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NATIONAL TRANSPORT NETWORK IN POLAND – DEFINING A GRAPH FOR 2015

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Abstract

The paper outlines the effects of data preparation for Accessibility Model for Evaluation of Transport Infrastructure Policy (AMETIP). A balanced and brief description of the main modes of national transport network (road, rail and air transport) in Poland along with their maps was presented. The quantified details of weighted graph (for AMETIP technical purpose) are ready at the level of a commune including a "road system" layer of 2479 vertices and 19 664 edges (134 "highways", 86 "express roads", 681 "roads", 18 763 "local roads"), a "railway system" layer of 1813 vertices and 364 edges, and an "airline system" layer of 15 vertices and 25 edges (including 11 "EGSS" edges). AMETIP multimodal accessibility in Poland can be calculated for the defined period. Simulation of national infrastructure improvements or novel modes of travel require creating another graph that takes into account all official plans for improvements of all modes of travel. The EU scale of analysis is not possible with this data as it would require to identify data sources for inputs to model all European Union Member States, to redefine and recalculate the graph, to estimate impact of the European Commission TEN-T plan execution on the AMETIP accessibility.
Keywords: transport policy, data preparation, road transport, railway transport, air transport.

1. INTRODUCTION

The 2004-2014 decade of the European Union regional cohesion policy support has given Poland a unique opportunity to intensify its transport infrastructure improvement (67 billion EUR for 2007-2013) [1]. The progress is clearly visible by looking at the increase of total length of highways. Since 1990 until the enforcing of the Treaty of Accession of 2003, Poland assiduously doubled its small highway system from 220 km to 552 km. Then, within ten years, the country nearly trippled the 2004 length of highways (up to 1,556 km).

Following the growth of GDP, the passengers numbers of collective road transportation means declined (2,564 million in 1989 to 466 million in 2013), but the ownership of cars sharply increased (about 120 cars per 1,000 inhabitants in 1989 to about 500 per 1000 in 2013).

During the same period, the old railway system of tracks total length had been decreasing. Yet, after the year 2004, the length of tracks stabilised at about 20 thousand km. The most important user of rail tracks, Polish State Railways, Inc. was improving its offer by renovating stations, upgrading tracks and modernizing the rolling stock (the new systems: Pendolino, Pesa Bydgostia, Pesa Dart, Stadler FLIRT).

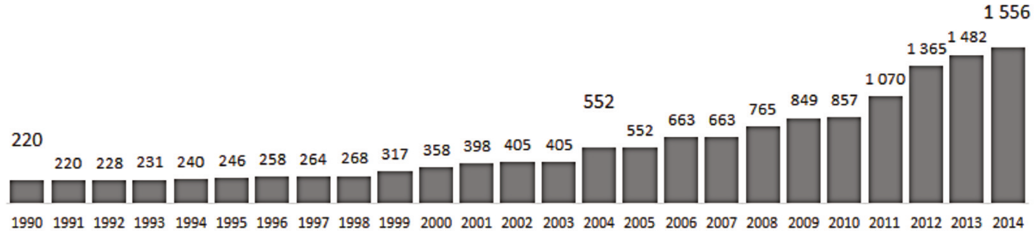


Fig. 1. Total length of highways in Poland 1990-2014 (kilometres) [data: GUS 2014] [Mączka, 2016]

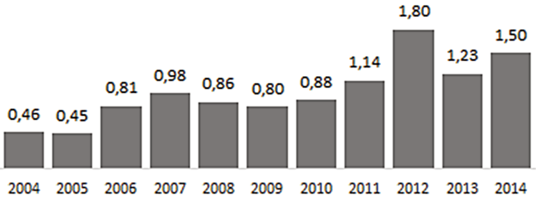


Fig. 2. Total domestic air passengers departures (millions) [data: GUS 2014][Mączka, 2016]

The domestic travellers seem to be enjoying air transport more and more as their total number has been constantly growing since the Polish accession to the EU (See Figure 2). Also, new airports started to operate during this period. These were EPMO – Warszawa-Modlin, EPRA – Radom-Sadków, EPLB – Lublin, and also the newest one, EPSY Olsztyn-Mazury that initiated its operations in 2016 [2]. In this dynamic environment some of the airlines took off, but failed to survive on the market (OLT Express [3]), others began to disappear despite fleet modernisation (EuroLOT/eurolot's routes taken over by LOT Polish Airlines [4]). A complete picture, however, requires mentioning new entrants to the domestic market which emerged, survived and recently enlarged their offer (Ryanair [5], SprintAir [6]).

Neither EUROSTAT, nor GUS (not mentioning the press releases) offer unrestricted access to detailed data needed to catch a point in time and define a total transport system graph. Identifying exact locations and the quality of the infrastructure components requires compromising and generalising information coming from multiple sources.

An effort was put in this paper to quantify all the identified information to use it as the inputs to the graph of Accessibility Model for Evaluation of Transport Infrastructure Policy (AMETIP) [7]. The graph was expanded and reshaped from its original, generalised form with "road system", "railway system", "airline system" layer to reflect the national transport system in Poland in 2015.

The 2015 transport system picture could be a starting point to evaluate plans to achieve the European Commission regional cohesion goal: "90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours" [8] [9].

2. POLISH TRANSPORT INFRASTUCTURE

2.1. Literature review

Accumulation of short-term liquidity loans due to coal and steel industry decline increased Polish Railways operating financial costs leaving railways in Poland financially weak at the end of the 90s. To revert this trend of losing market share to road transport on the contrary to financially strong railways of its eastern neighbours (Russia, Ukraine), Poland initiated reforms aiming at improving productivity, raising revenues, reducing costs by separation of passenger and freight businesses, divestment of non-core assets, business plan development and privatisation of network sections [1] [2].

Despite years of reform, ownership reorganisation, infrastructure access to private investors railroad transport continue to be slower than road transport [3]. Polish example of Via Baltica negotiations created an European precedence that NGO campaigning can significantly influence consent for strategic infrastructure development [4]. On the other hand, there is strong evidence for growth trends in road capacity utilisation after EU accession. Road and railway networks have different economic efficiency [2]. Yet, even road connections are relatively worse on the North-South routes and there are difficulties to reach Poland's capital city, Warsaw. Lack of origin-destination data hinders deeper, quantitative analyses [3].

The air transport static infrastructure is much easier to quantify and volumes of travellers are orderly reported. The researchers identified determinants and demonstrate that Poland is yet to fully realise a EU-wide air transport potential caused by liberalisation and decentralisation, despite a small slowdown of the 2009 global breakdown. More air transport infrastructure expansion or improvements, especially for some alternative business models undertakings (as low-cost carriers), are expected [5].

2.2 Data sources

The AMETIP method [7] requires inputs to its graph. In brief, these are coordinates and adjacency of vertices, as well as, the weights of adjacency connections (edges of graph) and the weights of vertices. The weight of an edge generalises all functional properties of travelling paths into one variable – a theoretical minimum time of travel that is derived from the distance and the maximum allowed speed. The weight of a vertex corresponds to its significance in terms of, for example, population.

All exclusive spatial points coordinates were limited to a certain set of locations – the coordinates of 2,479 Polish commune centroids. The centroids data were available in a Eurostat shapefile of administrative units of the EU [15].

Although population sizes in Eurostat database were not present at the commune level, luckily, the shapefile with the centroids shared the same identification codes with the codes of the Polish Central Statistical Office (GUS) census report of 2011 ("COMM_ID" and "*Symbol terytorialny"*) [16]. The two databases were merged.

Public access to Polish roads, rail tracks exact and current coordinates, structure and their qualities is also limited. Considering this difficulty, all of the shapes were manually coded by looking at two maps published by:

- The General Directorate for National Roads and Motorways (GDDKiA) of the Polish Ministry of Infrastructure and Development [17];
- The Polish State Railways, Inc. (PKP S.A.) [18].

For the air transport access nodes quantification, the airports coordinates from the online version of the AIP Polska [19] were used. Yet, due to the lack of access to the records of actual flight paths to identify the vertices and their adjacency and weights, examples from the timetables of 2015 domestic offer of the commercial airlines websites (LOT Polish Airlines [20], Ryanair [21], SprintAir [22] and airBaltic [23]) were chosen.

2.3 Area of concern, great-circle distances and population

Poland is a medium sized Member State of the European Union of about 38 million inhabitants [16] and the area of 312 thousand km^2 [24]. The country is divided into 2,479 communes, that is local administrative units (EU LAU2) [15] and includes 57 cities, 919 towns and about 50 thousand villages. The census of 2011 reported the largest single commune was inhabited by 1,708 million people (the capital city of Warszawa) and the smallest one (the Krynica Morska commune) by 1,353 people. Half of the communes were as large as 7,524 inhabitants or more. (See figure 3, 4, 5).

Fig. 3. The area of Poland into 2479 communes, the longest GC distance (781 km), min and max populations [15, 16][Mączka, 2016]

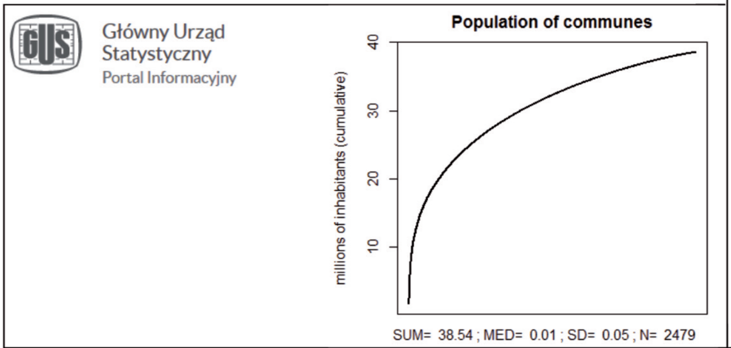


Fig. 4. Distribution of the communes populations [16] [Mączka, 2016]

eurostat

Land cover overview

[lan_lcv_ovw]

2012	km^2
EU27	4 306 586
FR	543 966
ES	498 511
SE	438 575
DE	357 134
FI	338 433
PL	**312 679**
IT	301 339
UK	248 530
RO	238 394
EL	131 958
BG	110 898
HU	93 023
PT	89 089
AT	83 880
CZ	78 865
IE	69 798
LT	65 300
LV	64 562
SK	49 037
EE	45 227
DK	42 895
NL	41 542
BE	30 526
SI	20 272
CY	9 251
LU	2 586
MT	316

Fig. 5. EU27 states land cover [24]

Instead of Euclidean distances originally used in the AMETIP method, the great-circle (GC) distances [25] were applied. The GC or orthodromic distance is the shortest distance between two points on the surface of a sphere, measured along the surface of the sphere. The GC distances haversine formula is the following:

$$\Delta\sigma = 2arcsin\sqrt{sin^2\left(\frac{\Delta\varphi}{2}\right) + cos\varphi_1 * cos\varphi_2 * sin^2\left(\frac{\Delta\lambda}{2}\right)} \qquad (1)$$

where: $\Delta\varphi$ – a difference between origin and destination latitude, $\Delta\lambda$ – a difference between origin and destination longitude, φ_1, φ_2 – origin and destination latitudes.

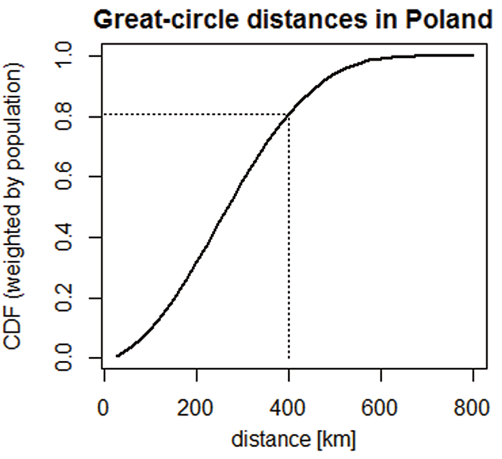


Fig. 6. CDF of great-circle distances in Poland weighted by population [Mączka, 2016]

The longest GC distance of 781 km is between the town of Świnoujście centroid (the north-western corner of Poland) and the Lutowiska commune centroid (the south-eastern corner of Poland). Half of the GC distances list contains the distances shorter than or equal to 271 km.

The GC distances were weighted with corresponding populations of communes of origin. Figure 6 shows a cumulative distribution of weighted distances. It also indicates theoretical significance of the distance intervals assuming one time travel of each person to all other communes.

80% of the GC distances were equal to or shorter than 400 km.

Further calculations revealed that a statistical mode of the weighted distances is in the interval of 250-271 km (an interval of the most frequent distance).

The mentioned values are just distances matched to populations. They should be considered with caution as potential travels proxies, because people hardly travel to all other communes throughout their lifespan. Thorough understanding of actual travel distances significance requires the unavailable big data of individual transport behaviour records.

2.4 Road transport

Road transport is the most decentralised system of all modes in Poland and its traffic control is dominantly static (visual signs, lights and code of rules).

The Polish law concerning public roads [26] defines the following types of roads according to their functionalities:

- national roads;
- voivodship roads;
- LAU1 roads;
- LAU2 roads (communes).

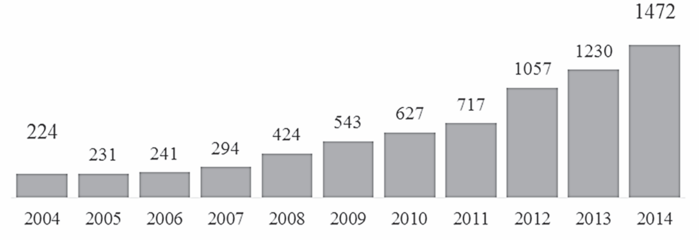


Fig. 7. Total length of express ways in Poland 2004-2014 (kilometres) [data: GUS 2014] [Mączka, 2016]

The Polish Central Statistical Office (GUS) does not report according to this typology. GUS reported 283 561 km of hardened surface roads in 2013 [27]. More accurate data were found in the 2013 General Directorate for National Roads and Motorways (GDDKiA) of the Polish Ministry of

Infrastructure and Development report which lists 1,491 km of completed highways (at the cost of 9 million EUR/km) and 1,247 km of express roads [28]. In 2014 they mentioned 1,553 km of highways and 1,472 of express ways (at the total cost of 34 billion of EUR including 10 billion EUR of EU support) [29]. See figure 1, 7.

As the GDDKiA report noticed, despite heavy investment, the road system continues to be inconsistent (60% of traffic uses 4.7% of all roads).

2.5 Rail transport

Due to its infrastructure nature, rail transport is the most static mode of travel. In Poland it is organised within the so called "EU model" [1] [2] [3] [4]. The model requires management independence for railway undertakings to operate commercially with the sound financial basis. According to the model, the infrastructure has to be separated from operation and access, as well as transit rights have to be granted to independent operators. The railway system is collectively used and centrally managed by the Centre of Rail Traffic Management of PKP Polskie Linie Kolejowe S.A. [36].

In the case of infrastructure, the Polish law on railway [34] defines the following types of the railroads according to their functionalities:

- a complete system of tracks and facilities enabling rail transport;
- the tracks system significant for the national transport;
- the dual purpose tracks system;
- the military tracks system.

The GUS report for 2013 mentioned 1,430 train stations and 383 hubs and 19.3 thousand km of rail tracks [27]. According the Master Plan for railway [35], only 12.3 thousand km of the tracks are significant for the national transport system. The best sections of the system included 579 km of tracks with a maximum speed of 160 km/h. The PKP Intercity, a subsidiary of PKP S.A., offered a long range passenger transport services using a rolling stock that includes systems moving at a speed of 160 km/h or more.(See figure 8).

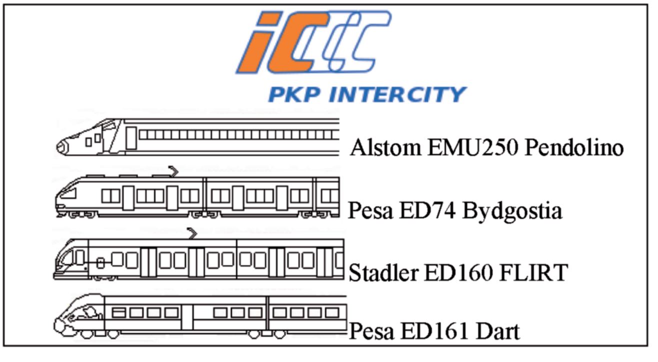


Fig. 8. The rolling stock capable of high speed [Mączka, 2016]

2.6 Air transport

Most of the air transport infrastructure is air. The most detailed source for air transport system components is the Aeronautical Information Publication (AIP Polska) [19] Polish airspace is called Flight Information Region Warszawa (EPWW). EPWW is divided into lower airspace located between GND and FL285 and upper airspace located between FL285 and FL660. The lower airspace is more complex than the upper one. Both of them include a list of prohibited, restricted or segregated sections enveloped by the borders of irregular shapes that could be different at different flight levels and could change over time. This airspace limitation prevents flights to be piloted along the shortest great-circle paths.

The air transport uses air navigation services (including traffic control) provided by Polish Air Navigation Services Agency (PANSA) [37]. The domestic air transport uses capacity of the lower airspace avoiding all restricted areas in EPWW by flying over or around them. The upper airspace is used by international and transit flights.

According to the AIP Polska, there were 14 international airports in Poland in 2015. The 15th Polish airport, EPSY Olsztyn-Mazury Regional Airport was not yet active at the time of data collection and it was not included in the 2015 picture of Polish transport system (the graph input). Except EPLL Łódź and EPRA Radom, all of the airports are capable of aircraft operations as big as Boeing 767 or Airbus 310. EPWA Chopin Airport is slightly larger than others and aircraft as Boeing 777, 787 or Airbus 330 can land there.

The 2015 domestic air transport offer in Poland was supplied by a fleet of Bombardiers Q400 Dash 8, Embraers ERJ-175, Boeings 737-700 and Saabs 340A. (See figure 9).

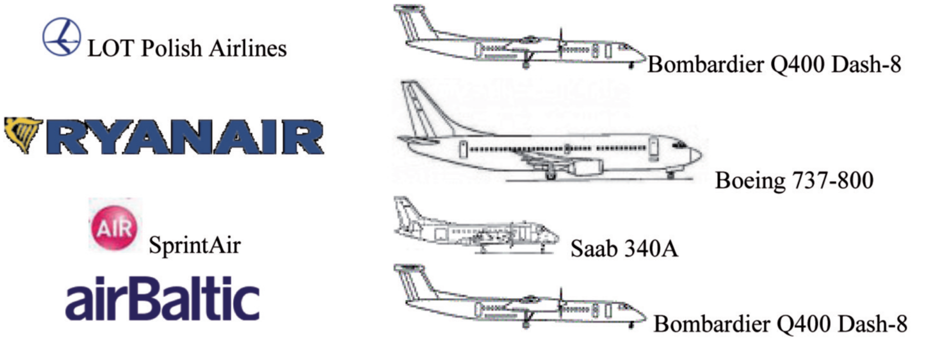


Fig. 9. The fleet of airlines providing domestic services in Poland [Mączka, 2016]

Table 1. Airlines domestic offer of 2015 (flight time in hours) [15, 16, 17, 18] [Mączka, 2016]

	EPBY	EPGD	EPKK	EPKT	EPLB	EPLL	EPMO	EPPO	EPRA	EPRZ	EPSC	EPWA	EPWR	EPZG	EGSS
EPBY	NA	NA	1,42	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2,17
EPGD	NA	NA	1,33	NA	NA	NA	0,92	NA	NA	NA	NA	1,08	1,08	NA	2,25
EPKK	1,42	1,33	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,83	NA	NA	2,50
EPKT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,83	NA	NA	2,33
EPLB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2,58
EPLL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2,33
EPMO	NA	0,92	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,92	NA	2,42
EPPO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,92	NA	NA	2,08
EPRA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*39,00	NA	NA	NA
EPRZ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,92	NA	NA	2,58
EPSC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,08	NA	NA	1,92
EPWA	NA	1,08	0,83	0,83	NA	NA	NA	0,92	*39,00	0,92	1,17	NA	0,92	1,17	NA
EPWR	NA	1,08	NA	NA	NA	NA	0,92	NA	NA	NA	NA	0,92	NA	NA	2,17
EPZG	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,17	NA	NA	NA
EGSS	2,17	2,17	2,42	2,25	2,50	2,25	2,33	2,08	NA	2,58	1,92	NA	2,17	NA	NA

* assumed total time of travel EPWA-EVRA-EPRA including waiting in EVRA

The domestic offer of the commercial airlines is not presented in the AIP Polska, it has to be extracted from the airlines websites (LOT Polish Airlines [20], Ryanair [21], SprintAir [22] and airBaltic [23]). The offer was organised in two larger sub-systems – a hub and spoke distribution of LOT Polish Airlines (7 routes to EPWA Chopin) and a point-to-point transit of Ryanair (5 routes). They were complemented by one route of SprintAir (EPZG Zielona Góra - EPWA Chopin). (See table 1).

Table 2. Assumed waiting for transfer within the airlines domestic offer of 2015 (in hours) [Mączka, 2016]

	EPBY	EPGD	EPKK	EPKT	EPLB	EPLL	EPMO	EPPO	EPRA	EPRZ	EPSC	EPWA	EPWR	EPZG	EGSS
EPBY	0.00	11.50	0.00	3.92	0.25	5.25	0.67	1.25	40.08	4.42	7.42	0.50	0.83	7.75	0.00
EPGD	18.08	0.00	0.00	5.92	1.42	5.25	0.00	5.92	39.58	5.92	11.67	0.00	0.00	9.83	0.00
EPKK	0.00	0.00	0.00	3.83	7.83	7.25	9.17	3.75	39.58	3.75	9.50	0.00	0.75	7.67	0.00
EPKT	0.67	5.25	0.25	0.00	8.58	0.42	7.17	5.25	39.58	5.25	11.00	0.00	2.25	9.17	0.00
EPLB	2.25	17.33	18.08	4.92	0.00	2.92	0.25	17.92	62.75	13.67	6.25	23.17	15.17	19.83	0.00
EPLL	16.08	16.67	14.67	17.25	13.08	0.00	14.33	17.25	58.50	13.00	2.00	18.92	2.58	19.17	0.00
EPMO	2.42	0.00	14.75	4.92	3.83	7.67	0.00	4.83	40.83	4.83	10.58	1.25	0.00	8.75	0.00
EPPO	2.25	0.67	2.25	3.83	15.25	0.83	5.67	0.00	39.58	3.75	9.50	0.00	0.75	7.67	0.00
EPRA	48.75	37.83	37.83	37.83	44.25	44.25	45.83	37.83	0.00	37.83	37.83	0.00	37.83	37.83	0.00
EPRZ	3.67	3.83	2.33	3.92	7.58	4.08	5.75	3.83	39.58	0.00	9.58	0.00	0.83	7.75	0.00
EPSC	11.17	0.58	1.75	3.33	8.00	16.42	5.17	3.25	39.58	3.25	0.00	0.00	0.25	7.17	0.00
EPWA	10.92	0.00	0.00	0.00	6.42	6.42	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EPWR	2.08	0.00	2.08	3.67	3.58	7.42	0.00	3.58	39.58	3.58	9.33	0.00	0.00	7.00	0.00
EPZG	0.33	4.92	0.33	5.00	5.25	5.25	6.83	4.92	39.58	4.92	10.67	0.00	1.92	0.00	0.00
EGSS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The Ryanair and LOT subsystems of Polish domestic airline system did not overlap. If the domestic travellers wanted to continue their travel by air, they would have to relocate to another airport using car or train. Yet, if they had used the dense (in terms of daily frequency of flights) Ryanair offer to EGSS London-Stansted airport, they would have reached several of their domestic destinations in Poland the same day [21].

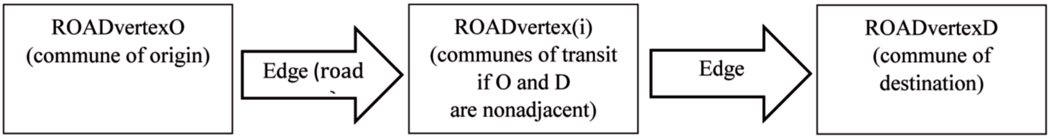
3. POLISH NATIONAL TRANSPORT NETWORK GRAPH

Polish national transport network model was assumed as a graph that consists of the following components:

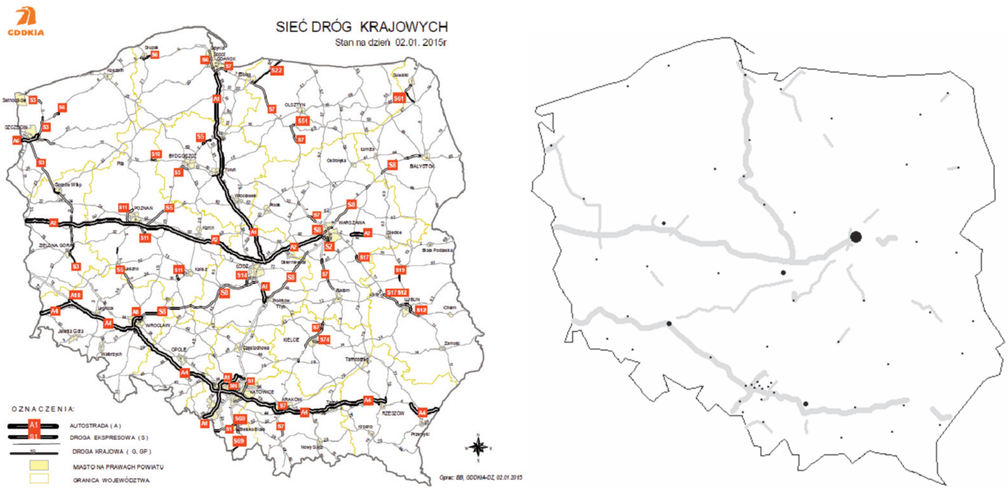
a) “road system” layer:
   2,479 vertices
   19, 664 edges (including 134 “highways”, 86 “express”, 681 “roads”, 18 763 “local roads”)
b) “railway system” layer:
   1,813 vertices (including 245 “railway hubs”)
   364 edges
c) “airline system” layer:
   15 vertices (including “EGSS” vertex)
   25 edges (including 11 “EGSS” edges)

3.1. Model input for the “road system” layer

For the definition of the “road system” layer, all but “local roads” vertices coordinates and their edges were manually recreated by extracting them from the GDDKiA map of 2015 [17]. (See Figure 10). The coordinates were averaged to their nearest LAU2 commune centroids location. All relations using adequate distance and speed matrices were recorded and prepared for calculations to follow the same logic of transport:



The generalisation, the compromises (and the possible minor errors of the manual extraction) caused some deviations from the GUS reported total lengths of roads. The total length of "highways" edges were nearly accurate, but for example, the "express roads" edges (1,108 km) were shorter than actual express roads lengths (1,247 km) due to the exclusion of many express road sections that are mostly discontinuous and irrelevant considering the whole network (See figure 10).



[GDDKiA 2015] [Mączka, 2016]

Fig. 10. The GDDKiA map of 2015 and the "road system" layer of the graph (NUTS0 Poland)

2,479 "road system" vertices and a total length of "road system" edges (339,391 km) were defined including:

a) 1,524 km at 140 km/h
b) 1,108 km at 120 km/h
c) 8,270 km at 90 km/h
d) 3,28 487 km at 50 km/h

The "local roads" edges were not available at the GDDKiA map of 2015. Due to this fact (and limited computer memory) they are a kind of a simplification. I assumed that a commune is connected to every other commune located within 25 km at least by a local road of 50 km/h maximum allowed speed. (See figure 11).

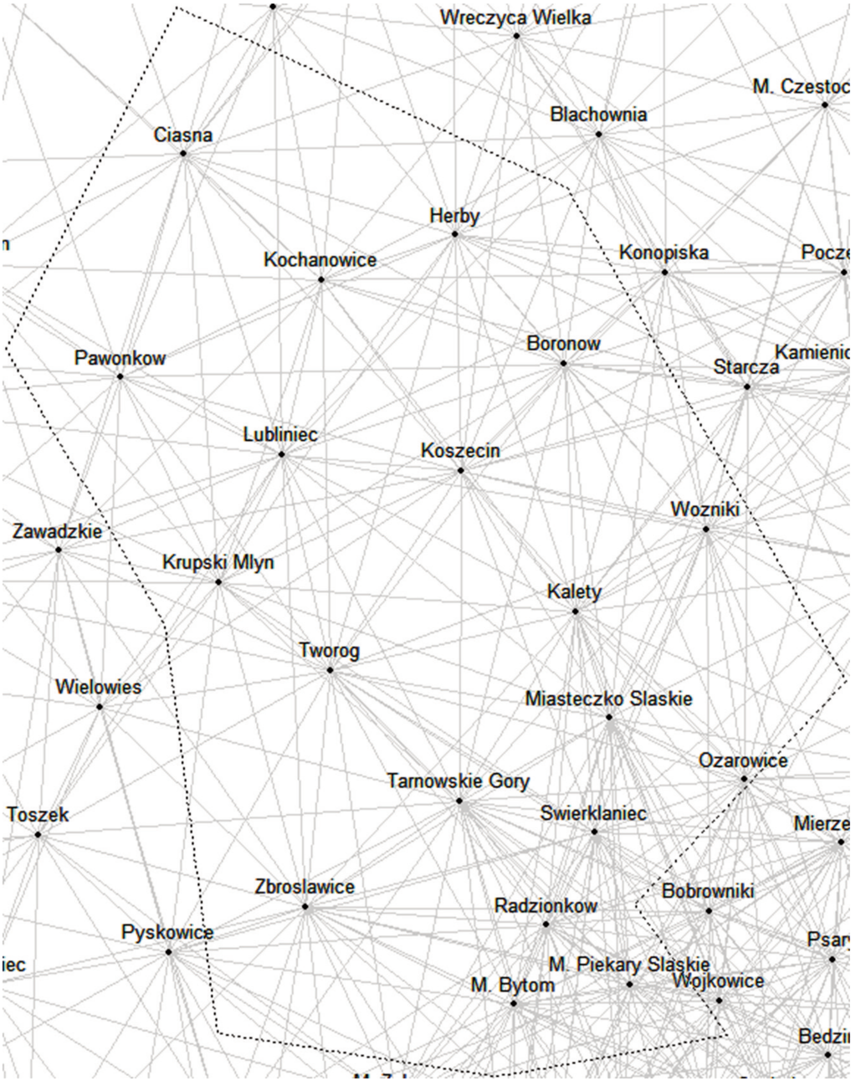


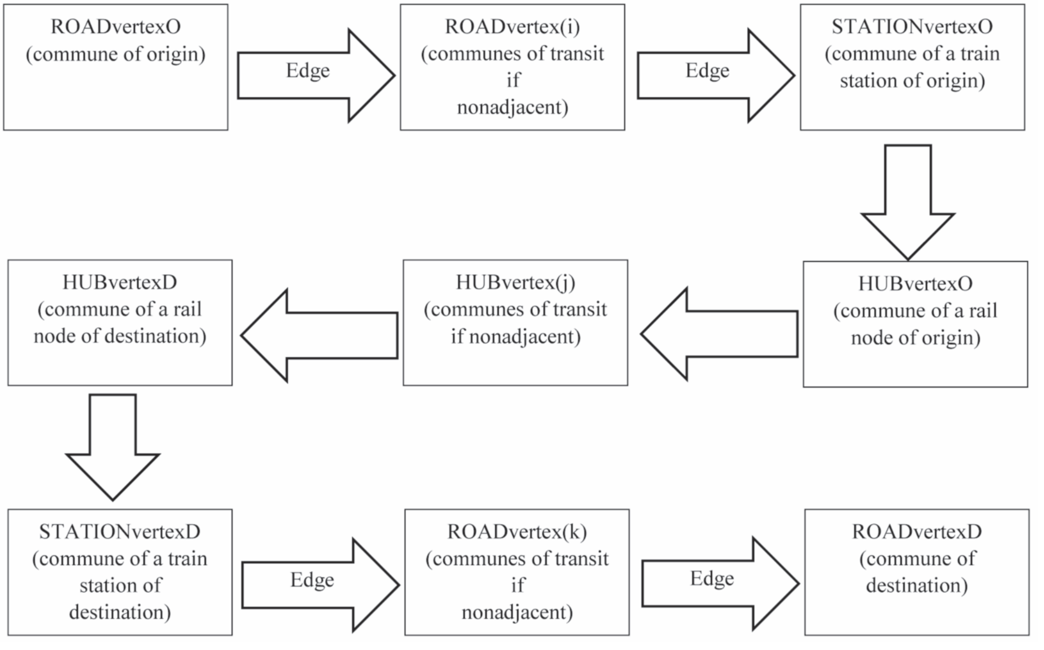
Fig. 11. The edges of lower speed in Poland of the assumed “road system” layer (example of NUTS3 PL228 Bytomski) [Mączka, 2016]

3.2. Model input for “railway system” layer

Similarly to the “road system” layer, the coordinates of the “railway system” layer vertices and their edges were recreated by extracting them manually from the PKP SA map of 2015 [18] .(See figure 12).

The rail transport has a limited number of access points usually located in the vicinity of densly populated areas. I assumed any “railway system” vertex, “station”, is reached using the “road system” layer with no transfer or waiting time penalty.

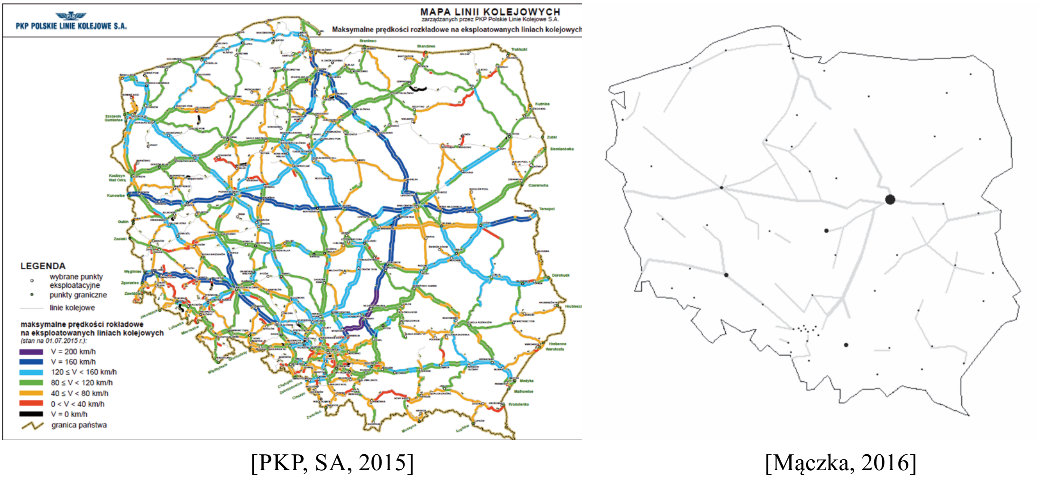
All relations were recorded using adequate distance and speed matrices and prepared to follow the logic of railway transport:



An extra property was attributed to some of the "stations" vertices. It was marked them as "hubs" vertices. A traveller initially needs to go by train to a railway "hub" to continue his longer range journey.

1813 "railway system" vertices were defined including 245 "hubs". The total length of the "railway system" edges was 13, 959 km of tracks and included (See figure 12):

a) 793 km at 10 km/h
b) 2,546 km at 120 km/h
c) 336 km at 20 km/h
d) 1,269 km at 160 km/h
e) 3,993 km at 40 km/h
f) 117 km at 200 km/h
g) 4,904 km at 80 km/h



[PKP, SA, 2015] [Mączka, 2016]

Fig. 12. The PKP, SA map of speeds in 2015 and the "railway system" layer of the graph (NUTS0 Poland)

Since rail transport access points are not assumed to be universally at a walking distance, some journeys would need a shuttle lift from a commune without a train station. Shuttles are assumed to be cars or buses and use the "road" layer of the graph. See the example of Dąbrowa Zielona and Sośnicowice in figure 13.

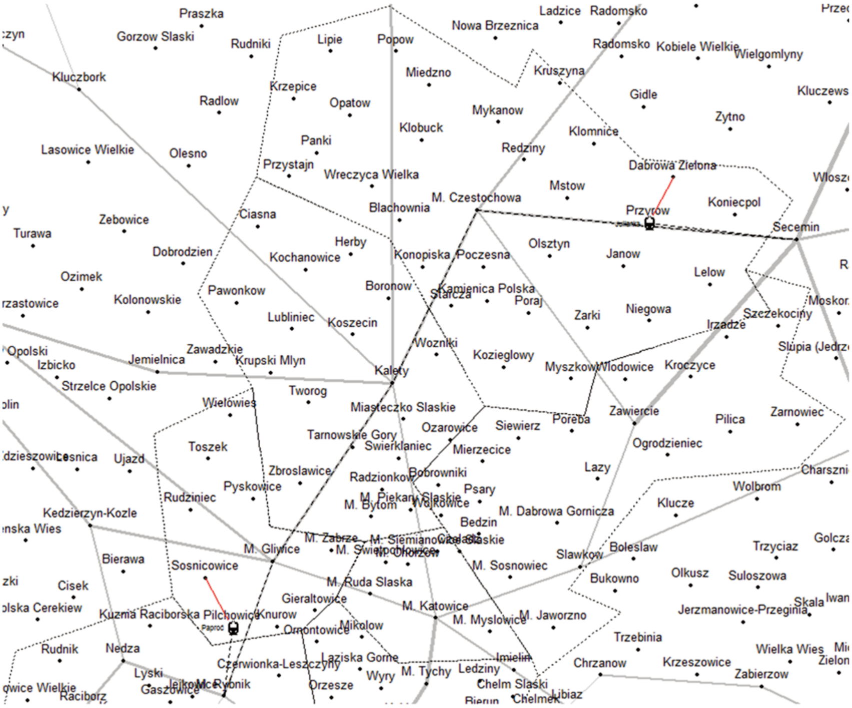


Fig. 13. An example of transport within the assumed "railway system" layer (north of NUTS2 PL22 Śląskie) [Mączka, 2016]

This assumption of "hubs" sometimes made the initial direction of travel oposite to the direction towards a destination commune, but seems to be fairly realistic for a railway travel.

Any train travel less than 100 km is assumed to be reflected as in the example of travel from Niegowa to Żarki. Both communes have no stations. They are located 10 km away from one another. A return travel to Zawiercie via Myszków at a fixed speed of 40km/h is assumed. (See figure 14).

Fig. 14. An example of short range (<100km) transport within the assumed "railway system" layer (south-east of NUTS3 PL224 Częstochowski) [Mączka, 2016]

3.3. Model input for "airline system" layer

Except for the airports, the "airline system" layer could not be recreated using any fixed map coordinates because the real-time controlled air traffic does not use any conventional, fixed or physical paths. Just as intended, the Wardrop's first principle [38] cannot be the main rule in flight trajectory choice. Moreover, no public database provides unrestricted access to historical records of the paths of commercial flights to generalise some assumptions.

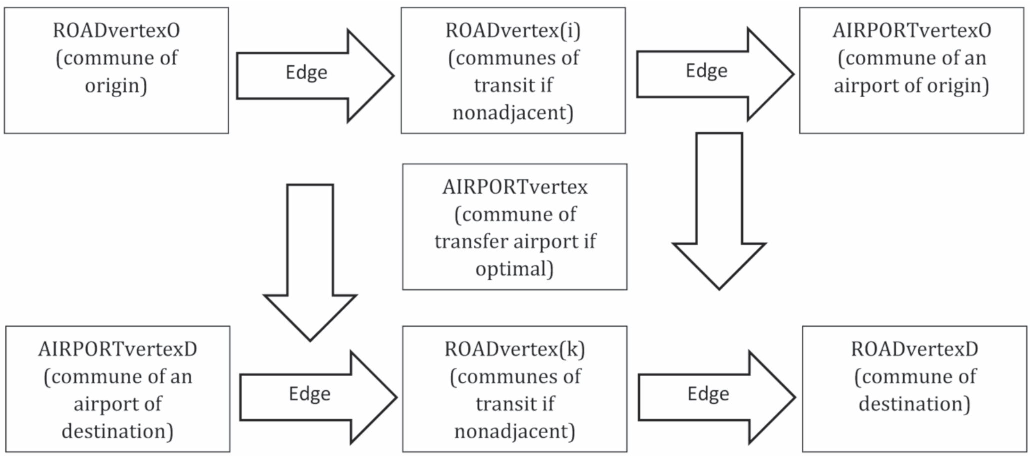
The "airline system" edges and their weights were determined using the 2015 airline offer of domestic scheduled flight. The edges weight ("flight" time) included:

a) average time of flight between origin and destination airports,
b) one hour assumed for a check-in.

In the case a traveller wanted to continue his travel using the airlines there was another inevitable time component. This component is specific and assumed waiting for transfer time. It cannot be directly incorporated to the Floyd-Warshall algorithm [39] [7]. However, to obtain the final "flight" time, the waiting time can be added to each leg of the flight itinerary according to the times in table 2.

Similarly to the railway transport, the air transport has a limited number of access points. Any "airline system" vertex ("airports") was assuemd to be reached using the "road system" layer with no transfer or waiting time penalty.

All relations were recorded using adequate time matrices and prepared to follow the logic of airline transport:



The "airline system" layer comprises of 15 vertices and 24 edges. (See figure 15).

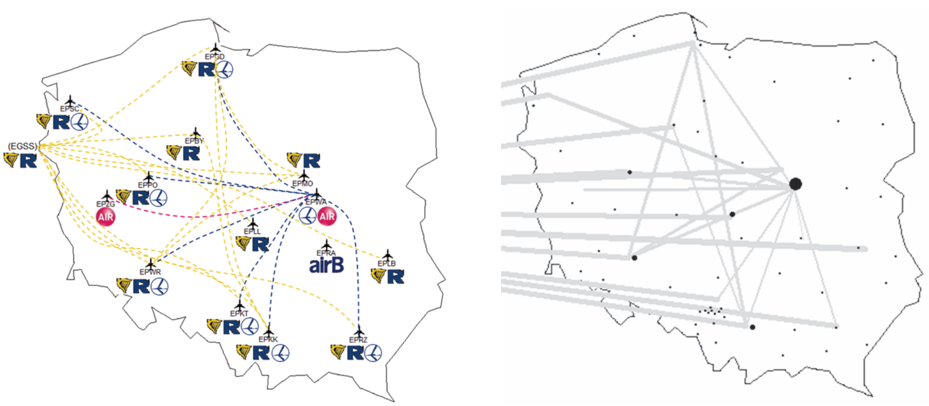


Fig. 15. The airlines offer of 2015 and "airlines system" layer of the graph (NUTS0 Poland) [Mączka, 2016]

The extra, 15th airport is the fourth busiest airport in the United Kingdom – London Stansted (EGSS). It was included as an extra vertex of the Polish domestic "airline system" layer to show a potential significant efficiency boost of the domestic network.

Although EVRA Riga airport seemed to be a good candidate for second network boosting vertex, this idea was dropped. The transfer time of airBaltic EPRA-EVRA-EPWA itinerary was too long (one day or more for waiting). Table 1 shows that EPRA-EPWA flight was possible at a cost of about 40 hours.

4. CONCLUSION

The available data sources (EUROSTAT, GUS, GDDKiA, PKP SA, EUROCONTROL and websites of the airlines operating in Poland) allowed to prepare the inputs needed to project the multimodal transport network in Poland in a quantifiable manner. The detail level of developed graph, and, thus, the transport policy evaluation accuracy, is limited by the following assumptions:

a) generalisation of all coordinates to the LAU2 centroids;
b) unlimited road and railway infrastructure capacity;
c) unlimited supply of rail transport services;
d) fixed, homogenous and unlimited capacity of airlines offer (chosen from the 2015 timetables);
e) uniform and universal travel type (single day, there and back again).

The research of the Institute of Aviation [40] on the transportation systems will be continued. The graph emulating Polish transport system and described by this paper will be used:

- to simulate AMETIP [7] daily multimodal accessibility in Poland of 2015;
- to estimate impact of the transport policy in Poland realization;
- to simulate potential new modes of travel (such as European Personalized Air Transport System, EPATS [41]) impact in Poland.

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KRAJOWA SIEĆ TRANSPORTOWA W POLSCE – DEFINIOWANIE GRAFU DLA 2015

Streszczenie

Artykuł przedstawia wyniki przygotowania danych do opisanego w poprzedniej publikacji modelu AMETIP (Model Dostępności Transportowej do Testowania Założeń Polityki). Zaprezentowano zrównoważony i krótki opis głównych środków transportu krajowej sieci transportowej (drogowy, kolejowy i lotniczy) w Polsce wraz z ich mapami. Wyrażone liczbowo elementy grafu ważonego (na potrzeby modelowania AMETIP) są gotowe na poziomie szczegółowości gminy w skali kraju i zawierają warstwę 2479 wierzchołków i 19 664 krawędzi (134 “autostradowych”, 86 “dróg ekspresowych”, 681 “drogowych”, 18 763 “dróg lokalnych”), warstwę „systemu kolejowego” składającą się z 1813 wierzchołków i 364 krawędzi oraz warstwę „systemu linii lotniczych” składającą się z 15 wierzchołków i 25 krawędzi (włączając w to 11 krawędzi „EGSS”). Zaproponowano zasymulować multimodalną dostępność transportową AMETIP w Polsce, zidentyfikować źródła danych do przygotowania wkładu dla wszystkich krajów członkowskich Unii Europejskiej, oszacować wpływ realizacji planów Komisji Europejskiej TEN-T na dostępność transportową AMETIP, a także zasymulować wpływ wprowadzenia potencjalnych, nowych środków podróży (takich jak European Personalized Air Transport System, EPATS) na dostępność transportową AMETIP w Unii Europejskiej.
Słowa kluczowe: polityka transportowa, przygotowanie danych, transport drogowy, transport kolejowy, transport lotniczy.