

# Traffic Safety Analysis in Silesia with Tram Communication Especially Included

Sylwester Markusik, Damian Gaška

*Silesian University of Technology, Faculty of Transport, Katowice, Poland*

The article discusses the subject of road safety by means of the analysis of road traffic accidents with particular emphasis on accidents involving tram fleet in terms of the planned tramway investment program for the years 2008 – 2013 in Silesian Agglomeration. Due to the nature of the location of tracks in the road or in their direct neighborhood, accidents involving tram fleet are included in the majority of road accidents. This article presents a summary of road accidents involving the tram fleet, and their cost compared to all road accidents in the years 2006 - 2008 in Silesia.

## 1. GENERAL SAFETY ANALYSIS IN POLAND AND SILESIA

Road transport is the most dangerous of all modes of transport. It is estimated that over 90% of all fatalities in transport arises as a result of road accidents. The need to take actions to reduce the number of road accidents and limit their impact results not only from humanitarian motives, but also from economic ones. The transport sector in the European Union employs more than 10 million people and generates approximately 10% of EU GDP. The total cost of road accidents in the EU, related to the liquidation of their consequences, rehabilitation of victims, loss of productivity, is estimated at 160 billion euros per year, equivalent to approximately 2% of EU GDP. In Poland, the annual losses due to the cost of road accidents are estimated at more than 2.11% of Poland's GDP [2].

The basic principle is that each traffic participant is required to avoid a collision with other vehicle, pedestrians, etc. regardless of whether the others had acted in accordance with the principles of Highway Code or not. When performing dangerous maneuvers (such as overtaking or changing the direction of travel) and in dangerous places (such as crossroads, pedestrian crossing etc.) Highway Code requires special attention.

Still, every year on EU roads in road accidents 40,000 people die and 1.7 million are injured. In 2008 there was a slight decrease in risk on the roads compared to 2007, but it is small in relation to growth in previous years. In 2008, in 49,030 road accidents 5,433 people died and 62,092 people were injured. Compared to 2007 the number of accidents fell by 1%, the number of deaths by 3% and injured by 2%. Statistics of road accidents and their consequences in a number of fatalities and the injured in the years 1990-2008 are shown in Figure 1.

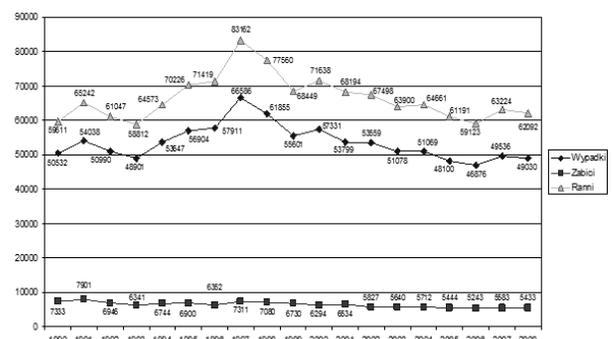


Fig. 1. Traffic accidents, fatalities and the injured in 1990-2008 in Poland

Source: own elaboration on the basis of [1]

Table 1. Road accidents and their consequences in Polish regions in 2006-2008

Region	Accidents			Fatalities			Injured		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Dolnośląskie	3034	3148	3006	345	362	364	3963	4369	4113
Kujawsko-pomorskie	2052	2041	1910	347	364	311	2561	2570	2351
Lubelskie	2211	2418	2359	341	351	372	2757	3050	2956
Lubuskie	835	908	906	147	155	170	1125	1191	1236
Łódzkie	4555	4848	4773	415	447	439	5624	6055	5954
Małopolskie	4440	4721	4680	308	341	344	5692	6147	5976
Mazowieckie	6639	6873	6927	856	959	920	8211	8469	8417
Opolskie	1050	1087	1043	128	136	141	1328	1395	1281
Podkarpackie	2224	2278	2359	260	257	234	2874	2985	3006
Podlaskie	1138	1171	1137	208	209	162	1429	1454	1483
Pomorskie	2755	3067	3201	259	271	265	3538	4004	4161
Śląskie	6183	6324	5908	427	476	455	7746	7877	7299
Świętokrzyskie	1897	1927	1904	222	256	243	2356	2409	2364
Warmińsko-mazurskie	1655	1979	2244	248	271	224	2123	2611	2954
Wielkopolskie	4503	4892	4884	513	511	553	5720	6358	6269
Zachodniopomorskie	1778	1937	1860	234	229	244	2180	2411	2342
<b>Total</b>	<b>46949</b>	<b>49619</b>	<b>49101</b>	<b>5258</b>	<b>5595</b>	<b>5441</b>	<b>59227</b>	<b>63355</b>	<b>62162</b>

Source: own elaboration on the basis of [1]

According to the information from the Regional Police Headquarters in Katowice, Silesia has been in second place nationwide in terms of number of accidents for 3 years now, ranking behind only the larger territorially Mazowieckie region. Summary data on the number of accidents and the number of fatalities and injured for the individual regions in the period 2006-2008 are included in table 1. General assessment of road safety determines accident ratios, namely:

- number of accidents per 1000 inhabitants,
- number of fatalities per 1000 inhabitants,
- fatalities per 100 accidents.

Accident rates for the region of Silesia in the 2006-2008 are shown in table 2.

Table 2. Road accident ratios in Silesia in 2006-2008

Accident ratio	2006	2007	2008
Number of accidents per 1000 inhabitants	1,32	1,36	1,27
Number of fatalities per 1000 inhabitants	0,09	0,10	0,10
Fatalities per 100 accidents	6,24	6,93	7,14

Source: own elaboration and [5]

## 2. TRAMWAY NETWORK IN SILESIA

The system of trams in Upper Silesian Industrial District which is 110 years old covers 332 km of tracks located in 13 towns of Silesian Agglomeration (trams also occurs in the area of Silesia in Czestochowa, which is not covered by this publication). It is, in terms of length, one of the most extensive networks in concentrated urban areas in Europe. Within this tram network the passenger traffic is handled by 34 tram lines. In rush hour, these lines are operated by 256 carriages (202 trains). These lines of communication routes run on double track, single-track, as well as those that run on both types of tracks. In total, the single-track tram network is 330 km long; the network is 212 km long [3].

The main feature of the entire track system is its explicit form in the two areas historically associated with the old annexations: the Russian and Prussian. This clearly visible division of the tram network covers two areas clearly visible in Fig. 2 and 3 (area 1 - Katowice, Bytom, Gliwice, Chorzów, Zabrze, Siemianowice Śląskie, Świętochłowice,

Ruda Śląska; area 2 - Sosnowiec, Będzin, Dąbrowa Górnicza, Mysłowice, Czeladź). The tram network operates on four depots located in Będzin, Katowice, Bytom and Gliwice.

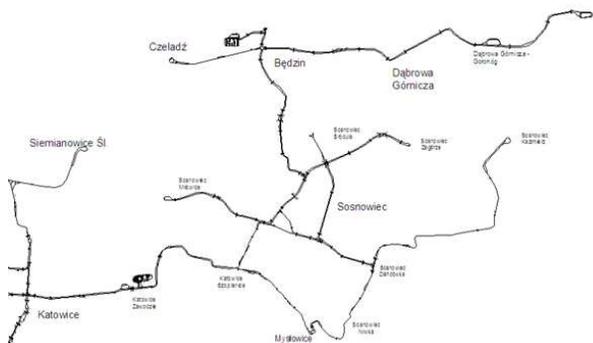


Fig. 2. Tram network in Silesia – east part.  
Source: own elaboration

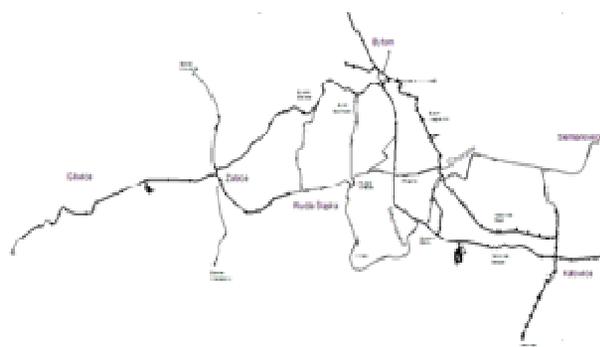


Fig. 3. Tram network in Silesia – west part.  
Source: own elaboration

Trackways are located mostly in the streets or in their immediate vicinity (Fig. 4), only in some cases occur as separated (Fig. 5). This is of great importance when concerning the road safety (the location of stops, repeatedly crossing the railway tracks to road traffic, etc.).



Fig. 4. Tram trackway at 3-go Maja Street in Katowice  
Source: own elaboration



Fig. 5. Separated tram trackway. Chorzowska Street in Katowice  
Source: own elaboration

### 3. TRAFFIC SAFETY IN ASPECT OF TRAM COMMUNICATION IN SILESIA

Due to the nature of the location of tracks in the road or in its immediate vicinity, accidents involving tram fleet are included in the majority of road accidents. This is also because 85% of accidents involving trams take place with a road vehicle drivers fault or the fault of pedestrians. Tram accidents, fatalities and injuries statistics for 2007 and 2008 are include in tab. 3. Accidents involving trams are only a 1.5% of all accidents in the Silesian Agglomeration. It can be therefore concluded that this means of transport is much safer than private transport vehicle.

Table 3. Tram accidents and their consequences in Silesia in 2006-2008

Year	Accidents	Fatalities	Injured
2007	108	10	152
2008	89	7	112

Source: own elaboration and [5]

Traffic accidents statistics only for trams in 2006-2008 in Silesia are shown in fig. 6, however fig. 7 shows traffic accidents statistics at the alternative roads in relation to tram trackway in 2006-2008 in Silesia. It is worth noting that, despite a small upward trend in traffic incidents, the number of fatalities falls for both tram and car accidents. Accidents and collisions involving trams occur mainly through the fault of motor vehicles drivers. Therefore vulnerable spots of tram network in terms of transportation security are places where tram traffic meets or

intersects with road traffic. Such points are the road intersections with the tram lines (Fig. 8), crossing the road in the vicinity of roundabouts, road sections where the tram line is located in the street (no dedicated lanes for trackways) and tram stops that do not have reserved areas (Fig. 9).

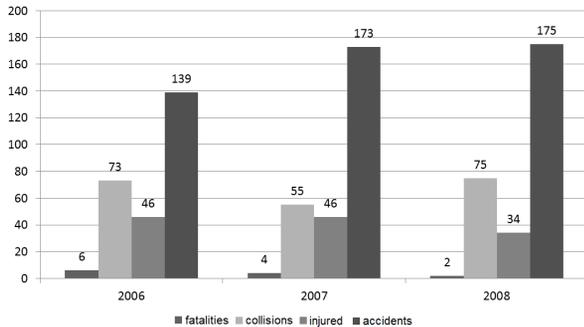


Fig. 6. Traffic accidents statistics only for trams in 2006-2008 in Silesia.

Source: own elaboration and [5]

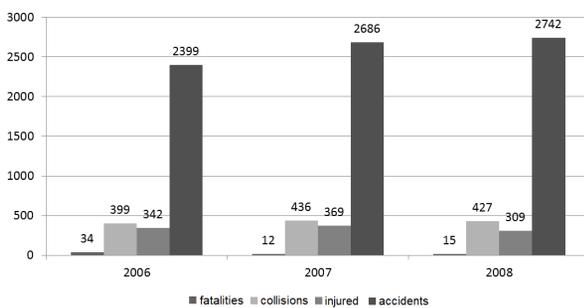


Fig. 7. Traffic accidents statistics at the alternative roads in relation to tram trackway in 2006-2008 in Silesia.

Source: own elaboration and [5]



Fig. 8. 3-go Maja and Słowackiego streets crossing in Katowice

Source: own elaboration



Fig. 9. Tram stop without safety island at 3-go Maja street in Katowice.

Source: own elaboration



Fig. 10. Tram trackway at Katowice market place.

Source: own elaboration

Unfortunately, quite important in the case of collisions, accidents and all other traffic incidents are, for tram transport in Silesia, the condition of track infrastructure (Fig. 10) and tram cars. Their condition unfortunately increases the possibility of collisions as well as generates too much noise.

In recent years, local authorities and the company Silesian Trams SA have slowly but steadily "rejuvenated" and modernized tram cars and trackways mainly with the help of EU funds and programs. One of such projects is the attempt to radically improve road safety in the field of tram lines and it's included in the "Program for investment development of tramway for the years 2008 - 2013" [5]. The authors of this paper took part in the preparation of this program.

Improving security should be manifested in this type of projects by elimination or significant reduction of the above risks (Fig. 11). In terms of

cost-benefit analysis economic factors are of decisive importance, as the economic benefits, resulting from the reduction in the number of road accidents, due to the acquisition of individual traffic by public transport. Potential cost savings road accidents are treated as economic benefits of public transport project.



Fig. 11. Renovated tram platform with traffic lights at 3-go Maja street in Katowice.  
Source: own elaboration

#### 4. ACCIDENTS COSTS WITH TRAM COMMUNICATION IN SILESIA ESPECIALLY INCLUDED

The costs of accidents and their consequences are calculated similarly as for road projects using the methodology contained in [4]. It also contains a unit cost forecast of accidents, injuries and fatalities on the horizon for several years (tab. 4).

The costs of accidents include:

1. losses resulting from the death of victims of accidents, including:

- estimated average loss of gross domestic product (minus consumption),
  - average cost of treatment,
  - average cost of a funeral,
  - average compensation (including payments from voluntary insurance)
2. losses resulting from the injuries in road accidents, which include the following:
    - heavy accident with permanent disability,
    - average case,
    - light accident,
    - including:
      - estimated average loss of gross domestic product,
      - average cost of treatment and rehabilitation,
  3. estimated material costs attributable to an accident

Table 4. Unit costs of road incidents (zł/incident)

Unit costs of road incidents			
Year	Fatalities	Injured	Material
2009	1 446 294	204 692	15 160
2010	1 606 790	230 310	17 295
2011	1 767 285	255 932	19 430
2012	1 927 781	281 553	21 566
2013	2 088 280	307 174	23 701
2014	2 248 775	332 795	25 836
2015	2 409 271	358 413	27 968
2016	2 569 769	384 034	30 103
2017	2 730 265	409 655	32 238
2018	2 890 760	435 277	34 373
2019	3 051 256	460 898	36 508
2020	3 211 755	486 516	38 643
2021	3 372 250	512 137	40 778
2022	3 532 746	537 758	42 913
2023	3 693 245	563 379	45 048
2024	3 853 740	589 001	47 183
2025	4 014 236	614 618	49 319
2026	4 174 731	640 240	51 454
2027	4 335 230	665 861	53 589
2028	4 495 725	691 482	55 724
2029	4 656 221	717 103	57 859
2030	4 816 720	742 724	59 994
2031	4 977 215	768 342	62 126
2032	5 137 711	793 964	64 261
2033	5 298 206	819 585	66 396
2034	5 458 705	845 206	68 531
2035	5 619 200	870 827	70 666
2036	5 779 696	896 445	72 801

2037	5 940 195	922 066	74 936
2038	6 100 690	947 687	77 072
2039	6 261 186	973 309	79 207
2040	6 421 681	998 930	81 342

Source: [4]

In order to calculate the benefits resulting from the reduction of the number of accidents, the number of accidents for the investment variant (one or more) must be estimated and then referred to the base case (variant 0). Basis for the estimate of the costs of accidents are:

- number of roads accidents in the last 3 years,
- expected number of accidents after the investment in each of the variants,
- unit cost per case.

The costs of accidents, injuries and fatalities for the base investment case (variant 0) of "Program for investment development of tramway for the years 2008 - 2013" was calculated on the basis of statistical data for the years 2006-2008 obtained from the Traffic Division of the Regional Police Headquarters in Katowice. The forecast of the number of accidents, injuries and fatalities for the base case is based on the same trend as in recent years (linear regression). All data and assumptions to calculate and analyze the costs associated with traffic safety, as a result of the investment, were taken from [5].

Table 5. Variants of "Program for investment development of tramway for the years 2008 - 2013"

Degree of modernization	Variant 0	Variant 1	Variant 2	Variant 3	Variant 4
Trackway modernization	-	+	+	+	+
Separation or moving trackway from the middle of the road	-	-	-	+	-
Collision-free intersection system	-	-	-	-	+
Traffic control improving	-	-	+	+	+
Tram stop platforms modernization	-	+	+	+	+
Modern fleet purchase	-	-	+	+	+
Fleet modernization	-	-	+	+	+

Source: [5]

In order to calculate the benefits from reducing the number of accidents for investment options (Table 5) the forecast number of accidents for these options, based on the change of transport work, was calculated. These values were referred to the base case with use of the calculated reduction factor due to the different technical parameters (that will improve safety in case of realization of the planned investment) from the field of traffic safety. The reduction factors were determined based on Traffic Division of the Regional Police Headquarters in Katowice and Silesian Trams SA data, own experiences and accident fall analysis for the investment already realized (tab. 6).

Table 6. Reduction factor values

Improving safety parameters	Reduction factor value
Modernization of infrastructure (track, platform stops, traction)	0,98
Traffic control as tram priority on the modernized sections	0,90
Modern fleet purchase and fleet modernization	0,98
Partial trackway offset by eliminating the left turnings downtime	0,90
Collision-free intersection system on main crossways	0,50

Source: own elaboration

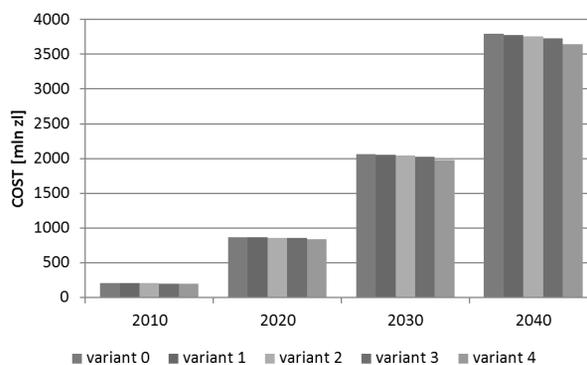


Fig. 12. Costs in case of safety related to traffic accidents, fatalities and injured in individual years. Results from execution of investment variants.

Source: own elaboration and [5]

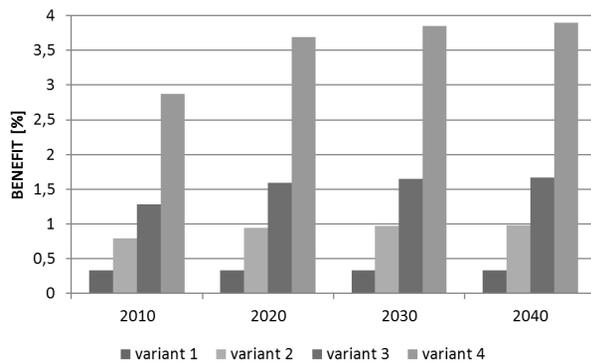


Fig. 13. Percentage profit in case of safety related to traffic accidents, fatalities and injured. Results from execution of investment variants.

Source: own elaboration and [5]

It was also adopted that the change of accidents on the road sections that are an alternative to tram lines will result from a possible modal shift (from car to tram) for current road users. After analyzing questionnaire data it was assumed to reduce the number of accidents by 1%. Summary of accident costs for investment options and comparison with base case (variant 0) are shown in fig. 12 and fig. 13.

## 5. SUMMARY

Because the expenditures on road safety are of high profitability, appropriate investment in safety improvements would save resources that can then be spent on economic development. Traffic safety is the part of public safety and should be treated as actions to improve the living conditions of society.

As a result of investments related to improving the technical parameters of modernized road sections and tram trackways in Silesian Agglomeration, as well as with the new fleet, the comfort of traveling on the lines will significantly increase. It will result in an increase in the number of customers travelling by trams and a reduction in the number of individual transport trips, thus reducing the number of road accidents alternative to the tram lines. According to the assumptions decrease in the number of injuries and fatalities will appear. Such a change will have its impact, as well as economic indicators, which are the basis for evaluation of infrastructure projects in transport security.

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