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TRUCK TRIP GENERATION RATES FOR DIFFERENT TYPES OF FACILITIES IN POLAND

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Abstract

Measurements to estimate truck trip generation of particular facilities, such as warehouses, factories and logistics centres are rarely conducted in Poland. Those measurements are quite easy to conduct by counting vehicles entering and leaving a particular facility. Results of these studies might be used as the first step in a 4–stage model. Obtaining trip generation rates per 1 employee or 1000 sq m of company area would be useful for aggregation of trip generation from single generators to a given traffic zone. Moreover, the results would give information about daily variability in time (e.g. the peak hour). This paper presents research conducted in Krakow. The obtained trip generation rates are provided and compared with trip generation rates from other studies. Additionally, advantages and disadvantages of single generators measurement are discussed.

Keywords: trip generation, trip modelling, freight transport, 4–stage model, traffic measurements

1 Introduction

Freight traffic is very often generated by particular facilities, like manufacturing plants, warehouses, distribution centres or intermodal facilities. Those might be called single traffic generators as they are characterized by high accumulation of freight trips origins and destinations in one place. Although estimation of trip generation of different freight generators seems to be crucial to trip modelling, there were only a few studies conducted in Poland ([4], [11]). Nevertheless, the results of the research done so far provide interesting information, some of which will be reported in this paper. While reviewing trip generation studies, it is easy to notice that the majority of them were done in the United States of America. Trip generation studies were conducted for different types of facilities (e.g. [1], [2], [8]). Results of many different studies were gathered in Quick Response Freight Manual I/II ([5], [6]) as well as in NCHRP Reports ([9], [10]). Trip generation studies for particular cities were conducted as well ([7]). Since this paper deals exclusively with the situation in Poland, only Polish studies will be reviewed.

1.1 Review of Polish studies

Zipser T. et al [11] present the results of 24–hour measurements done at two shopping centres placed in the city of Wrocław. Trip generation rates, given in Table 1, were calculated per 1000 m2 of shopping centres usable area. Abbreviations used in Table 1, as well as throughout the whole text, are as follows: SD – delivery trucks, SC – single unit trucks, SCP – articulated trucks (a truck with a trailer or a tractor with a semitrailer).

Table 1   Trip generation rates for shopping centres in Wrocław [11].

Facility	Usable area in 1000 m²	Trip generation rates per 1000 m² of the usable area [trips/day/1000 m²]		
		SD	SC	SCP
1	36.7	2.23	1.63	0.33
2	58.0	3.14	1.69	0.76

In [4], the author analysed deliveries to one large–space building material store in Krakow for two months. This analysis was conducted under the supervision of the author of this paper. The data about the inbound and outbound traffic was given provided by the store operator. On the basis of the available data all trucks were classified as light (gross vehicle weight below 3.5 t) or heavy (gross vehicle weight above 3.5 t) trucks. It was proved that the number of deliveries on Mondays, Wednesday and Fridays are statistically significantly different from the number of deliveries on Tuesdays and Thursdays. The relevant trip generation rates are provided in Table 2.

Table 2   Trip generation rates for large–space building material store in Krakow [4].

Days of week	Trip generation rates per 1000 m² of the building area [trips/day/1000 m²]		
	All trucks	Light trucks	Heavy trucks
Mon, Wed, Fri	2.78	1.18	1.60
Tue, Thu	3.22	1.28	1.94

2 Trip generation for different facilities in Krakow

This part of the paper presents the results of the author's own research. The trip generation model was developed for different types of facilities as well as for different types of vehicles. Traffic measurements results were used for developing the model.

2.1 Data collection

The measurements were conducted in the year 2011. Different types of facilities were taken into account. For the majority of them measurements lasted from 6:00 to 18:00, which in most cases coincided with the facilities opening hours. For two logistic centres and manufacturing plant 24–hour measurements were conducted. Depending on facility registered number of trips varied from 31 to 344.

During the measurements, the number of freight vehicles that entered or left the analysed facility was recorded. For each vehicle entry and exit time, the registration number (if possible) and vehicle type were recorded. Freight vehicles were divided into 3 groups: SD – delivery trucks, SC – single unit trucks, SCP – articulated trucks (a truck with a trailer or a tractor with a semitrailer).

Table 3 Average trip generation rates for different types of facilities in Krakow [trips/12 hours].

Objects group	Unit	Trip generation rates per unit [trips/12 hours]					
		Production			Attraction		
		SD	SC	SCP	SD	SC	SCP
Concrete–mixing plant	1 are of site area	0.011	0.074	0.207	0.011	0.081	0.196
Office	1000 m² of office area	0.005	0.000	0.000	0.003	0.000	0.000
Large space shopping centre	1000 m² of usable area	1.145	0.314	0.225	0.853	0.269	0.205
Logistic centre	1000 m² of building area	3.721	2.381	2.348	3.501	3.227	2.055
Wholesale	1000 m² of building area	2.957	8.279	3.548	4.140	8.279	2.957
Warehouse	1000 m² of building area	0.395	0.000	0.099	0.444	0.000	0.049
Manufacturing plant	1000 m² of building area	2.007	0.973	0.519	2.506	1.346	0.561
Large space building materials store	1000 m² of building area	1.826	0.925	0.336	1.826	0.925	0.224
Building materials yard	1 are of site area	0.645	0.154	0.031	0.673	0.174	0.054
Waste sorting plant	1 are of site area	0.033	0.543	0.033	0.054	0.435	0.011
Truck service	1 are of site area	0.076	0.023	0.121	0.061	0.038	0.091

2.2 Review of the obtained results

2.2.1 Trip generation

The facilities were divided into different groups on the basis of the collected data. Trip generation rates (productions and attractions) were calculated for each group. The results are shown in Table 3. The sample sizes varied from 1 to 8 due to the scope of measurements which was to cover different types of facilities.

The results given in Table 3 confirm the obvious fact that truck trip generation is highly dependent on the facility type. Moreover, the production and attraction rates for a particular facility may differ. In some cases the reason is the measurement time (some trips were not registered), in others it is the facility type (e.g. logistic centres, manufacturing plants). On the other hand, for the concrete–mixing plant, large–space building materials stores or building material yards, production and attraction rates are equal. The obtained truck trip generation rates for the large–space building materials stores (the average trip generation rate for production and attraction equals 3 [trips/1000m²/day]) are the same as the results of [4] (average trip generation rate for all days equals 3 [trips/1000m²/day]

Table 4   Comparison of trip generation and trip generation rates for two logistic centres in Krakow [trips/day].

Logistic centre		Trip generation (A) Trip generation rates per 1000 m² building area (B) Trip generation rates per 1 are of site area (C)					
		Production			Attraction		
		SD	SC	SCP	SD	SC	SCP
LC 1	A	19	34	33	34	45	42
	B	1.056	1.889	1.833	1.889	2.5	2.333
	C	0.049	0.088	0.085	0.088	0.116	0.108
LC 2	A	17	31	30	10	18	27
	B	1.545	2.818	2.727	0.909	1.636	2.455
	C	0.049	0.089	0.086	0.029	0.051	0.077

For two logistic centres 24–hour measurements were conducted. The results are presented in Table 4. Trip generation (row A) and trip generation rates (rows B and C) are given for three types of freight vehicles. Although productions for both logistic centres are almost equal, trip generation rates are significantly different, which is the result of a different building area. A big difference in trip generation rates might also be observed for attractions. Differences in trip generations result from various characteristics of the logistic centres (in LC1 the warehouse space is rented by various companies while LC2 is used by only one company trading in household appliances).

2.2.2 Variability in time

For both logistic centres (LC1 and LC2) variability of inbound and outbound traffic during day was identified. The facilities operate 24 hours a day, and the analysis of variability covered the time from 6:00 to 6:00 the next day.
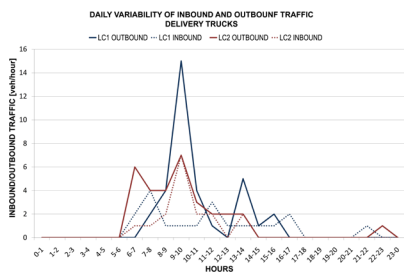

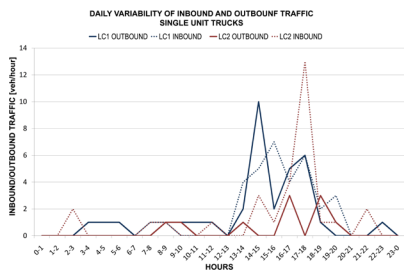**Figure 1**   Inbound and outbound traffic daily variability in time – delivery trucks.

Figure 2   Inbound and outbound traffic daily variability in time – single unit trucks.
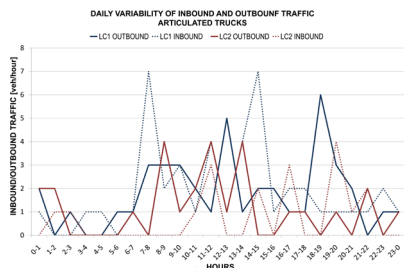
Figure 3 Inbound and outbound traffic daily variability in time – articulated trucks.

On presented figures high variability of inbound and outbound traffic might be seen. For delivery trucks peak hours might be determined between 8:00 and 10:00 (Fig. 1) while for single unit trucks between 14:00 and 18:00 (Fig. 3). For articulated trucks peak hours can be hardly specified (Fig. 3). Share of night traffic (from 18:00 to 6:00) for analysed logistic centres varies from 0 to 5 % for delivery trucks, from 15 to 40 % for single unit trucks, and from 22 to 50 % for articulated trucks.

A different time period was used to identify the variability in time in the case of the other logistic centre. Measurements were conducted on Thursdays for two subsequent weeks and covered the facility's whole opening time. The results presented in Table 5 show that even for the same day of the week trip generations for the same facility might be significantly different.

Table 5 Comparison of trip generation rates for one logistic centre on two days, measurement period 6:00 – 18:00 [trips/12 hours].

| No | Date | Trip generation Trip generation rates per 1000 m² of the building area | | | | | |
| | | Production | | | Attraction | | |
		SD	SC	SCP	SD	SC	SCP
1	20-11-2011	23 5.141	11 2.459	8 1.788	31 6.929	15 3.353	9 2.012
2	27-11-2011	18 4.023	5 1.118	13 2.906	23 5.141	11 2.459	14 3.129

2.3 Model development

On the basis of the sample sizes, a trip generation model was developed for logistic centres and manufacturing plants. The linear regression model was used, as shown in Eq. (1):

$$TG = a \cdot X \qquad (1)$$

where: TG – trip generation (production or attraction) [trips/12 hours], a – model parameter, X – building area of the facility in 1000 m².

Due to the limited number of available explanatory variables, only the area of the building was used. The analysed objects were single–storey so the area of the buildings is almost equal to the usable area. Moreover, the model was developed for 12–hour period since such was the length of the measurement time. Model parameters for logistic centres are presented in Table 6 while for manufacturing plants in Table 7.

The obtained results show that only the trip generation model for delivery trucks for logistic centres and for single unit trucks for manufacturing plants has the satisfactory coefficient of determination. In other cases R^2 values are too low for the model to be acceptable.

Table 6   Trip generation model parameters for logistic centres.

Vehicle type	Production		Attraction	
	a	R^2	a	R^2
SD	2.96	0.93	2.95	0.93
SC	2.03	0.73	2.22	0.64
SCP	1.52	0.75	1.38	0.80

Table 7   Trip generation model parameters for manufacturing plants.

Vehicle type	Production		Attraction	
	a	R^2	a	R^2
SD	0.64	0.40	0.54	0.41
SC	0.33	0.93	0.32	0.83
SCP	0.34	0.67	0.45	0.68

3   Summary and conclusions

The reviewed Polish studies as well as the presented author's own research should be considered pilot studies. The scope and time period of the measurements permit showing only a fraction of the truck trip generation by different single freight generators. The aim of the author's research was to identify different types of facilities and the appropriate methodology. Nevertheless, the results it has brought are very interesting and may constitute a starting point for further research.

One of the problems that occurred during conducting the study was getting permission from facilities operators to do the measurements. None of the operators the author had approached agreed to provide data about inbound and outbound freight (except [4]). It was also impossible to get the information form the truck drivers. Because of these obstacles there is no information about the start (for inbound traffic) or end (for outbound traffic) of the freight trips. In further research, some support from the relevant authorities will need to be secured, which may encourage operators to cooperate.

One day measurement is too short and may give unreliable results. Measurements that cover a longer period (e.g. a week, a month) or several measurements during one year may give more accurate results. It may enlarge the sample size as well as enable the weekly, monthly or yearly variability of freight trip generation. The results presented in this paper proved that freight traffic is highly variable in time. Although it may seem a trivial conclusion, yet it confirms the results of other freight studies.

The developed model needs to be improved in further studies. It should cover a 24–hour time period and take more types of facilities and more sites into account. For manufacturing plants, the division into different lines of trade should be introduced. Nevertheless, the developed model may be used for making rough estimations of trip generation at planned logistic centres, manufacturing facilities or stores. Assuming the average share of night traffic, its daily trip generation may be estimated, as shown in Table 8.

Table 8   Proposed trip generation rates for three types of facilities [trips/day].

Facility	Trip generation (production or attraction) rates per 1000 m² of the building area [trips/day]		
	SD	SC	SCP
Logistic centre	3.02	2.80	2.32
Manufacturing plant	0.63	0.36	0.63
Large space building materials store	3.00		

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