

**RELATIONSHIP BETWEEN (HEAVY) FREIGHT TRAFFIC
AND MANAGEMENT/MAINTENANCE COSTS**



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Abstract

This paper outlines the relationship between freight traffic and usage-dependent management/maintenance costs for the main road network. The approach adopted is a practical one, utilising extensive data analysis without necessarily arriving at a road engineering explanation. Relationships derived from the data have been incorporated into a calculation tool so as to explore various “what-if” scenarios.

Key words

freight traffic, management and maintenance, asset management

1. New questions – new tools

1.1 Background

Due to their complexity, decisions about the infrastructure and its use by (heavy) freight traffic are not considered sufficiently from the perspective of the level and development of the costs for management and maintenance. It is well known that heavy freight vehicles have a major impact on the maintenance regime for road surfacing and that overloaded vehicles cause additional damage to roads and civil engineering structures every year. Figure 1 (source: Department of Public Works and Water Management) shows that damage to the roads is caused mainly by freight traffic and by non-standard freight traffic in particular.

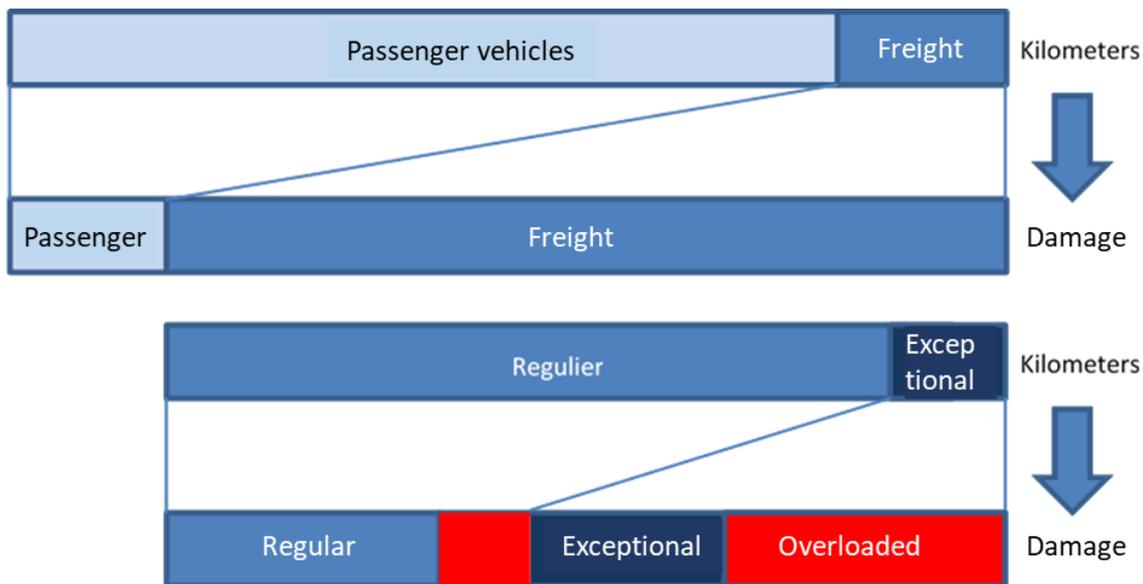


Figure 1: Relationship between use and damage

It is important to fully understand the relationship between (heavy) freight traffic and management/maintenance costs:

- in order to be able to make targeted, well-founded policy decisions (for example about routing and transport systems);
- to enter into well-founded discussions of the costs relating to use;
- to make better long-term forecasts and therefore have greater control of the expected performance, risks, and costs.

1.2 Chosen approach

The Directorate-General for Public Works and Water Management [*Rijkswaterstaat*] (RWS) and the Ministry of Infrastructure and Water Management (I&W) have teamed up with Goudappel Coffeng and DAT.Mobility to increase understanding of the composition and volume of freight traffic on the one hand and the management and maintenance costs for the main road network on the other. The approach adopted is a practical one, utilising extensive data analysis without necessarily arriving at a road engineering explanation. In addition to the exact directional impact of a change, the relational impact is more important. The results have been incorporated into a calculation tool called “Zwaarteblik”.

1.3 Reader's guide

Section 2 explains what information was collected and how the relationship was established between the volume and composition of traffic and management and maintenance costs. Section 3 comprises three examples, making use of the Zwaarteblik calculation tool. Section 4 presents the conclusions.

2. The information combined

2.1 Previous work

In the past, several attempts have been made to make statements about the relationship between traffic and management/maintenance costs. Most recently, a Dutch project team, called Gravitation (an informal project organization focused on this subject) compiled a detailed report with the state of art concerning the knowledge about this relationship. However it has never come to quantitative relationships because of its complexity. There are many damage images associated with different aspects of use. Some damage simply arises because a certain total weight on the infrastructure has come along, other damage is caused by (overloaded) vehicle axles. Moreover, vehicles are not the only cause of the damage. The weather and the quality of the material also play a role in this.

2.2 Approach: extensive data analysis

The approach followed is a practical one, utilising extensive data analysis without necessarily arriving at a road engineering explanation.

The approach adopted was intended to collect the following data on the use of the main road network (MRN):

- volumes and axle load range;
- road characteristics;
- management and maintenance costs.

The relationship between use of the MRN on the one hand and management and maintenance costs on the other can be determined on the basis of relevant literature and expert assessments. Figure 2 sets out the framework diagrammatically.

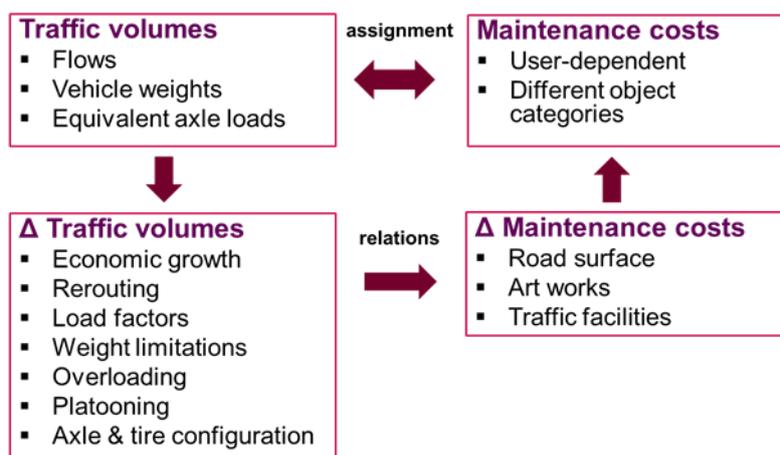


Figure 2: Framework

The following subsections deal in greater detail with the sources of information used and the relationships applied.

2.3 The data sources used

Use by freight traffic

With its INWEVA (the Dutch abbreviation for “Volumes on Road Sections”) database, RWS has an up-to-date source in house which shows the annual average volumes per road section for the main road network (MRN), categorised according to passenger cars, medium-weight freight traffic and heavy freight traffic. The INWEVA data is updated annually for the Dutch MRN. The database also contains information about road section lengths. The data from this source was used to determine the vehicle kilometres and vehicle type distribution (passenger cars, light freight traffic and heavy freight traffic) on the national road network for the year 2015.

Freight traffic weight load

Loading/overloading is a major cause of damage to the roads. Information on levels of loading/overloading was taken from the national Weigh-in-Motion (WiM) measurement system. That source was analysed by the Environment and Transport Inspectorate (ILT) and the Netherlands Vehicle Authority (RDW) using measurement data from 2014 and enhanced with technical vehicle data and exemption data. That data was made available for this project.

Road characteristics

The WEGGEG database (open data from RWS) comprises administrative data and visually inventoried data on trunk roads. The following WEGGEG features are relevant for this study: dedicated lanes for particular types of traffic, civil engineering structures along the roads (bridges, underpasses, tunnels, and flyovers), and the type of surfacing (permeable asphalt (ZOAB), dense asphalt (DAB), and cement concrete (CB)). This source therefore provides information on the features of the infrastructure.

Links were also made between the data from WEGGEG and INWEVA in order to determine the vehicle kilometres per surfacing layer and the number of vehicles crossing civil engineering structures. Because the relationship for steel bridges is different to that for concrete bridges, a list (from RWS) of the steel bridges was added to WEGGEG.

Management and maintenance costs

The management and maintenance costs were taken from a number of sources. The categorisation was based on both I&W’s Management and Maintenance Frame of Reference (MFR) and RWS’s Maintenance Management Regime (MMR) for 2015.

The relationship between use of the infrastructure and management and maintenance costs is based not so much on fixed and variable maintenance, but rather on the distinction between usage-dependent and non-usage-dependent. For that reason, management and maintenance costs based on literature and input from various experts (including road engineers) were divided into usage-dependent and non-usage-dependent costs.

2.4 The relationships applied

The following relationship diagram (Figure 3) was drawn up on the basis of relevant literature and input from experts. It shows the relationships between the type of management and maintenance and the factors that determine the damage. It also indicates the quantitative relationship (linear, 4th power, etc.) that was assumed.

	Non-usage-dependent			Usage-dependent		
Type of management & maintenance	climate	weather (frost)	construction quality	vehicle weight	axle loads (overloading)	incidents
Road surfacing:						
- major maintenance:						
total replacement of surfacing structure	ZOAB linear		linear, accelerated		4th power	
replacement of top layer of road stretch	DAB: linear ZOAB: linear		linear, accelerated		linear => progressive	
resurface	linear				remaining life	
- minor maintenance, repairs:						
surfacing (local)		++			4th power	linear
road furniture local						linear
Civil engineering structures:						
- concrete bridges:						
wear & tear supporting structure				linear		
concrete decay etc.	progressive over time					
- steel bridges:						
wear & tear supporting structure					4th power	
painting etc.	progressive over time					
- short spans					linear	
Incidents						linear

Figure 3: The relationships identified

Because we were concerned with the relationship between freight traffic and management/maintenance costs, the usage-related factors of vehicle weight, axle loads (see Figure 3) were implemented. The main factors are explained below. For the time being, a single common generic factor was used for climate, weather and construction quality, so as to make it possible to clarify the main differences in the distribution between usage-dependent and non-usage-dependent.

Relationship axle loads – road surfacing

As explained, the axle load range was compiled on the basis of information from INWEVA and WiM. The share by vehicle type of total vehicle kilometres on the MRN and the average equivalent axle load per vehicle (based on an equivalent axle load of 100 kN) are shown.

Table 1: The range of axle loads use

Vehicle category	Frequency distribution vehicle kilometres	Average equivalent axle load per vehicle
passenger cars	87.2%	0.00
freight vehicles up to 20 tonnes	5.8%	0.26

freight vehicles 20 to 40 tonnes	1.0%	0.74
freight vehicles 40 to 50 tonnes	5.5%	3.00
freight vehicles 50 to 60 tonnes	0.1%	4.88
freight vehicles over 60 tonnes	0.4%	7.39

Given this axle load range, the vehicle kilometres were converted into kilometres of equivalent axle loads (vehicle kilometres * share by vehicle type * average equivalent axle load per vehicle) and the total extent of the usage-dependent management and maintenance costs for road surfaces was categorised in proportion to the kilometres of equivalent axle loads per vehicle category. The costs allocated to the vehicle categories were then divided again by the vehicle kilometres within a vehicle category. This resulted in a key costs figure per vehicle kilometre per vehicle type for road surfaces.

Although passenger cars by far account for the largest share, they make only a relatively small contribution to degradation of the road surface because the equivalent axle loads are near zero.

Because the relationship for steel bridges was also established using axle loads, this method was also applied for steel bridges, whereby the distribution of the number of vehicles crossing steel bridges in the MRN was examined.

Relationship vehicle weight – concrete bridges

It was deduced from INWEVA in combination with WEGGEG (see *The information combined* section) how many vehicles for each vehicle type crossed over the concrete bridges on the MRN. The result is shown in Table 2.

Table 2: Loads on concrete bridges on MRN

Vehicle category	Number of crossings of concrete bridges (in millions) in 2015	Average vehicle weight
passenger cars	14,782	1,300
light freight vehicles (up to 20 tonnes)	922	12,000
heavy freight vehicles (over 20 tonnes)	1,097	42,750

Using this information, the usage-dependent management and maintenance costs for concrete bridges were divided up according to the total weight crossing over per vehicle type (number of crossings * average total vehicle weight). This resulted in a key costs figure per vehicle crossing per vehicle type for concrete bridges. This method was also applied for tunnels, road flyovers, and underpasses.

Relationship overloading – road surfacing

A change in the overloading percentage in a vehicle type category leads to an adjustment of the equivalent axle load in the relevant weight category. The relationship between both was determined as follows. In the WiM data, the axle load per weight category for all measured vehicles was increased in steps. For each step, a check was made per vehicle to see whether the axle load exceeded 10 tonnes. If it did, then the vehicle concerned was considered to be

overloaded. The overloading percentage and the average equivalent axle load in the relevant weight category were then re-determined in one step. This procedure was also repeated by reducing axle load in steps.

3. Calculating the relationship

The Zwaarteblik calculation tool makes it possible to gain an idea of the effects of a changing traffic load on management and maintenance costs. Here are three examples.

Example 1: More traffic

Figure 4 shows the effects on (usage-dependent) management and maintenance costs as a result of 10% more traffic. It can be seen that the usage-dependent management and maintenance costs for civil engineering structures and traffic facilities also increase by 10%. However, the management and maintenance costs for road surfaces increase slightly more, namely by 12%. Total management and maintenance costs rise by almost 4%.

Example 2: Higher share of freight traffic

Figure 5 shows the effects on (usage-dependent) management and maintenance costs as a result of a 50% increase in the share of freight traffic (from a share of 12.8% to 19.2%). Because the total volume of traffic remains the same, we do not see any increase in the costs for traffic facilities. On the other hand, the usage-dependent management and maintenance costs for civil engineering structures increase by 50%, and for road surfaces even more, namely 53%. Total management and maintenance costs rise by 17%.

Example 3: Less heavy freight traffic

Figure 6 shows the effects on (usage-dependent) management and maintenance costs in order to determine the effects of banning heavy freight vehicles weighing more than 50 tonnes. This share of 3.7% of total freight traffic was allocated to the 40 to 50 tonnes category. It can be seen that the usage-dependent management and maintenance costs for road surfaces decreases by 6%. No change was calculated for civil engineering structures because the traffic remains in the category exceeding 20 tonnes and no further distinction is made (as yet). Total management and maintenance costs fall by almost 2%.

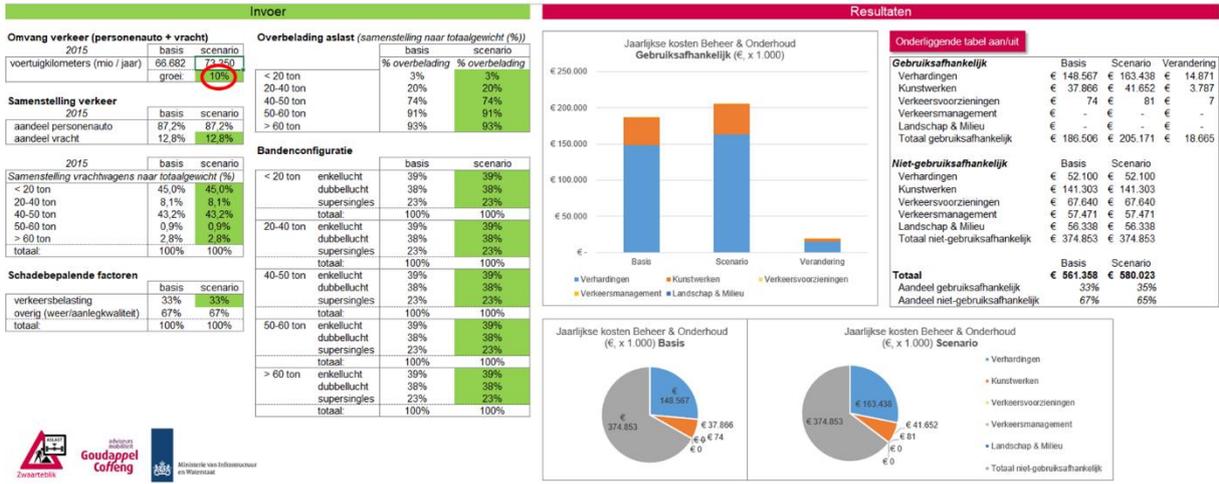


Figure 4: Example 1 with 10% more traffic (with the alteration in red)

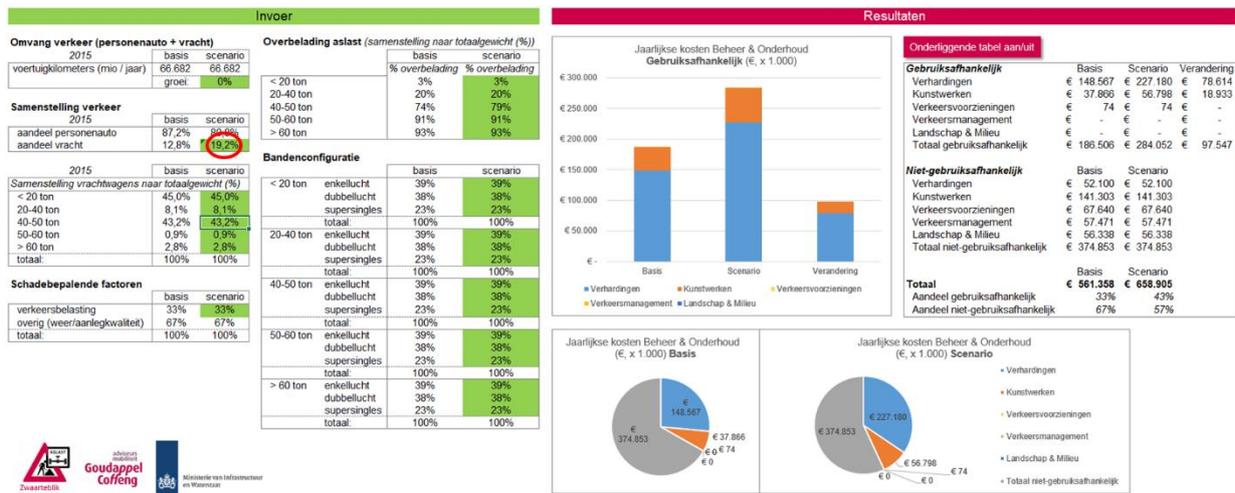


Figure 5: Example 2 with double the amount of freight traffic

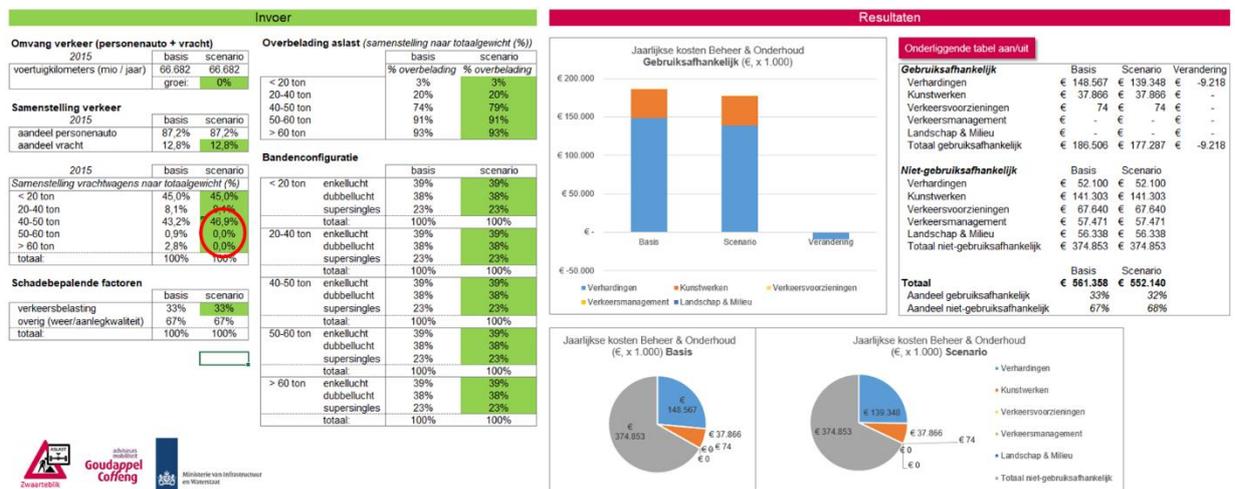


Figure 6: Example 3 with less heavy freight traffic

4. Conclusions and recommendations

Attempts have been made in the Netherlands since as far back as the 1980s to clarify the relationship between (heavy) freight traffic and management and life cycle costs. Whereas in the past those attempts were largely based on road engineering explanations, the approach is now far more one of linking the available data from an input and output perspective. The law of large numbers helps of course, i.e. numbers that have been collected in recent decades through advances in high-quality measurement methods and data collection. We have succeeded – through a public-private partnership effort – in establishing a link that we had been seeking for a long time. But it has in particular been the bringing together of data management, asset management, and civil engineering expertise – i.e. bringing together different worlds – that has contributed to this practical, efficient, and manageable model.

The need for maintenance depends not only on the actual and future traffic but also on traffic that has been using the roads for years. This time aspect was ignored for the purposes of this study. This study looked at standard maintenance costs, based on long-term insights. For traffic volumes, information for a single year was used. Using information for a longer period will bring about an improvement.

It should be noted, finally, that the tool was set up for the main road network, but the approach would also seem to be practical for a provincial road network, provided that relevant data are collected and available.