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IMPLEMENTATION OF THE MODEL OF PROECOLOGICAL TRANSPORT SYSTEM

Roland Jachimowski, Michał Kłodawski, Konrad Lewczuk
Emilian Szczepański, Mariusz Wasiak

Warsaw University of Technology
Faculty of Transport
Koszykowa Street 75, 00-662 Warsaw, Poland
tel.: +48 22 2347582, fax: +48 22 2347582
e-mail: rjach@wt.pw.edu.pl, mkloda@wt.pw.edu.pl, kle@wt.pw.edu.pl
eszczepanski@wt.pw.edu.pl, mwa@wt.pw.edu.pl

Abstract

Paper presents assumptions to build simulation model allowing computational experimentation and inference on impact of various factors on transport modal split and the impact that transport has on environment. It presents a general mathematical model of environmentally friendly transport system and characterizes particular elements of this model. The structure of transport network is mapped with a graph. The characteristics describing elements of this structure, vehicles, and characteristics of harmful compounds emission are given. Model will be implemented in PTV VISUM environment – a tool supporting planning of transport processes as well as analysis and designing of transport systems. The model of proecological transport system developed in PTV VISUM will consist of model of demand for both passenger and freight transport, and model of transport network cooperating with various means of transport. Road and rail vehicles for passenger and freight transport are characterized and divided into groups according to type of fuel and harmful emission. The demand for transport services and emission of exhaust gases components are reflected in model of proecological transport system of Poland. The last part of paper presents a sample of preliminary research on estimating emission from particular type of vehicle.

Keywords: *proecological transport system, transport, simulation, traffic modelling, emissions of harmful compounds of exhaust gases*

1. Introduction

Transport has a key role in economy, but has a destructive impact on environment to. It is necessary to look for opportunities to meet all transport needs with a minimal negative impact on the environment. Competitiveness of the economy forces taking into account technical, social and economic aspects of transport. It is necessary to find solutions minimizing environment degradation, and optimizing transportation costs under technical and technological limitations of different modes of transport. At the same time, it is extremely important to seek effective and efficient methods of reducing the impact of transport on the environment with an unchanged modal split.

Considering above, the EmiTranSys project contractors assumed as one of the objectives gaining a simulation tool that will allow carrying out computational experiments and inferencing about impact of various factors on modal split and environment. The tool will be potentially used to analyse a variety of scenarios of transportation needs and transport system development to predict the impact on the environment.

According to agreed research methods and disposed informatics tools, the mathematical model was developed and implemented into PTV VISUM environment. At this stage of research the implementation of a model of proecological transport system has not been completed, so some of the data are not yet fully verified.

2. The general characteristic of the model of proecological transport system

Developing environmentally friendly transport system requires the inclusion of relationship between the structure of transport network, its parameters, and the level of emissions of harmful exhaust compounds by road transport mostly. Thus, the model of proecological transport system (EST) of Poland is an expanded version of the model of Logistics System of Poland (see [2]) recognizing not only movement of goods and personal means of transport, but also aspects related to emission of exhaust harmful compounds by means of road transport. Confronting technical parameters of vehicles and road infrastructure with demand for transport services leads to gaining characteristics of traffic conditions, which are base to model emission levels, performance of transportation system and answer to ask "what if" questions for system development. To assess the impact of technological and organizational solutions determining level of harmful emission on investment expenditures and operational cost, it is necessary to take into account economic parameters of the vehicles and infrastructure.

The model of proecological transport system is then given as follows:

$$\mathbf{MEST} = \langle \boldsymbol{GE}, \boldsymbol{FE}, \boldsymbol{QE}, \boldsymbol{OE}, \boldsymbol{IE} \rangle \,, \tag{1}$$

where:

MEST – model of proecological transport system,
GE – structure of EST representing connections between its elements,
FE – set of characteristics representing real features of EST elements,
QE – transportation tasks performed by EST representing all material and passenger flows given as origin-destination matrixes,
OE – organization – the way of realizing transportation tasks by EST with regard to emission of harmful compounds of exhaust gases – apportion of material and passenger flows on transportation network,
IE – databases and information systems.

The structure of proecological transport system is modelled by a graph ***GE***:

$$\boldsymbol{GE} = \langle \boldsymbol{WE}, \boldsymbol{LE} \rangle \,. \tag{2}$$

Nodes ***WE*** of graph represent spatially extracted origin and destination points of material and passenger streams, and transition points where goods are handled and passengers serviced (i.e. loading points, logistics centres, intermodal terminals, stations). Therefore, the set of transportation nodes is defined as follows:

$$\boldsymbol{WE} = \{1,\ldots,a,\ldots,b,\ldots,i,\ldots,i',\ldots,WE\} \,, \tag{3}$$

where *WE* is a number of different transportation nodes in the system.

The set ***WE*** is divided into three subsets: the set of origins of material and passenger flows ***N***, the set of destinations of material and passenger flows ***O***, and set of intermediate (transition) points ***P***. Then, set ***W*** is will take a form:

$$\boldsymbol{WE} = \boldsymbol{N} \cup \boldsymbol{P} \cup \boldsymbol{O} \,, \tag{4}$$

where ***N***, ***P***, ***O*** are disjoint sets.

The elements of a set of graph edges ***LE*** reproduce existing rail and road links. It was assumed that $\boldsymbol{LE}^{p,ab}$ is a set of transport links belonging to the *p*-th path in relation (*a*, *b*), wherein $(a, b)\in\boldsymbol{E}$. Moreover $\boldsymbol{P}_{ii'}^{ab}$ is a set of paths in relation (*a*, *b*) passing the (*i*, *i'*)-th transport link.

A set of characteristics of EST elements ***FE*** provides specifications of particular point-wise system components servicing, generating or taking away material and passenger flows, as well as technical parameters of transport links, such as length (*i*, *i'*), section speed limits *v*(*i*, *i'*), flow capacities *q*(*i*, *i'*), and other technical parameters.

The size of transportation tasks is determined by a volume of material and passenger flows appearing in origin points and disappearing in destination points. It is described as a two-piece vector $\boldsymbol{QE}$:

$$\boldsymbol{QE} = [\mathbf{X1}, \mathbf{X2}]. \tag{5}$$

The first element $\mathbf{X1} = [x1(a, b)]$ is a matrix of freight transport demand, and second one $\mathbf{X2} = [x2(a, b)]$ is a matrix of passenger transport demand, where $a \in \boldsymbol{N}$, $b \in \boldsymbol{P}$, and pairs (a, b) belong to the set of transport relations $\boldsymbol{E}$. To model apportionment of material and passenger flows on the transport network the matrixes **X1** and **X2** must be decomposed into a matrixes containing requests for transport services in particular segments of demand. These segments are significantly different according to technological and organizational conditions of realizing (i.e. differences in transporting bulk materials – like ores, or transporting furniture as well as passengers to and from workplaces). Set of segments of demand for freight transport is described as $\boldsymbol{SPT}$, while set of segments of demand for passenger transport is described as $\boldsymbol{SPP}$. Both sets are defined as follows: $\boldsymbol{SPT} = \{1, 2, ..., spt, ..., SPT\}$, $\boldsymbol{SPP} = \{1, 2, ..., spp, ..., SPP\}$. The matrixes of request for transport services in particular segments are described as $\mathbf{X1}(spt) = [x1(a, b, spt)]$, and $\mathbf{X2}(spp) = [x2(a, b, spp)]$.

The set of types of means of transport is defined as $\boldsymbol{ST} = \{1, ..., st, \ldots, ST\}$. For each type of mean of transport, and for each demand segment, the maximum capacities of vehicles $qt(st, spt)$ and $qp(st, spp)$ are known. These capacities depend on maximum loading capacity $q_{max}(p(st))$, permissible loading capacity $q_{dop}(st)$, and cubic capacity $p(st)$, as well as parameters of transported goods characteristic for demand segments spt and spp, i.e. $qt(st, spt) = qt(st, q_{max}(st), q_{dop}(st), p(st), spt)$ and $qp(st, spp) = qp(st, q_{max}(st), q_{dop}(st), p(st), spp)$. Taking into account additionally the schedule of transportation tasks $x1(a, b, spt, t)$ and $x2(a, b, spp, t)$, the material and passenger flows can be converted into streams of vehicles $xt(a, b, sp)$ and $xp(a, b, sp)$.

The particular means of transport emit specific amounts of harmful compounds dependently on type of engine, EURO emission standard, and travel conditions during transportation (and in fact even outside this time). Set of types of harmful compounds of exhaust gases is described as $\boldsymbol{S} = \{1, ..., s, \ldots, S\}$. Defining two additional sets:

- $\boldsymbol{RSP} = \{1, 2, 3, 4, \ldots, rsp, \ldots, RSP\}$ – set of engine types,
- $\boldsymbol{NEU} = \{0, 1, 2, \ldots, neu, \ldots, NEU\}$ – numbers of EURO emission standards

allows finding the general functional dependences $em(s, st, neu, rsp, i, i')$ of the unit emissions. These dependences are functions of type of engine and vehicle, EURO standard, traffic conditions, and terrain (i.e. city area, mountainous area). Assuming that the structure of vehicles according to engine types and EURO standards is always known in given time, the $em(s, st, neu, rsp, i, i')$ can be approximated to $ema(s, st, i, i')$.

The influence of engine type, EURO standard and the length of travelled p-th path in transport relation (a, b) on emission levels is described by coefficients $\psi(s, st, neu, rsp, p, a, b)$. After approximation they take a form of $\psi a(s, st, p, a, b)$. When the model parameters are defined as above, the problem of developing proecological transport system is reduced to searching for the values of decision variables $xt(p, a, b, st)$ and $xp(p, a, b, st)$ constituting the numbers of st-th type vehicles performing transport tasks or moving through the network on p-th paths in relations (a, b).

Then the criteria function:

$$\forall s \in \boldsymbol{S} \quad \sum_{st \in \boldsymbol{ST}} \sum_{(i,i') \in \boldsymbol{LE}} \sum_{(a,b) \in \boldsymbol{E}} \sum_{p \in \boldsymbol{P}_{ii'}^{ab}} \left[xt(p,a,b,st) + xp(p,a,b,st) \right] \cdot \\ \cdot d(i,i') \cdot ema(s,st,i,i') \cdot \psi a(s,st,p,a,b) \longrightarrow \min \tag{6}$$

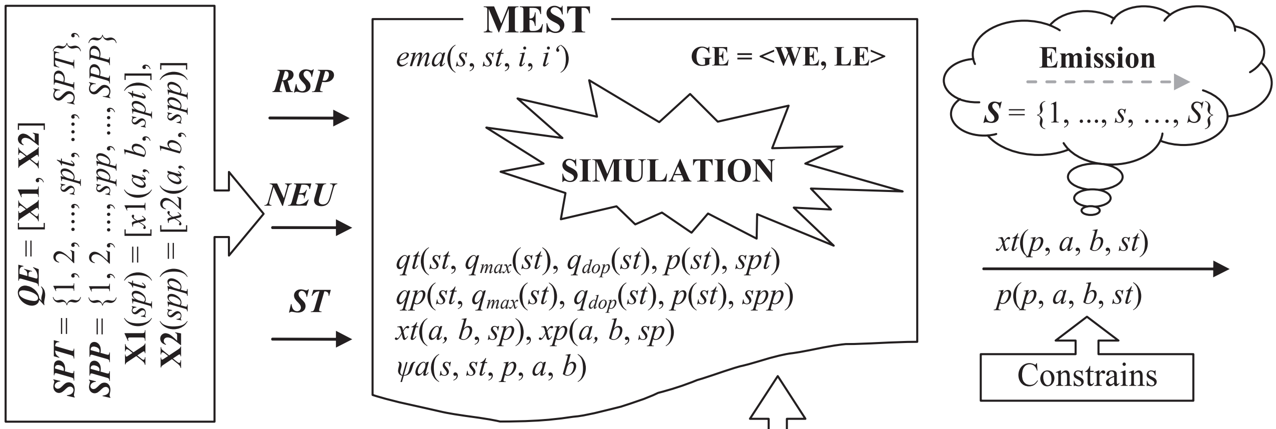
must be minimized.

Feasible solutions must keep the following constrains:

- all transport demand must be met,

– capacity of transport links (sections) can't be exceeded,
– material and passenger flows must be kept,
– area access restrictions according to environmental pollution can't be exceeded,
– acceptable levels of harmful compounds emission can't be exceeded,
– loading capacity and defined number of passengers per vehicle cannot be exceeded.

The simplified scheme of proecological transport system model is presented in Fig. 1.



$$\forall s \in \boldsymbol{S} \quad \sum_{st \in \boldsymbol{ST}} \sum_{(i,i') \in \boldsymbol{LE}} \sum_{(a,b) \in \boldsymbol{E}} \sum_{p \in \boldsymbol{P}_{ii'}^{ab}} \left[xt(p,a,b,st) + xp(p,a,b,st) \right] \cdot$$
$$\cdot\, d(i,i') \cdot ema(s,st,i,i') \cdot \psi a(s,st,p,a,b) \longrightarrow \min$$

Fig. 1. The scheme of the proecological transport system model MEST

3. Implementation of the proecological transport system model

3.1. Introduction to PTV VISUM environment

PTV VISUM is a tool supporting planning of transport processes as well as analysis and designing of different transport systems. By this tool planners can gradually improve their models (as suggested investment variants) and evaluate the quality of proposed solutions in refer to current state. The whole process aims in preparing a model to support decisions in real time [2].

Computer implementation bases on a model being a kind of simplified representation of the reality with all the important features of this reality identified and correlated to serve the purpose of modelling. In most cases the mathematical models are used as it was in presented problem. Model of EST identifies and correlates private and public means of transport, infrastructure, demand for transport services, and evaluation criteria to serve the purpose of finding environmental friendly solutions for transport system of Poland.

Model of proecological transport system developed in PTV VISUM will consist of demand model and network model (see [6]):

– *demand model* contains information about the passenger travel needs and the tasks for different modes of freight transport. The PTV VISUM estimates and models origin-destination matrices for homogeneous groups of passengers or types of freight. The model must include different motivations to travel in passenger segment and different types of cargo and shippers in freight segment,
– *network model* describes the availability of necessary means of transport. It consists of communication areas cumulating dispersed freight shippers or recipients, as well as residential areas for passenger transport. Areas are connected to the network nodes representing crossroads or stops and stations of public transport. Nodes are connected by segments representing roads and lines. If necessary, the specific public transport systems can be implemented by defining

lines with appropriate timetables and attributed vehicles. PTV VISUM provides advanced, user-friendly methods to enter and modify network data.

The results of calculations obtained in PTV VISUM can be represented graphically or in tables. This allows analysing routes and connections for pairs of origin and destination points, traffic, isochrones, and streams in the particular nodes. Indicators such as travel time, transit time, number of transfers, and frequency of service are calculated as a matrix of indicators.

3.2. The model of transport network of Poland

As already mentioned proposed model of transport system comprises the model of transport network. In case of the Polish transport system, the road transport has the largest share in goods movement (about 83%) and in passenger movement (about 66%). Second place, although with a much smaller share, has rail transport (about 13% of the transport of goods and about 32% of the transport of passengers). The other modes such as air or inland transport have negligible share in the whole volume of moved passenger's and goods [8]. For air transport, this is mainly due to the high cost of transportation, and for the inland transport it is because of poorly developed network of waterways and lack of infrastructure enabling material handling.

The infrastructure is crucial for meeting transport needs in passenger and cargo segments. From the other hand the scale of model restricts included elements of infrastructure. According to that, the model of environmentally friendly transport system of Poland embraces national and regional roads, and important railway lines for freight and passenger transport. Accordingly, the computer implementation of the model will take into account information about actual course of those roads and lines, as well as their basic technological characteristics. Additionally the above elements must be included into model:

– transportation nodes located in the network (i.e. cross-roads, road and rail stops and stations, loading points, terminals, points where infrastructure characteristics are changed),
– areas representing areas of special land use and determining their position in relation to transport network (i.e. regions, counties, municipalities, cities, housing estates; all the places where material and passengers streams appear and disappear),
– connections linking areas to the transport network and stating in which node the material and passenger streams appear and disappear,
– turn relations determining possible directions of traffic movement in particular nodes od transport network,
– fields grouping areas.

The sections of the transport network implemented into model are described by relevant characteristics like: individual name and number, length, number of tracks, number of roads and lanes, traffic directions, speed limit, railway or road category, technical class of road, tonnage (capacity) limits, vertical and horizontal marking on the section, surroundings (e.g. the terrain around the road or rail track, noise barriers, etc.), types and characteristics of vehicles allowed to move through the section, the average speed, and wind direction (important to estimate dispersion of pollutants), etc.

Describing sections of roads and railways with these characteristics allows using proposed model for traffic apportionment on the transport network of Poland, and estimating the levels of pollutants emitted into the environment. An example of configuring the transport network segments in PTV VISUM is shown in Fig. 2.

All transport nodes in the network are the beginnings and ends of network's sections. Moreover they can reproduce also:

– existing and planned intersection of national, regional and municipal roads,
– significant technical changes in the cross-sections of roads,
– places where surroundings change (e.g. suburban road turns into urban, etc.),
– places where other characteristics of the road change significantly,
– the places of appearance (origin) and disappearance (destination) of material and passenger flows.

The transport nodes are correlated to the turning relation. They indicate if the turn in the specified direction is allowed. In addition, they allow defining the time necessary for a specific manoeuvre by various means of transport. In this way, it is possible to estimate the full route overcome time, with regard to detention at intersections, waiting at bus stops, etc.

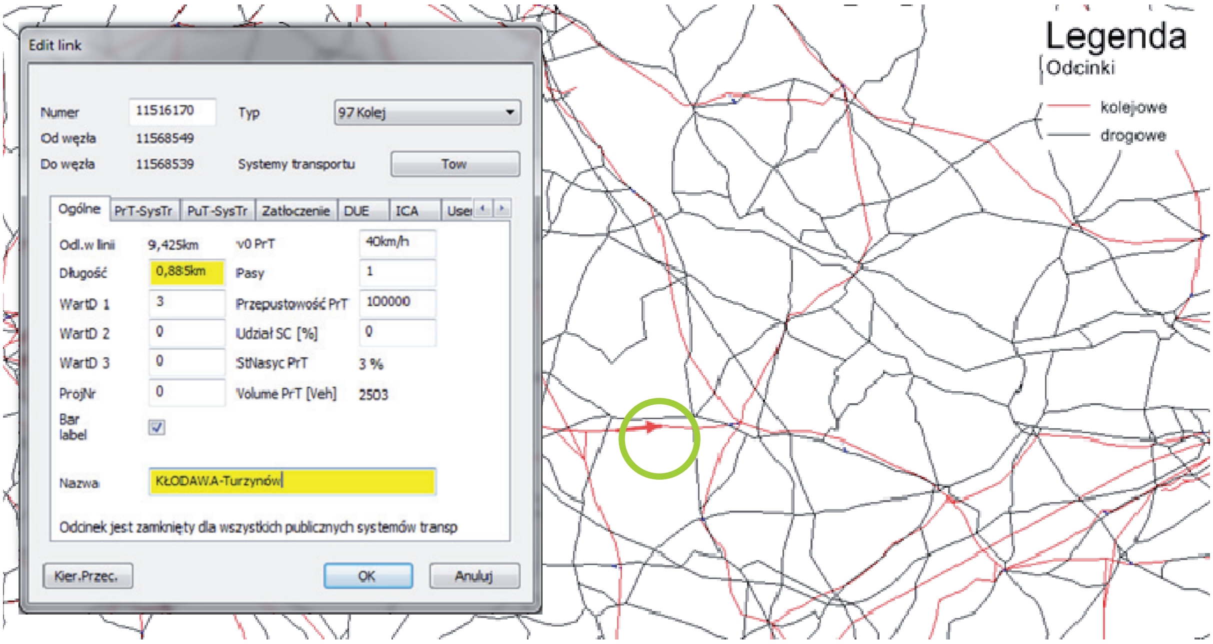


Fig. 2. The example of parameterisation of one of rail network connections

3.3. Means of transport in proecological transport system of Poland

Modelling environmentally friendly transport system requires not only identification of transport infrastructure but also identification of modes of transport used to convey passengers and cargo. The model takes into account road and rail means of transport. A set describing means of transport for MEST consists of different types of vehicles numbered with consequent numbers. Passenger vehicles in road transport are then:

- mopeds and motorcycles, $st = 1$,
- cars, $st = 2$,
- minibuses with 6 to 9 places, $st = 3$,
- buses with 10 to 15 places, $st = 4$,
- buses with 16 to 45 places, $st = 5$,
- buses with more than 45 places, $st = 6$.

Conveying cargo in road transport requires trucks of a fairly wide range of loading capacity starting from vans up to 3.5 tonnes of GVW to the high-tonnage trucks with GVW up to 24 t. These types of vehicles have appropriate numbers $st = 7, ..., st_d$.

Passenger rail transport is performed by coaches with the number of seats from 54 to 88, depending on the length of the car and class of compartments. Coaches are hauled by electric or diesel locomotives as well as electric multiple units. The type of used freight cars depends on the form and vulnerability of transported material, and railway class. Freight cars identified in MEST can carry from 20 to 65 tons of cargo, ($st = st_d+1,..., ST$) and include among others:

- standard and specialized coal cars,
- covered wagons of standard and special construction,
- freight platforms,
- freight cars with an opening roof,

– special freight cars,
– tank wagons.

Due to the different environmental impact of different means of road transport, MEST takes into account not only the loading capacity and technical purpose, but also [4]:

– the type of engine and fuel used for vehicle propulsion, including an internal combustion engines driven by: motor gasoline, diesel, liquid propane-butane gas LPG, compressed natural gas CNG, or hybrid engines, ***RSP*** = {1, 2, 3, 4, 5},
– the EURO emission standard, including: EURO 0 to EURO 6, *NEU* = {0, 1, 2, 3, 4, 5, 6}.

The study reveals functions describing emission of selected harmful compounds of exhaust gases. Taking into account current structure of vehicle stock engaged in transport processes, and those emission functions, will let to set close to the actual levels of emissions of harmful exhaust components from road transport [3]. Analysing anticipated changes in the structure of vehicle stock with regard to importance in meeting the transportation needs and forecasts of future transportation needs will allow identifying expected impact of road transport on the environment for different scenarios of the system development.

The EmiTranSys research is focused on the following harmful compounds:

– carbon monoxide CO, $s = 1$,
– hydrocarbons HC, $s = 2$,
– nitric oxide NO, $s = 3$,
– nitrogen dioxide NO_2, $s = 4$,
– particulate matter PM, $s = 5$,
– carbon dioxide CO_2, $s = 6$.

The unit emission factors for listed pollutants will be ascertained for different traffic conditions determined by type of road (railway) as a function of mean velocity of the vehicle, its load, and the time that elapsed since the start of the engine.

3.4. Demand model in a model of proecological transport system of Poland

The quality of the experimental results obtained from the model is highly dependent on the quality of data on the demand for transport services. In turn, the quality of that data will be a function of source it came from, the needed (or disposed) level of detail, and the way of preparation to implement it into PTV VISUM.

PTV VISUM requires acquiring data on matrixes – in most cases converted from relational databases. More difficult is using the descriptive data, as well as the general characteristics available in source materials. Descriptive data must be converted into corresponding coefficients in the constraints and objective function of a model. For this reason, the correct representation of the demand for transport services in the form of a matrix is important.

Demand for transport services should be expressed by OD (origin-destination) matrixes in a specific unit of measure. Finding a universal unit of measure for different segments of demand is difficult. In case of passenger transport it can be a number of passengers, and for freight transport it can be a ton of moved goods per unit of time. OD matrix construction requires identification of points of origin and reception of material and passenger flows. It is assumed that in MEST these points will correspond to counties. PTV VISUM will distribute freight and passenger traffics on transport network using evaluation criteria implemented into model and characteristics of means of transport. The traffic is defined by OD matrixes.

Central Statistical Office gathers the production data of 488 types of products grouped into 26 product groups (classification PKWiU 2008). The transport activity data are described in 16 groups of NST 2007 classification. The simplified relations between these classifications are shown in Tab. 1.

Passenger transport requires formalization and quantitative description of motivations and destinations of travels. Then appropriate OD matrixes for: commuting to work/school, tourism, business, and other, must be developed. Information on this subject will be raised on the basis of existing timetables for the different modes of transport and data on the use of private transport.

The basic sources of data on the demand for services in passenger and freight transport are:

- studies of the Central Statistical Office on the activities of transport, industrial production, or housing,
- adequate studies of the Eurostat,
- results of the project: The model of a Logistics System of Poland as a way of co-modality of transport in European Union,

Tab. 1. Classification of goods. Source: [2]

No.	The name of cargo group in NST 2007	The name of material group in PKWiU 2008 according to data on industrial production
1	Products of agriculture, hunting, forestry, fishing and fisheries	
2	Coal and lignite, crude oil and natural gas	Hard and brown coal (lignite), peat Crude oil and natural gas
3	Metal ores and other mining and quarrying products	Ores Other mined raw materials
4	Food products, beverages and tobacco	Food and beverage, Tobacco
5	Textiles and clothing, leather and leather products	Textile products (textiles) Clothing, fur products Leather and leather products
6	Wood, products of wood and cork (excluding furniture), articles of straw, paper, paper products, printing products, and voice recording	Wood and products of wood and cork, except furniture, articles of straw and plaiting materials Pulp, paper and paper products
7	Coke, briquettes and refined petroleum products	Coke, refined petroleum products and nuclear fuel
8	Chemicals, chemical products and fibres, rubber, plastics, nuclear fuel	Chemicals, chemical products and man-made fibres Rubber and plastic products
9	Production of other non-metallic materials	Production of other non-metallic materials
10	Metals, fabricated metal products (except machinery and equipment)	Metals, fabricated metal products, except machinery and equipment
11	Machinery, equipment, electrical and electronic equipment	Machinery and equipment not elsewhere classified Office machinery and computers Electrical machinery and tools not elsewhere classified Radio equipment and telecommunications Tools and instruments for medical, precision and optical instruments, watches and clocks
12	Transportation equipment	Motor vehicles, trailers and semi-trailers Other transport equipment
13	Furniture and other finished products	Furniture, other manufactured goods not elsewhere classified
14	Recyclable materials, municipal waste	Recyclable materials, municipal waste
15	Empty containers and packaging	
16	Other	

- results of the General Traffic Measurements in 2005 and 2010,
- railway timetables and a statistics about non-routine services,
- lists of flights to major domestic airports,
- traffic statistics for selected cities.

3.5. Formalizing the emissions of harmful compounds of exhaust gases in a model of proecological transport system of Poland

A series of tests under real and laboratory conditions will be performed to map the emission of harmful substances generated in Polish transportation system. The research is to find unit emissions of harmful substances of different types for different vehicles in various conditions. Obtained characteristics will be implemented into PTV VISUM tools and used for simulations.

The specialized test equipment is used to find the levels of emission of environmentally harmful compounds of exhaust gases (e.g. CO, HC, PM, NO, NO_2, CO_2) for various types of vehicles with different types of internal combustion engines (listed in section 3.3). The tests are performed in laboratory conditions (dyno), and in the actual traffic conditions (urban and sub-urban). Obtained results allow estimation of unit values of emission from individual vehicles and using it in the simulations on the model of proecological transport system of Poland. The functional dependencies indicting expected intensity of harmful compounds emission by the different types of vehicles depending on their instantaneous moving patterns will be developed. The exemplary results of research performed in real conditions are presented below. Details and assumptions of the test are summarized in Tab. 2. The results are shown in Tab. 3, and presented in Fig. 3 in the form of a graph of CO_2 emission intensity change dependant on the vehicle speed and acceleration.

Tab. 2. Details and assumptions of the test

Vehicle	Mercedes C200
Engine	1.8 dm^3, Gasoline
Duration	2111 s
Distance travelled	30.163 km
Fuel consumption	3.193 dm^3
Fuel consumption (average)	10.587 dm^3/100km
Stop time	20.17%
Mean velocity	51.439 km/h
Mean acceleration	0.00416 m/s^2

Tab. 3. The test results – a sample

	CO	HC	NO_x	kNO_x	CO_2	PM
The mass of harmful compounds [g]	47.567	1.0255	0.3016	0.2413	7619.5358	0
Road emission [g/km]	1.577	0.034	0.01	0.008	252.612	0

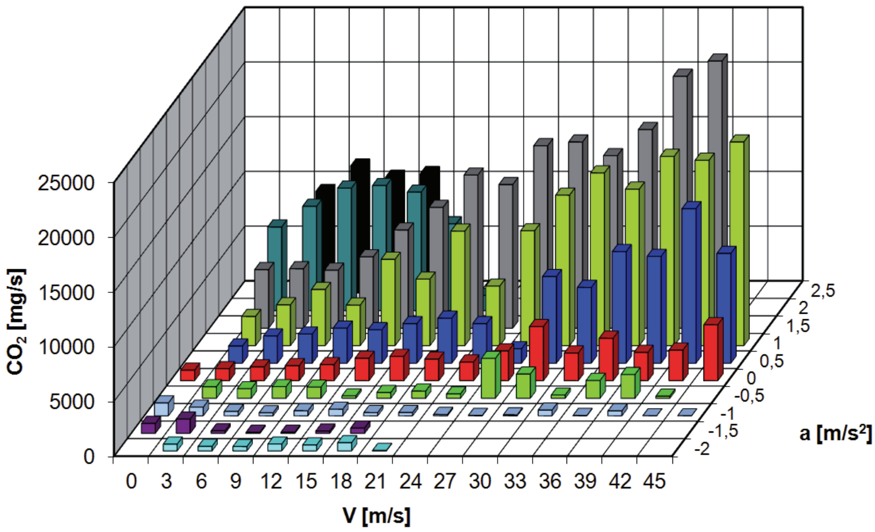


Fig. 3. The CO_2 emission as a function of instantaneous velocity and acceleration

The functional dependences developed on the basis of performed tests and unit values of emissions will be implemented into model of proecological transport system of Poland, and then used for simulation in PTV VISUM.

The apportionment of vehicles streams on the transport network in PTV VISUM requires appropriate decision criteria. Defined criteria function adjusts the movement resistance on the network edges, in the nodes, and while considering turning relations or setting connections between origin and destination points. The resistance can be identified as a length of travelled path or travel time between origin and destination. It can be also a total cost of passing the route stated in any countable unit. The resistance function should tend to extreme (respectively maximum or minimum). In proposed model of proecological transport system, a criterion of flows apportionment can be the total amount of all (or some) pollutants emitted into the environment during the movement of freight and passengers. This criterion was adapted in formula (6). Efforts are made to minimize it. For this purpose, the appropriate mathematical and logical dependences indicating the impact of relevant parameters and characteristics of the transport system (vehicles, sections, etc.) on the emission levels must be implemented. Another resistance function can be a financial cost of movement, which must be minimized while proper ecological characteristics should be kept.

The study includes the issue of dispersion of pollutants along the elements of Polish transport network. Introduction of a mean wind speed and directions for particular sections (or areas) of the network, and estimation of the pollution intensity will make possible to estimate the range of influence of these substances in the cross section of the road. Each individual vehicle (point source), or whole section of road (line source) can be treated as a source of pollution in the forthcoming implementation. In the case of line sources the total emission is a sum of individual emissions from all vehicles moving through the section in a given time. To study the dispersion of pollutants in the crossroads the guidelines and principles presented in [1, 5, 7, 9] will be used.

The model calibration and verification of functional dependencies describing emission of harmful compounds can be performed by additional module of PTV VISUM: Environment Pollution Calculation Module HBEFA. It allows the calculation of the impact of road traffic in transport system on the environment. The results can be presented in both tabular and graphical form.

The program, independently for each direction of traffic, performs calculating emissions internally. The intensities of pollution in both directions are then summed and results are presented as the intensity in cross section of a transport network. Emissions of harmful compounds are determined for each type of vehicle on the transport network. Then the indicators defined for different types of vehicles multiplied by the number of vehicles (trucks or cars). Unit emissions of harmful compounds are retrieved from the database HBEFA (Handbook Emission Factors for Road Transport).

The mechanism of pollution calculation used in PTV VISUM is based on emission factors provided by the Swiss Federal Office for the Environment (BUS) for the pollutants: NO_x, CO, HC and SO_2, for both passenger cars and trucks [6].

4. Conclusions

Paper presents the principles and guidelines for the implementation of the model of proecological transport system (MEST). Particular attention was paid to the model of Polish transport network (road and rail), the model of demand for transport services (passenger and freight), and the model estimating emission of pollutants by transport system users. Appropriate integrating of these models allowed the preparation of the computer implementation of MEST.

Developing a model of proecological transport system will permit a wide range of research, experimentation and simulation of apportioning traffic streams on the transport network of the analysed area (in this case the transport network of Poland). This will make possible estimating the level of harmful emissions generated by the transport network users across the country or the particular areas.

Conducted experiments may involve changing parameters or adding new road or railway sections to the transport network, or changing demand segments, and then observing changes in emissions of harmful substances into the environment. Another advantage of MEST implementation could be simulating changing the attractiveness of different modes of transport to the users, or restricting the use of network in the areas of special protection (near national parks, natural monuments, city centres, areas of Natura 2000, etc.), and analysing the distribution of environmental pollutants from the transport sector. This will allow making studies and preparing proposals for amendments and modernization of the transport policy of the country.

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