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CONSTRUCTION OF A MODEL FOR DATA PROCESSING IN THE SETTLEMENT OF THE COSTS OF PUBLIC TRANSPORT OPERATING IN THE MUNICIPALITIES OF THE UPPER SILESIAN METROPOLITAN UNION – PART TWO

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Purpose: Development of a model for processing and sharing of data which were prepared and developed according to the assumptions described in the article titled „Model of data of the settlement of costs of public transport operating on the territory of the Upper Silesian Metropolitan Union". The developed model should have the possibility of practical use in local government units operating in the Upper Silesian and Zagłębie Metropolitan Area (GZM) (https://metropoliagzm.pl), support public transport managers in the analysis of public transport costs, and present to municipalities the components of the costs they incur in the framework of the joint venture implementing public transport in the GZM. The solution presented is intended to ensure that the analysis can be performed in terms of the various cross-sections to which the analysed data can be subjected.
Design/methodology/approach: due to the fact that one of the constraints during the implementation of the task was the need to use only those tools that have been used so far and for which the GZM has appropriate licenses, the study was limited to the functionality provided by the Office 365 suite.
Findings: In the course of the work, it was found:
- dispersion of data between different cost-controlling units,
- lack of uniform data structures between units,
- inconsistency of dictionaries over time.

Practical implications: The data model developed during the work was used to build the analytical platform used within the GZM.
Social implications: The developed model was used for presentation to the mayors of the municipalities that make up the GZM. It is an analytical tool used by the management of the GZM to present and optimize the scope of communication in the designated area.
Originality/value: Authorial model for processing data from heterogeneous sources into a coherent and unified data structure has been developed.
Keywords: Public transportation, public transport, data modeling, visualization.
Category of the paper: Practical implementation of data processing system and data model construction.

1. Genesis

In November 2017, the Metropolitan Transport Authority (ZTM) was established by the Assembly of the Upper Silesian and Zagłębie Metropolis (GZM), which took over the responsibilities of the three previous public transport organizers by combining the public transport system operating in Silesia and Zagłębie and serving the territory of 56 cities and municipalities (https://metropoliagzm.pl/droga-do-metropolii).

Resolution No. 7/2020 of January 15, 2020, of the Board of Directors of the Upper Silesia-Zagłębiowska Metropolis (https://bip.metropoliagzm.pl/uchwala/125860/uchwala-nr-07-2020) adopted a document on "principles of proceeding in calculating the variable part of the Annual Contribution for municipalities of the Upper Silesia-Zagłębiowska Metropolis and subsidies for municipalities not belonging to the GZM" On December 23, 2021, amendments were made to the above-mentioned resolution, which were announced by Resolution 325/2021 of the GZM Board (https://bip.metropoliagzm.pl/uchwala/128104/uchwala-nr-325-2021).

These documents set out the rules of procedure for calculating the variable portion of fees to be paid by individual GZM municipalities and subsidies to non-GZM municipalities for public transportation provided on their territory.

The company responsible for organizing public transportation is the Metropolitan Transport Authority (ZTM) (https://www.metropoliaztm.pl/pl). It should be noted here that ZTM performs its tasks mainly on the territory of the GZM, however a partial scope of its activities is also implemented on the territory of municipalities not belonging to the GZM.

Based on the aforementioned resolutions, employees of ZTM's controlling department have prepared planning and settlement sheets determining remuneration for individual operators providing public transportation, as well as sheets calculating the variable premium (https://metropoliagzm.pl/tag/skladka-zmienna) which is charged to individual municipalities.

The amount of the variable premium is determined by two main factors:

- the portion resulting from the amount of transportation provided, and,
- the part resulting from the surcharge covering the organization's operating costs.

Implemented plans and settlements are carried out in annual cycles, their rules are gradually modified and therefore variable in subsequent years.

In 2021, there was a need to develop a data model that would allow the heads of individual municipalities (mayors, aldermen, mayors) to present the components of the surcharge that burden each municipality in a relatively simple way. This paper presents the issues and stages of building such a model.

2. Data analysis and sharing model

2.1. Input data

The input data for the model were binders of data provided by two departments that deal with the settlement of transportation costs One of them deals with the determination of the so-called variable contribution, i.e. the fee that individual municipalities pay to the joint budget.

The process of collecting the transformation of cleansing and unifying the data was presented within the framework of the article entitled ”Model of data of the settlement of costs of public transport operating on the territory of the Upper Silesian Metropolitan Union”.

All post-processing data was aggregated into a single standardized dataset. The dataset was organized in such a way that the data could be processed and grouped using the standard mechanism offered by spreadsheet pivot tables.

2.2. Tabular summary

The first columns of the dataset contain data allowing the grouping of objects in the following sections:

1) Affiliation:
   a) GZM municipalities - municipalities belonging to the GZM (http://gzmetropolia.pl/metropolia),
   b) Foreign municipalities - municipalities not belonging to the GZM,
   c) GZM - a virtual group collecting three virtual "municipalities" that are directly financed by GZM funds:
      – COMMUTING - a "municipality" that shows funding for tram access between the tram depot and the end stops,
      – GZM - "municipality" which shows funding for metropolitan lines (marked M), some bus and tram lines funded directly by GZM,
      – EVENTS - "municipality" which shows funding for additional tram lines created to serve events held in the GZM,
   d) OTHER - a virtual group collecting two virtual "municipalities" that have additional funding:
      – Hypermarkets - lines created for the purpose of access to hypermarkets,
      – Detours - additional routes resulting from the need to create detours,
   e) Airport - a group of lines serving access to Pyrzowice airport (marked AP).
2) Operator Type:
   a) PKM - the operators are Public Transport Companies:
      – PKM Gliwice,
      – PKM Katowice,

- PKM Sosnowiec,
- PKM Świerklaniec,
- PKM Tychy,

b) PRYW - operators are private carriers and Motor Transport Companies (PKS),
c) TRAM - operator is the company TRAMWAJE ŚLĄSKIE S.A.,
d) TROLLEYBUS – operator is the company TLT Sp. z o.o.

3) Type of Line:
   a) A – buses,
   b) T – trams,
   c) TB – trolleybuses,
4) Operator – all operats taking part in organizing the transport,
5) Line number – number of particular lines,
6) Municipality – all municipalities including virtual "municipalities" participating in the organization of transportation,
7) Year – years from 2020 to 2024,
8) Data type – presents the plan and execution data, respectively.

The appearance of the cross- section selection panel is shown in Figure 1.

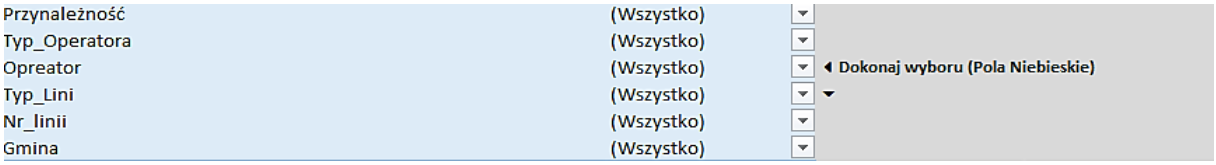

Figure 1. Cross-sectional data analysis panel.

Source: own study.

The tabular part of the cost analysis is divided into six sections.

The first section of the data model shows net transportation costs, where the following types of costs are distinguished:

1) M net cost – Costs of bus transport operated by M-type vehicles,
2) A net cost – Costs of bus transport operated by A-type vehicles,
3) B net cost – Costs of bus transport operated by B-type vehicles,
4) C net cost – Costs of bus transport operated by C-type vehicles,
5) TB net cost – trolleybus transport costs,
6) T net cost – tram transport costs by group:
   a) A - capacities < 150seats (length < 20m), high-floor,
   b) AN - capacities < 150 seats (length < 20m), low-floor,
   c) B - capacities > 150 seats (length 20-30m), high-floor,
   d) BN - capacities > 150 seats (length 20-30m), low-floor,
   e) CN - capacities > 150 seats (length > 30m), low-floor.

The classification of each type of tram carriage is shown in Table 1 (Tundys, 2008; Lubka, Stiasny, 2011, pp. 20-21).

Table 1.
Tram rolling stock - groups

Wagon type	Group
105N/E1	A
2x105N	B
116th	BN
PT-8	B
PTM	BN
2012N	CN
2017N	BN
2020N	CN
MF10AC	AN
MF/AC	BN
105NK	A
2*105NK	B
105HF	A
2*105HF	B

Note. Division of tram rolling stock into groups.

The appearance of the first section is shown in Figure 2

Wartości	2022 Plan	2022 Wykonanie	2022-2022 Różnica Wykonanie-Plan	2022-2022 Odchylenie % Wykonanie-Plan	2022-2022 Efekt wzkm (PLN)	Wykonanie-Plan Efekt stawki (PLN)
M koszt netto	18 237 880	21 409 468	3 171 589	17,4%	-320 846	3 492 434
A koszt netto	25 196 638	26 766 548	1 569 910	6,2%	-1 116 020	2 685 930
B koszt netto	419 601 661	448 100 021	28 498 361	6,8%	-31 504 798	60 003 159
C koszt netto	254 812 186	280 706 644	25 894 458	10,2%	-9 470 299	35 364 757
TB koszt netto	14 156 758	14 262 718	105 960	0,7%	105 960	0
T koszt netto	175 326 942	142 147 550	-33 179 392	-18,9%	-32 173 144	-1 006 248
T "A" koszt	*51 720 216*	*21 310 802*	*-30 409 413*	*-58,8%*	*-31 720 659*	*1 311 246*
T "AN" koszt	*8 931 089*	*8 718 949*	*-212 141*	*-2,4%*	*-224 952*	*12 811*
T "B" koszt	*17 889 353*	*34 269 347*	*16 379 994*	*91,6%*	*16 932 898*	*-552 904*
T "BN" koszt	*60 861 792*	*49 234 302*	*-11 627 490*	*-19,1%*	*-8 894 478*	*-2 733 013*
T "CN "koszt	*35 924 492*	*28 614 151*	*-7 310 342*	*-20,3%*	*-4 039 007*	*-3 271 334*

Figure 2. Section I.

Source: own study.

Section two of the data model includes additional costs charged to the bus and trolleybus fleet among which costs are distinguished:

1) AIR CONDITIONING – costs of air conditioning,
2) MONITORING – costs of monitoring installed in the fleet,
3) WIFI – costs of wireless access to the Internet available in the fleet,
4) SDIP – costs of operating the Dynamic Passenger Information System (SDIP). SDIP is an integrated information system that provides information on the performance of transportation tasks performed by public transportation to passengers and makes it available to supervisory services (https://sprint.pl/pl/uslugi/sdip-system-dynamicznej-informacji-pasazerskiej),
5) PPK – the cost of operating the Employee Capital Programs (ECP) program,
6) Wage_min – costs of handling the equalization of wages to the statutory minimum wage level,
7) OTHERS – other costs unclassified before.

The appearance of the second section is shown in Figure 3.

Wartości	2022 Plan	2022 Wykonanie	2022-2022 Różnica Wykonanie-Plan	2022-2022 Odchylenie % Wykonanie-Plan
A i TB koszty dodatkowe	48 412	522 206	473 795	978,7%
KLIMA koszt netto	*0*	*0*	*0*	
MONITORING koszt netto	*0*	*0*	*0*	
WIFI koszt netto	*0*	*0*	*0*	
SDIP koszt netto	*0*	*0*	*0*	
PPK koszt netto	*48 412*	*97 626*	*49 215*	*101,7%*
Płaca_min koszt netto	*0*	*370 234*	*370 234*	
INNE koszt netto	*0*	*54 346*	*54 346*	

Figure 3. Section II.

Source: own study.

The third section of the data model determines the size of the contribution that individual municipalities must make to the joint budget that finances public transportation on the territory of GZM.

The following elements are additionally included in the settlement:

1) Ticket revenue;
2) Costs of the organization;
3) Lost revenue (free rides for children and youth);
4) Lost income (railroads);
5) Lost income (other);
6) Sheds (W);
7) Other settlements (I).

The appearance of the third section is shown in Figure 4.

Wartości	Plan	Wykonanie	Różnica Wykonanie-Plan	Odchylenie % Wykonanie-Plan
Koszty Przew. finansowane przez Gminy	**915 634 120**	**944 062 900**	**28 428 780**	**3,1%**
Dochody z biletów	260 751 747	189 113 356	-71 638 391	-27,5%
Koszty organizacji	19 655 853	13 886 148	-5 769 705	-29,4%
Utracone dochody (bezpłatne przejazdy dzieci i młodzież)	16 416 400	18 192 550	1 776 150	10,8%
Utracone dochody (kolej)	1 125 306	3 084 893	1 959 586	174,1%
Utracone dochody (inne)	0	2 639 902	2 639 902	

Figure 4. Section III.

Source: own study.

Another, fourth section of the data model includes the incremental costs charged to the tram fleet. These costs have been accounted for differently between partners over the years. Thus, until 2021, these costs were fully funded by individual municipalities. Starting in 2022, part of the costs were separated and their financing was taken over directly by the GZM. The additional costs of the trolley fleet include such elements as:

1) Air conditioning – costs of air conditioning in trams,
2) Cost of commuting trips – the cost of commuting of tram fleet between the depot and the end stops,
3) Stop fees – fees related to maintenance of stops,
4) Property tax,
5) Perpetual use of land,
6) Depreciation of other assets,
7) Maintenance of tracks, networks, substations,

8) Depreciation of infrastructure,
9) Depreciation of fleet,
10) Redemption of bonds,
11) Financial costs.

The value of the designated contribution in this section is the amount that is charged to the budgets of each municipality. The values from the previous sections allow you to understand the individual components that burden the municipal budget. The appearance of the fourth section is shown in Figure 5.

Wartości	Plan	Wykonanie	Różnica Wykonanie-Plan	Odchylenie % Wykonanie-Plan
Podatek od nieruchomości	*22 753 208*	*20 421 970*	*-2 331 238*	*-10,2%*
Użytkowanie wieczyste gruntów	*390 118*	*402 694*	*12 576*	*3,2%*
Amortyzacja pozostałego majątku	*11 391 440*	*12 654 324*	*1 262 884*	*11,1%*
Utrzymanie torów, sieci, podstacji	*33 593 489*	*36 159 231*	*2 565 742*	*7,6%*
Dodatkowe wynagrodzenie Tramwajów Część inwestycyjna (TrIn)	48 515 813	49 373 622	857 809	1,8%
Amortyzacja infrastruktura	*15 499 859*	*12 727 109*	*-2 772 750*	*-17,9%*
Amortyzacja tabor	*11 419 048*	*10 923 411*	*-495 637*	*-4,3%*
Wykup obligacji	*6 216 256*	*0*	*-6 216 256*	*-100,0%*
Koszty finansowe	*15 380 650*	*25 723 102*	*10 342 452*	*67,2%*
Rozliczenie wiat (R1)	2 297 773	2 955 116	657 343	28,6%
Rozliczenie audytu rekompensaty PKM Świerklaniec (R2)	0	5 520	5 520	
Rozliczenie audytu rekompensaty PKM Tychy (R3)	0	-994 366	-994 366	
Rozliczenie audytu rekompensaty Tyskie Linie Trolejbusowe (R4)	0	927 160	927 160	
Dopłata do linii 69 w gminie Żory (R5)	0	40 724	40 724	
Zmienna część składki rocznej dla gmin z uwzględnieniem dodatkowych rozliczeń (ZczS+TrBi+TrIn+R1+R2+R3+R4+R5)	**776 438 361**	**867 270 856**	**90 832 495**	**11,7%**

Figure 5. Section IV.

Source: own study.

The fifth section contains quantitative data showing the amount of kilometers traveled by each type of the fleet. The appearance of the fourth section is shown in Figure 6.

Wartości	Plan	Wykonanie	Różnica Wykonanie-Plan	Odchylenie % Wykonanie-Plan
J. W. bez części inwestycyjnej TŚ SA	**727 922 548**	**817 897 234**	**89 974 686**	**12,4%**
M wzkm	4 140 760	4 074 327	-66 433	-1,6%
A wzkm	4 675 328	4 478 939	-196 390	-4,2%
B wzkm	64 370 130	59 870 432	-4 499 698	-7,0%
C wzkm	32 423 771	31 298 202	-1 125 568	-3,5%
TB wzkm	1 437 234	1 447 992	10 757	0,7%
T pkm	14 496 559	11 827 952	-2 668 607	-18,4%

Figure 6. Section V

Source: own study.

The sixth section shows the cost per kilometer of each transport unit. The appearance of the fourth section is shown in Figure 7.

In addition, in the columnar layout there are two areas that allow you to select any combination of comparisons of data type (Plan-Execution) and time (Years 2020-2024). This means that you can compare, for example, the assumed plans between years or compile a comparison of the plan and execution for a set period (year). After determining the dimensions of the data, you get basic information such as the difference in value and percentage between the selected dimensions.

Wartości	Plan	Wykonanie	Różnica Wykonanie-Plan	Odchylenie % Wykonanie-Plan
Praca eksploatacyjna (wzkm;pkm)	**121 543 781**	**112 997 844**	**-8 545 938**	**-7,0%**
Koszt M PLN/wzkm	4,40	5,25	0,85	19,3%
Koszt A PLN/wzkm	5,39	5,98	0,59	10,9%
Koszt B PLN/wzkm	6,52	7,48	0,97	14,8%
Koszt C PLN/wzkm	7,86	8,97	1,11	14,1%
Koszt TB PLN/wzkm	9,85	9,85	0,00	0,0%
Koszt T PLN/pkm	12,09	12,02	-0,08	-0,6%
Koszt przewozowy PLN/wzkm;pkm	7,47	8,26	0,80	10,7%
Koszt całkowity z narzutami PLN/wzkm;pkm	6,39	7,68	1,29	20,1%

Figure 7. Sekcja VI.

Source: own study.

A sample table and charts are shown in Figure 8.

Przynależność	(Wszystko)	
Typ_Operatora	(Wszystko)	
Typ_Lini	(Wszystko)	◂ Dokonaj wyboru (Pola Niebieskie)
Opreator	(Wszystko)	
Nr_linii	(Wszystko)	
Gmina	(Wszystko)	

Wartości	2021 Plan	2021 Wykonanie	2021-2021 Różnica Wykonanie-Plan	2021-2021 Odchylenie % Wykonanie-Plan	2021-2021 Efekt wzkm (PLN)	Wykonanie-Plan Efekt stawki (PLN)
M koszt netto	16 295 957	15 676 879	-619 078	-3,8%	-994 362	375 284
A koszt netto	22 599 137	22 454 352	-144 786	-0,6%	-743 747	598 961
B koszt netto	308 501 419	328 288 699	19 787 280	6,4%	5 001 140	14 786 140
C koszt netto	196 232 930	212 817 356	16 584 426	8,5%	6 754 663	9 829 763
TB koszt netto	11 817 481	12 704 174	886 694	7,5%	886 694	0
T koszt netto	222 617 629	199 627 138	-22 990 490	-10,3%	-19 088 796	-3 901 695
A i TB koszty dodatkowe	13 333 495	13 531 146	197 651	1,5%		
T koszty dodatkowe	39 467 920	38 834 920	-633 000	-1,6%		
Klimatyzacja	*0*	*0*	*0*			
Koszt kursów dojazdowych	*0*	*0*				
Finansowane przez Gminy (T)	*39 467 920*	*38 834 920*	*-633 000*	*-1,6%*		
Finansowane przez GZM			*0*			
Koszty Przew. finansowane przez Gminy	**791 398 049**	**805 099 745**	**13 701 696**	**1,7%**		
Dochody z biletów	237 800 000	145 752 718	-92 047 282	-38,7%		
Koszty organizacji	35 383 179	13 516 178	-21 867 001	-61,8%		
Utracone dochody (bezpłatne przejazdy dzieci i młodzież)	15 616 653	15 697 000	80 347	0,5%		
Utracone dochody (kolej)	2 314 815	1 537 396	-777 419	-33,6%		
Utracone dochody (inne)	0	61 724	61 724			
Składka zmienna	**571 049 760**	**655 567 085**	**84 517 324**	**14,8%**		
Wiaty (W)	1 024 743	0	-1 024 743	-100,0%		
Inne rozliczenia (I)	0	31 238	31 238			
Składka zmienna + T + W + I	**611 542 423**	**694 433 242**	**82 890 819**	**13,6%**		
M wzkm	3 949 423	3 711 261	-238 162	-6,0%		
A wzkm	4 589 286	4 440 258	-149 028	-3,2%		
B wzkm	54 579 660	55 443 906	864 247	1,6%		
C wzkm	29 407 592	30 395 515	987 923	3,4%		
TB wzkm	1 320 389	1 419 461	99 072	7,5%		
T pkm	13 818 542	12 622 690	-1 195 852	-8,7%		
T "A" pkm	*6 200 316*	*4 731 969*	*-1 468 347*	*-23,7%*		
T "AN" pkm	*785 775*	*899 111*	*113 336*	*14,4%*		
T "B" pkm	*2 790 504*	*2 119 947*	*-670 557*	*-24,0%*		
T "BN" pkm	*2 033 852*	*2 838 831*	*804 979*	*39,6%*		
T "CN" pkm	*2 008 095*	*2 032 832*	*24 737*	*1,2%*		
Kursy Dojazdowe pkm	*0*	*0*	*0*			
Praca eksploatacyjna (wzkm;pkm)	**107 664 892**	**108 033 092**	**368 199**	**0,3%**		
Koszt M PLN/wzkm	4,13	4,22	0,10	2,4%		
Koszt A PLN/wzkm	4,92	5,06	0,13	2,7%		
Koszt B PLN/wzkm	5,65	5,92	0,27	4,8%		
Koszt C PLN/wzkm	6,67	7,00	0,33	4,9%		
Koszt TB PLN/wzkm	8,95	8,95	0,00	0,0%		
Koszt T PLN/pkm	16,11	15,81	-0,30	-1,8%		
Koszt przewozowy PLN/wzkm;pkm	7,23	7,33	0,10	1,4%		
Koszt całkowity z narzutami PLN/wzkm;pkm	5,68	6,43	0,75	13,2%		
Wydatki ZTM + UM nie finansowane składką zmienną - razem	**64 234 842**	**22 258 913**	**-41 975 929**	**-65,3%**		
Wydatki UM nie finansowane zmienną częścią składki rocznej	64 234 842	22 258 913	-41 975 929	-65,3%		
Wydatki ZTM nie finansowane zmienną częścią składki rocznej	151 361 633	73 047 799	-78 313 834	-51,7%		

Figure 8. Example of the result table for bus fleet settlements.

Source: own study.

In addition, for the data of the first section, two values are determined for each type of rolling stock, which break down the value difference into parts showing the changes in costs due to the difference in fare rates in the compared dimensions (price effect) and the difference in the number of kilometers traveled between the set dimensions (distance effect), respectively.

3. Graphical overview

In addition to the analytical tabular presentation which can be difficult for some audiences to perceive, a graphical presentation of the changes of individual component factors on the change in the variable premium was prepared. The graphical presentation shows the individual components that affect the change in costs between the two selected points chosen in the tabular section. The first point is the parameters determined in the first column of the selection and, respectively, the second point in the second column. Each point is determined by a selection from a pair of parameters:

– Years (2020-2024),

– Plan – Execution.

With this approach, the types can be compared:

– Plan – Plan,

– Execution – Execution,

– Plan – Execution.

Compiled within the framework of different years.

The starting point is the amount of the variable contribution determined for point one, then the cost factors that affect the change in costs are shown until reaching the amount of the contribution selected in point two. Components marked in green indicate an element that reduces costs, and components marked in red indicate elements that increase costs. An example of a cost analysis summary is shown in Figure 9.

Analogous to the cost visualization, a summary is presented showing the distance settlement in thousands of kilometers for each type of rolling stock used in the public transport organization. An example of a summary of the settlement of kilometers is shown in Figure 10.

The next graphic shows the structure of costs at both boundary points. An example is shown in Figure 11.

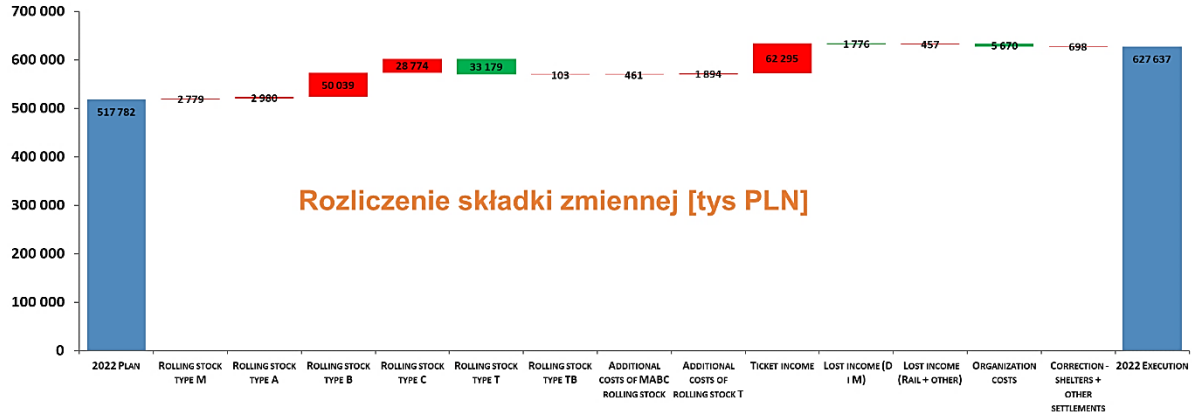

Figure 9. Costs settlement.

Source: own study.

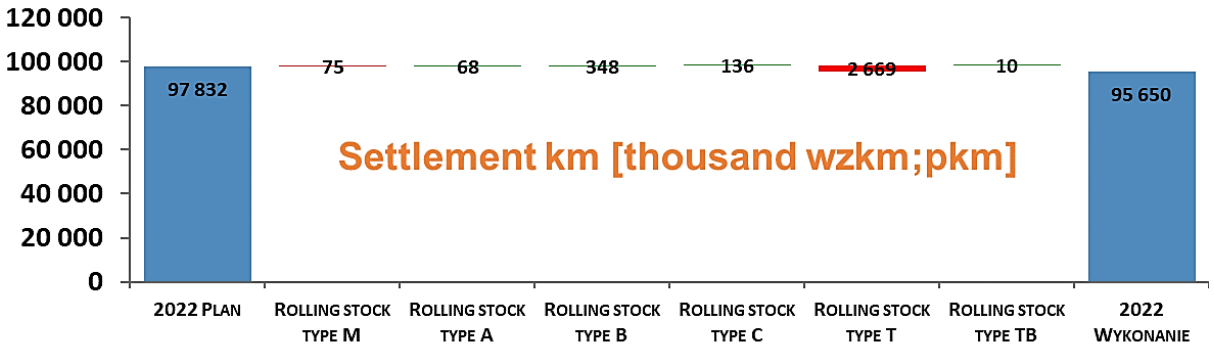

Figure 10. Kilometers settlement.

Source: own study.

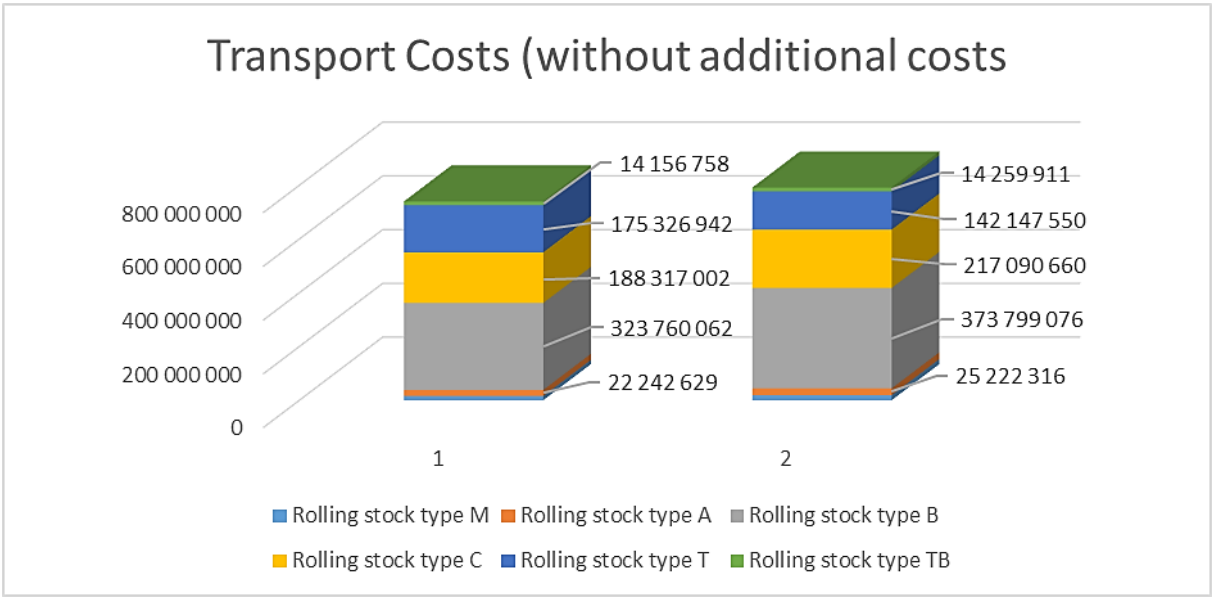

Figure 11. Cost structure.

Source: own study.

4. Final conclusions

The scope of this study is limited to the second stage of work which included the scope of construction of the data processing model and the tool for its analysis. Preparation of the tool in a clear and precise manner allows the end user to analyze the causes of deviations between the compared points. Explain the components that go into the variable premium allowing municipal administrators to better understand the reasons that determine the amount of fees that must be paid by the municipal budget to the GZM.

The expediency and correctness of the application of the presented solution is evidenced by the fact that to date three cycles of settlements, carried out at annual intervals, have already been implemented using the presented tool.

Data analysis using the developed tool will be presented by the author as part of the next article in this series.

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