Freight trip generation by firms

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Abstract

Traffic congestion problems are a constant cause of concern in today's centres of economic activity. While measures that deal with these problems, generally focus on the use of private cars, increasing freight traffic as a cause of road congestion should not be ignored. Forecasts of freight traffic at a local and regional scale are necessary to predict traffic flows on specific routes, and might be helpful in planning adequate infrastructure for future industrial estates. Such forecasts, however, require knowledge of the generation of freight trips by firms, a field in which little research has been done so far.

This paper describes an attempt to uncover the relationship between firm characteristics and freight traffic. The main purpose of the research described in the paper is to build a freight trip generation model which takes differences between sectors of industry into account. The study shows that trip intensity can vary over sectors by an order of magnitude, thus making this material of interest for city and infrastructure planning purposes. Specific attention is also given to the problems encountered in this type of research, which is based on firm-level survey data from a heterogeneous population.

1 Introduction

Road congestion is gradually becoming worse, and while much attention has been given to the role of the private car in this context, the contribution of freight transport by trucks to traffic congestion has received relatively little attention so far. Freight transport should be a matter of concern however, since economic growth is generally accompanied by a disproportionate increase of freight traffic. According to the middle scenario of a series of forecasts for the Dutch government, inland freight transport, measured in tonkilometres, is expected to increase by 60% in the period from 1999 to 2020 (AVV, 2000). Road freight transport will grow even faster, showing an increase of 72%. It will remain the most important mode in inland transportation, and its market share will increase even further. In all scenarios of the forecasts mentioned by the AVV, the predicted growth of freight transport is considerably larger than the growth in passenger transport, with the exception of air transportation.

Congestion is not just a problem for car drivers, but for shippers and carriers of freight as well. On a local scale, road infrastructure on and around industrial sites often has insufficient capacity to handle the occurring traffic flows, which results in congestion. Expected freight traffic flows are often not taken into account when the dimensions of the infrastructure on and around industrial sites are being planned.

For a better integration of spatial planning and traffic planning, it would be important to include the effects of industrial activities on transport and traffic in the early phases of the planning process of industrial estates. Supporting instruments and information are necessary for the implementation of suitable policy measures. In this context, a mobility check will be developed in assignment of the Dutch ministry of transport (Nationaal Verkeers- en Vervoersplan, 2000). Part of this mobility check is the estimation of the traffic flows that are generated by industrial sites.

In order to predict traffic generation by industrial sites, the relation between the different activities on an industrial site and the number of freight trips has to be specified. Information about this relation is scarce however. In the Netherlands and elsewhere, it has hardly been studied yet.

The research project described in this paper was meant to provide more information about this relation. This research was carried out by TNO Inro in assignment of the Dutch ministry of transport. It focuses on quantitative indicators of freight transport to and from industrial sites. This paper gives an outline of the main results.

2 Research framework

At the level of the individual firm, the number and type of freight trips can be regarded as the outcome of a series of decisions about products, markets, production locations, delivery times and frequencies, transport modes, types of vehicles and routes. At a collective level, the decisions of the individual firms result in transport and traffic flows at various geographic scales.

The relation between economic activity and transport flows is not a static one. It is influenced by internal and external factors such as company strategies, technological developments, government rules, etc.

The freight transport indicators to be examined in this study need to be practicable in all stages of the planning process for industrial sites. There are two main typologies that are important in this process, namely a typology of industrial sites and a typology of firms. Indicators based on the type of site are especially important at the start of the planning process, when knowledge of the particular firms that will be established at the site is lacking. During the later stages of the planning process, a more detailed analysis based on a typology of firms is needed.

A typology of industrial sites is given in the Nota ruimtelijk economisch beleid (1999):

- seaport sites: sites with quays, accessible for large sea-going vessels;
- heavy industry sites: sites that are suitable for large-scale industrial activities ;
- distribution sites: sites that are suitable for transport and distribution activities;
- high-quality business sites: sites that are suitable for companies with high-grade activities (production, research and development);
- mixed sites: sites that are suitable for economic activities that do not belong to the other types of sites.

A typology of firms may be based on firm characteristics like branch (trade, industry, service, etc.), size (measured in terms of employees, sales or area), environmental category, etc. In the research, we use the branch of industry as a starting point, since this characteristic gives a good indication of the kind of activity and commodities.

Important variables explaining freight trip generation are the number of employees, turnover, the (covered) floor area and the site area occupied by the firm(s) (Ortúzar and Willumsen 1994). These authors also point out that to their knowledge neither accessibility nor type of firm have ever been considered as explanatory variables; the latter is curious because it would appear logical that different products have different transport requirements.

In this research, we focus on the number of employees and the site area occupied by the firm as explanatory variables, since the relevant data are relatively easy to collect. The number of employees can be found in national databases, the area occupied by a firm in documents about the planning of the site in question.

3 A review of freight trip generation studies

The existing literature about traffic generation has a strong focus on passenger transport. Ortúzar and Willumsen (1994) notice that freight demand modelling is still less advanced than passenger demand modelling. The leading edge of research and development seems to have been passenger demand forecasting, with freight demand forecasting following its footsteps, trying to adapt the models to its particular needs.

A number of studies, carried out in the United States and the Netherlands in the past, were analysed within the context of the research described in this paper. The models that have been used in these studies to quantify the relation between economic activities and freight trip generation, are all based on simple linear regression analysis, of the form $Y_{l,t} = c + b.X_{l,t}$, where:

Y = the dependent variable, in this case the freight trip generation (differentiated into type of land use on the location and type of vehicle);

X = the independent variable;

l = type of land use on the location;

t = type of vehicle;

c = constant;

b = regression coefficient.

The explanatory factors for freight trip generation that are used in these studies, are various indicators of employment and area (number of employees, number of jobs, floor area, site area, production area). To a lesser extent, the number of companies in an industrial site is used in explaining the freight trip generation for the site as a whole.

In the United States, a small number of studies of the relation between economic activities and freight traffic have been carried out (table 1), often focusing on freight flows between states or parts of states. Relevant studies to be mentioned here are:

- Bureau of Transportation Statistics (BTS). It gives indicators of daily freight traffic for several areas. The studies are based on data that was collected before 1990. Part of it is rather old (1964, 1979). Indicators are (a.o.) trip generation rate per employee, per square foot company area and per acre.
- Chatterjee et al. (1979). They developed indicators of freight trip generation for ten types of land use, based on research in several urban areas.
- Zavattero & Weseman (1993). They developed indicators for freight trip generation, based on research in 64 areas around Chicago. Seven types of land use are distinguished and three types of vehicles.
- Tadi & Balbach (1994). They carried out research on the trip generation for a number of land use types in Fontana, California. The total area used by the company serves as the independent variable. Seven types of land use are distinguished and two types of vehicles.

Table 1: Freight trip generation by sector of industry (U.S. studies)

	Per 1000 m² floor area		Per hectare site area of firm		
	BTS	Tadi & Balbach	BTS	Chatterjee et al	Zavattero & Weseman
Production	2.4	3.9 – 6.5	7.6	10.1 – 16.1	8.9
Wholesale	2.4 – 9.9	4.0			
Light industry	16.0	6.5			
Services				43.9	35.2

Source: editing of data from Bureau of Transportation Statistics, Chatterjee et al (1979), Zavattero & Weseman (1993) and Tadi & Balbach (1994)

In the Netherlands, research on the relation between economic activities and freight traffic generation is also limited. AGV (1996) states that it appears that only little structural research has been dedicated to the relation between firm characteristics, accompanying production quantities and freight traffic. The studies that are carried out mainly focus on a particular industrial estate or city centre.

The following Dutch studies should be mentioned here:

- Zonnenberg (1989) conducted extensive traffic counts around industrial estates in the province of Zuid-Holland and studied the relation with the size of the estate.
- Heidemij Advies (1994) carried out a research concerning the freight trip generation of industrial sites in a line of cities within the province of Noord-Brabant.
- CROW (1996) developed a manual for municipalities to estimate freight traffic flows. The indicators are based on several studies in the Netherlands and elsewhere.
- BRO (2001) analysed traffic flows to and from seven mixed industrial sites by counting vehicles.
- Klaver (2001) held a telephone survey among 210 companies about freight trip generation.

The results of these Dutch studies are summarised in table 2.

Table 2: Freight trip generation by sector of industry (Dutch studies)

Sector	Average number of freight trips per employee or job per day				
	Zonnenberg	Heidemij	CROW	BRO	Klaver
Food		0.53			0.09
Textile		0.05			
Chemicals		0.10			0.08
Building		0.37			
Metal/electro		0.04			0.07-0.10
Other		0.06			0.22
Wholesale		0.22			0.26
Road transport		0.77			
Rubber and synthetics					0.05
Transport vehicles					0.08
Miscellaneous	0.7-1.5			0.9-2.0	
Manufacturing/building			0.50		
Wholesale/transport			0.58		
Services			0.24		

Source: editing of data from Zonnenberg (1989), Heidemij Advies (1994), CROW (1996), BRO (2001) and Klaver (2001)

The results of the studies mentioned in this section, diverge and therefore it is hard to make general statements about the relation between economic activities on industrial sites and the amount of freight traffic generated by these activities. These studies do not make clear which variables are best suited to explaining the relationship: employees or area. Furthermore, the various studies are difficult to compare because of differences in time, place and classification of activities. The main conclusions are that:

- the sources and their data are out-dated;
- the analyses are limited to a few branches of industry;
- the sector classification is not presented in a uniform way;
- the independent variables are not presented in a uniform way;
- the methods used in these studies vary (postal surveys, telephone surveys, vehicle countings)

In order to fill this gap we conducted a large scale survey, which is described in the next section.

4 A large-scale survey

In order to get a more recent and more comprehensive picture of the variables affecting freight trip generation, additional data were collected by means of a large-scale survey in the Netherlands, set up by TNO Inro, in assignment of the Ministry of Transport, Waterways and Public Works. Intomart carried out the actual (postal and on line) survey in assignment of TNO Inro, in September and October 2001. Bearing in mind the types of sites and firms as mentioned above, and the explanatory variables that were used in previous studies, the aim was to obtain information about spatial, economic and logistic characteristics of the selected firms.

The initial sample size was 10,000: 5,000 firms were approached in the densely populated western part of the Netherlands (known as the Randstad) and 5,000 in other parts of the country. The target response rate, given experiences with other, similar surveys, was between 10% and 20%. The main selection criteria for the sample were type of activity and size. The selected types of activity were chosen based on their presence on industrial estates, meaning that e.g. retail trade, hotel and catering industry, agriculture, services, etc. were excluded. Only firms with at least 5 employees were included in the research population.

The survey contained questions about the following subjects:

1. core business (type of activity);
2. site and floor area and number of employees;
3. type of industrial site on which the firm is located;
4. average number of trucks per day bringing in and taking out freight (per type of vehicle);
5. other logistic characteristics like transport mode, transport distances of trucks, dispersion of trucks over time (day and week), loading units and organisation of transport. These characteristics will not be discussed in this paper.

The postal interviews were anonymous in the sense that they were not addressed to a specific individual or function within the firm. The choice for a postal interview was made for two reasons. The first one was that the main data requested in the survey (pertaining to the subjects 1-4) were believed to be easily retrievable without further explanation. Note that only because of this, an anonymous addressee was considered to be acceptable. The second reason was that a postal survey made it possible to approach a relatively large number of firms. Altogether, a telephone survey among 1000 to 2000 firms was estimated to take much more time and effort to complete. In earlier studies, telephone interviews proved to be a good choice in the case of complex interviews where different managers in a firm needed to be consulted and where, in addition, the sample size was much smaller than in this case.

The number of respondents was 1529, yielding a response rate of 15%, which is satisfactory for this type of research. The response has been stimulated in a number of ways:

- the survey was short and allowed completion by managers in various functions, not relying on the availability of one or more particular persons;
- the choice for a well known surveying bureau (Intomart) allowed for a close and efficient control over potential non-response and also increased the acceptance of the survey;
- the inquiry form was accompanied by a letter of recommendation by the customer: the Ministry of Transport, Waterways and Public Works;

- the announcement of a prize (digital camera) to be awarded to a randomly selected respondent improved the response rate and made sure that contact details were filled in.

The primary processing of the returned survey forms was carried out by Intomart. The analysis was carried out as a three stage regression exercise. This included a first round of linear regression analysis; secondly, the identification, inspection and removal of (selected) outliers and, thirdly, the final round of estimating the trip generation models. The removal of outliers from the sample did not merely take place on a statistical basis. The main aim of the inspection of these outliers was to identify whether the company at hand had assigned itself to the correct sector. This was not always the case, and individual firms which were considered to be assigned wrongly were re-assigned or, in some rare cases, left out from the regression sample.

5 Results of the analysis

As mentioned above, a linear model was assumed to explain the number of freight trips, with an indicator for 'firm size' (e.g. number of employees or total company area) as the independent variable and the number of freight trips (either bringing in freight or taking it out) as the dependent variable (freight trip generation).

The results of the regression for the sectors with more than 10 respondents each are shown in tables 3 and 4, in particular the number of cases, the explained variance, the constant ***c*** and the regression coefficient ***b***. The typology used for the branch of industry is the SBI-code (Standard Company Classification).

For most of the sectors in these tables, a relation between size (measured either by area or by number of employees) and number of freight trips can be proven. The strength of this relation varies considerably, however. In some branches of industry (like wood products, chemicals, glass and pottery) R^2 is rather high. For wholesale activities, the relation is weak but nevertheless significant. For the machinery industry, on the other hand, a relation between size and freight trip generation seems to be non-existent.

Table 3: Regression analysis: number of trips bringing in freight, by sector of industry

SBI-code		Site area of firm (in m^2)				Number of employees			
		N	R^2	c	b	N	R^2	c	b
15	Food & drinks	45	.52	**3.81**	**.07**	47	.28	**6.73**	**.06**
17	Textile	19	.40	**2.40**	**.04**	19	.32	**2.88**	**.04**
19	Leather & leather products	16	.00	4.39	-.01	19	.39	**0.45**	**.22**
20	Wood products (excl. furniture)	37	.68	**1.89**	**.02**	36	.59	**2.46**	**.04**
22	Printed matter	38	.03	5.42	.01	37	.62	**3.53**	**.12**
24	Chemicals	36	.71	**5.97**	**.03**	39	.71	**5.39**	**.05**
25	Products of rubber & synthetics	39	.32	**3.30**	**.02**	42	.15	**3.67**	**.03**
26	Glass, pottery etc.	35	.67	**7.19**	**.02**	38	.60	**6.95**	**.06**
28	Metal products	66	.43	**4.02**	**.04**	71	.00	6.42	.00
29	Machinery	46	.01	8.43	.00	46	.00	8.75	.00
33	Medical devices & instruments	19	.00	8.58	.00	19	.08	6.38	.05
34	Cars, trucks, trailers	40	.32	**5.79**	**.03**	42	.35	**6.53**	**.05**
36	Furniture & various commodities	24	.40	**3.02**	**.02**	25	.32	**2.35**	**.09**
45	Construction	254	.21	**5.76**	**.02**	264	.01	6.54	.01
50	Trading & repair of motor vehicles	78	.12	**3.97**	**.06**	87	.09	**5.28**	**.06**
51	Wholesale	241	.11	**6.25**	**.02**	257	.03	**6.87**	**.03**
60	Land transport	89	.15	**15.03**	**.04**	91	.13	**15.98**	**.09**
63	Services for transport	15	.88	**8.75**	**.09**	17	.16	15.14	.05

* **Bold**: F sign. ($p < .05$)

Table 4: Regression analysis: number of trips taking out freight, by sector of industry

SBI-code		Site area of firm (in m^2)				Number of employees			
		N	R^2	c	b	N	R^2	c	b
15	Food & drinks	45	.24	**5.98**	**.04**	47	.24	**6.67**	**.05**
17	Textile	20	.46	**3.53**	**.01**	19	.70	**2.58**	**.03**
19	Leather & leather products	16	.00	3.64	.00	19	.34	**1.25**	**.13**
20	Wood products (excl. furniture)	36	.60	**1.73**	**.02**	36	.39	**2.57**	**.03**
22	Printed matter	38	.04	5.14	.02	38	.73	**2.62**	**.10**
24	Chemicals	36	.52	**5.62**	**.02**	39	.43	**5.47**	**.04**
25	Products of rubber & synthetics	40	.15	**3.54**	**.02**	42	.71	**0.79**	**.13**
26	Glass, pottery etc.	37	.83	**5.51**	**.04**	38	.68	**7.59**	**.12**
28	Metal products	66	.41	**2.71**	**.04**	71	.00	4.83	.00
29	Machinery	46	.02	5.79	.01	46	.00	6.45	.00
33	Medical devices & instruments	19	.01	4.99	.00	19	.14	3.49	.04
34	Cars, trucks, trailers	40	.33	**2.90**	**.03**	42	.40	**3.64**	**.05**
36	Furniture & various commodities	24	.59	**1.68**	**.02**	25	.28	**1.49**	**.08**
45	Construction	254	.14	**6.29**	**.02**	264	.01	6.82	.01
50	Trading & repair of motor vehicles	77	.05	3.03	.03	86	.15	**3.01**	**.10**
51	Wholesale	240	.24	**4.15**	**.08**	257	.02	**7.56**	**.04**
60	Land transport	89	.35	**11.01**	**.09**	90	.49	**7.89**	**.33**
63	Services for transport	16	.72	**12.46**	**.11**	17	.17	15.45	.05

* **Bold**: F sign. ($p < .05$)

6 Interpretation of results

The relative importance of the independent variables varies strongly between sectors (table 3 and 4). For metal products for instance, the site area seems to do better as an explanatory variable than the number of employees. In other sectors, e.g. the leather and the printing industry, it is the other way around: the number of employees is much more important for the number of freight trips in these sectors than the site area of the firm.

Interesting differences can also be observed between incoming and outgoing trips: In some sectors, the effect of the number of employees on the number of trucks picking up freight is considerably larger than its effect on the number of trucks delivering freight. This is true for the textile industry, for the manufacturing of rubber and plastic products, and for the transport industry itself. In these same sectors, similar differences in the effect of the site area of the firm are much smaller.

Regional differences for the freight traffic indicators turn out to be small. In some sectors, the correlation between size and trip numbers for the Randstad is higher than for the area outside, in others it is lower. The question remains whether this can be attributed to characteristics of the regions or to characteristics of the respondents' firms (e.g. firm size within the response group was smaller in the Randstad).

In some cases, the regression formulas based on size that are discussed here may not be used, for instance when the size of the firms that are (or will be) established on a site, is unknown, or for those sectors where a relation between size and freight trip can not be proven. Under such circumstances, a rough estimate of traffic flows can be made based on the average number of freight trips per firm by sector (table 5).

The transport industry and services for transport are the activities that generate the largest numbers of trips per company in general. Firms that produce glass and pottery generate many outgoing trips. The food industry, machinery production and wholesale are other sectors with a higher than average generation of freight trips per firm. The standard deviation in most sectors is high, indicating large differences in trip numbers between individual firms.

Table 5: Average freight trip generation per firm per day

SBI-code		N	For incoming freight	For outgoing freight
15	Food & drinks	49	10.3	9.2
17	Textile	21	4.7	5.0
19	Leather & leather products	20	4.1	3.5
20	Wood products (excl. furniture)	40	4.0	4.3
22	Printed matter	42	7.9	7.9
24	Chemicals	45	9.7	9.7
25	Products of rubber & synthetics	45	4.9	5.8
26	Glass, pottery etc.	51	13.3	21.4
28	Metal products	76	7.0	4.7
29	Machinery	49	10.6	8.2
33	Medical devices & instruments	22	7.7	4.7
34	Cars, trucks, trailers	44	8.7	5.7
36	Furniture & various commodities	28	4.5	3.5
45	Construction	279	8.2	8.4
50	Trading & repair of motor vehicles	92	7.4	16.1
51	Wholesale	275	12.2	13.2
60	Land transport	95	31.9	24.4
63	Services for transport	26	30.8	31.3

Freight trip generation can also be differentiated by type of industrial site (table 6). Distribution sites generate the largest numbers of trips per firm. Interesting is that the number of vehicles bringing in freight to this type of site is considerably larger than the number of vehicles taking it out, due to differences in the size of shipments. Seaport sites in the Netherlands on the other hand generate more outgoing than incoming freight trips. The number of freight trips per company on heavy industry sites is also above average, the lowest numbers are shown by high-quality business sites and mixed sites.

Table 6: Average freight trip generation per firm per day, by type of site

	N	For incoming freight	For outgoing freight
Seaport sites	7	7.43	13.86
Heavy industry sites	47	12.74	11.21
Distribution sites	60	28.77	14.62
High-quality business sites	77	8.45	9.13
Mixed sites	734	8.38	8.25

Based on the results of the survey, it is possible to give an indication of the share of different types of vehicle in the total number of trips: delivery vans, light trucks, heavy trucks. Policy makers can make use of the knowledge of these proportions in estimating the effects of freight traffic on accessibility, emissions and safety. Table 7 shows the

share of the three kinds of vehicles for different types of sites. Heavy trucks are responsible for the majority of the trips to and from seaport sites, heavy industry sites and distribution sites. Delivery vans are relatively important for high-quality business sites and mixed sites, along with trucks.

Table 7: Proportion of vehicle types in freight trip generation per firm, by type of site

	N	For incoming freight			For outgoing freight		
		Delivery van	Light truck	Heavy truck	Delivery van	Light truck	Heavy truck
Seaport sites	7	15%	17%	67%	36%	10%	54%
Heavy industry sites	47	20%	14%	65%	14%	9%	76%
Distribution sites	60	13%	6%	81%	32%	7%	61%
High-quality business sites	77	38%	27%	35%	36%	20%	44%
Mixed sites	734	36%	21%	43%	46%	14%	40%

Regional differences in the proportions of vehicles are rather small. Only where the number of cases is small (e.g. seaport sites outside the Randstad), differences between regions may be substantial. Most respondents are established on mixed sites, where the average number of vehicle movements per company is about eight, within the Randstad and outside as well.

7 Conclusion

This study has resulted in a unique set of statistics about the patterns of freight transport produced by firms from various sectors of industry. The results shown here indicate that variations in freight trip generation are large, between individual firms and also between sectors of industry. Nevertheless, for most sectors the effect of firm size on the number of freight trips is obvious. Regression analysis provides a basis for estimating the amount of trips generated by individual firms, and where this is not possible, the average number of trips generated by firms in specific sectors of industry, might serve the same purpose.

When it comes to choosing an indicator of firm size, the choice between the firm area and the number of employees is hard to make. Their relative importance depends on the type of activity and the direction of the flows (incoming or outgoing).

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