. Such a difference may cause unwillingness to change the route among travellers. What would be required in this case is some additional actions discouraging travellers from choosing the quickest route (such as traffic organisation changes).

The public transport travelling option included the possibility of switching between different means of public transport (changing). When using public transport (Table 2) and the Park&Ride system (Table 3) for travelling purposes, lesser travelling time extension was observed for the parameter limiting criterion of DALY. The travelling time was only 11% longer. One could expect that such

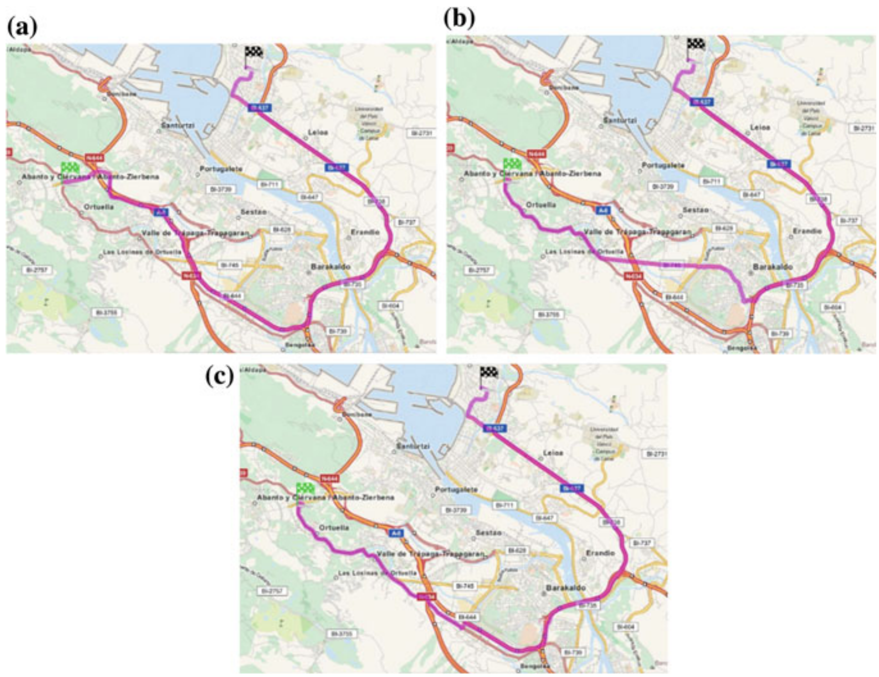

Fig. 2 Sample courses of routes established using GT Planner for a passenger car travel according to **a** criterion “quicker”; **b** criterion “shorter”; **c** criterion “greener” for parameter CC. *Source* Own research

alteration, when attained under conditions of wide promotion of eco-friendly transport, may trigger changes in travellers’ behaviours.

It should be added that the travelling forms taken into consideration, i.e. those entailing public transport, are also characterised by one more aspect contributing to reduction of external costs, namely limitation of area occupancy compared to multiple passenger cars running at the same time in a column.

Figure 2 shows sample routes set for the analysed points of travel start and destination. The courses of eco-friendly routes result from types of the variables affecting the result obtained for parameter CC or DALY.

For the case depicted in the above figure, the route change mainly involved the first half of the distance; however, it is exactly such changes that can be translated into significant differences in terms of individual route parameters (collations in Table 1).

Conclusions

Reduction of negative environmental impact of transport, including emission of harmful substances, requires technological and organisational changes. However, besides providing the society with specific solutions, it must also receive suitable information (through promotion of specific transport behaviours). The tool discussed in the article, i.e. GT Planner, may ensure support for this type of communication. Dedicated to travellers, it enables them to find a travelling mode and the route itself following numerous different criteria, and equally important, it offers the user a final ranking (filtering according to the given parameter) of results which makes it possible to find, for instance, a solution still acceptable in terms of time, but at the same time, one which reduces environmental costs.

On account of the multitude of variables defining the chosen environmental and social parameters (CC and DALY) as well as the traveller's subjective evaluations (including habits and customs), the problem of finding an optimum solution is one which features numerous criteria to be entailed and requires a comprehensive approach. In the course of further works to be conducted under the Green Travelling project, the GT Planner tool will be expanded with a module enabling simulation of the impact exerted by the deployed transport-related solutions on travellers' behaviours.

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