OPTIMAL PROCESSING OF PERMIT APPLICATIONS FOR EXCEPTIONAL HEAVY VEHICLES

Dick G. Schaafsma, MSc.

Ministry of Public Works and Water Management The Netherlands Directorate-General RWS Civil Engineering Division PO Box 20000, Utrecht, The Netherlands +31 30 2858659 d.g.schaafsma@bwd.rws.minvenw.nl

ABSTRACT

The continuously increasing number of both exceptional heavy vehicles (>50 metric ton) and ordinary freight in the traffic flow on the highways in the Netherlands forms a threat to the constructive safety and durability of the bridges. The key factors in this threat are the load on the bridge due to the heavy vehicle itself, the load due to other traffic and the strength of the bridge.

In the past the Department of Transportation issued permanent (transport?) permits for vehicles under 100 metric ton (100 t), specifying individual bridges or stretches of highways that were excluded from the permit. Heavy vehicles above 100 t were assessed individually by the DOT. The time necessary to process these individual applications motivated the transport branch to lobby for an increase in the boundary weight from 100 to 120 t.

This led the DOT to undertake 2 consecutive research studies with the goal of raising the 100 t boundary and optimizing the method of assessment for exceptional heavy vehicles, in order to reduce the processing time.

The first study, OABT (Optimalisation of the Advice for Exceptional Heavy Vehicles), including an accurate assessment of other traffic and determining a uniform safety control, came to the conclusion that the 100 t boundary weight could not be raised but should instead be lowered to 80 t in order to maintain an adequate safety margin.

Since this conclusion would mean a tenfold increase in individual applications, it was decided that a second study, SAAB (Standardization Processing Applications for Exceptional Heavy Vehicles), should be started to investigate and develop an integral assessment system that would reduce the processing time to a minimum. An important part of this system is an algorithm to characterize heavy vehicle configurations and a database containing the characteristics of (all) the bridges and viaducts in the major highways in the Netherlands.

OPTIMAL PROCESSING OF PERMIT APPLICATIONS FOR EXCEPTIONAL HEAVY VEHICLES

Dick G. Schaafsma MSc.

Ministry of Public Works and Water Management The Netherlands Directorate-General RWS Civil Engineering Division

1 INTRODUCTION

Conveniently located in the Rhine, Maas and Scheldt delta, the ports of Amsterdam, Rotterdam and Antwerp and their contributory roads, water- and railways form major links within Europe's transportation infrastructure. The infrastructure is extensively used by not only the heavy goods vehicles that distribute goods, machines and materials deep into Europe's hinterland but also by the vehicles that transport the machinery and construction material to build and maintain these roads, water- and railways. In the past decade, the number of heavy vehicles has increased exceptionally, both in number and total weight.



Figure 1 Highway network in the Netherlands

Under Dutch legislation all vehicles weighing more than 50 metric tons (50 t), that want to travel on the highways must apply for a permit from the Ministry of Public Works and Water Management. In the past its Department Of Transportation (RDW) issued permanent permits for vehicles under 100 t, specifying individual bridges or stretches of highways that were excluded from the permit. Heavy vehicles over 100 t were assessed individually by the Civil Engineering Division of the Directorate-General RWS as owner and manager of the road infrastructure.

Dutch policy is to issue as many permits as structural safety allows, without reducing the reliability, availability and maintainability of the infrastructure network. To keep the disruption for other traffic to a minimum the policy of the RDW is that exceptional heavy vehicles must be allowed,

as far as possible, to use the highways alongside other traffic. In 2004 over 60,000 permits were issued to vehicles over 50 t, with 1,400 for vehicles over 100 t.

The time taken to process these individual applications motivated the transport branch to lobby for an increase in the boundary weight for individual assessments from 100 to 120 t. This led the RDW to undertake 2 consecutive research studies with the goals of raising the

100 t boundary and optimizing the method of assessment for exceptional heavy vehicles, in order to reduce the processing time.

The first study, OABT (Optimalization of the Advice for Exceptional Heavy Vehicles), had 3 major objectives:

- to determine a uniform safety check for bridges in highways;
- to make an accurate assessment of the additional loading due to other traffic
- to search for a common denominator in the load bearing capacity of bridges.



OABT came to the conclusion that the 100 t boundary weight could not be raised but should instead be lowered to 80 t in order to maintain an adequate safety margin in the future. Since this conclusion would mean a tenfold increase in the number of individual applications, it was decided that a second study, SAAB

(Standardization Processing Applications for Exceptional Heavy Vehicles), should be

started immediately to investigate and develop an integral assessment system that would reduce the processing time to a minimum. The SAAB system has the following main functionalities (functions?):

- Basic information about traffic lanes, (standard) transport configurations and the management and input of new route sections and structures (bridges)
- Structures registration
- Route sections
- Vehicle axle configurations
- Analysis of structures and vehicles.

The system makes an assessment of whether a vehicle is allowed to travel on a certain transport route (a set of route sections), whether the heavy vehicle is allowed to travel alongside other traffic and whether there are any other restrictions (vehicle speed, specified lane, etc..).

2 TRADITIONAL METHOD

The traditional method of assessing exceptional heavy vehicles originated in the 1970's when the Civil Engineering Division was asked by the RDW to specify the conditions under which heavy vehicles would be allowed to travel on highways in the Netherlands. The traditional way of assessing heavy vehicles was based on a traffic load model defined in 1963 (VOSB 1963). An average bridge would be checked for a 2 axle-systems consisting of 3 axles each weighing 0.8 x 2 x 3 x 20 t \approx 100 t. The additional load due to other traffic was determined by applying a uniformly distributed load. For a dual carriageway this would mean a traffic load of (0.8x2x3x4=) 1.92 t/m. For a common 30 meter span bridge this would mean that the bending moment caused by two axle systems would be approximately 80% of the total design bending moment caused by the combination of the axle systems and the uniformly distributed load. Where necessary the shear forces, stresses and reaction forces would be checked in the same way.

 $M_{q,spec} > M_{d,VOSB63} \qquad \blacktriangleright \text{ transport not allowed *})$ $0.8 M_{d,VOSB63} < M_{q,spec} < M_{d,VOSB63} \qquad \blacktriangleright \text{ transport allowed without other traffic}$ $M_{q,spec} < M_{d,VOSB63} \qquad \blacktriangleright \text{ transport allowed with other traffic}$

*) Transport may be allowed with certain restrictions



This model takes insufficient account of present day loading due to other traffic and its duration, and was no longer a valid representation of current traffic flow. It was therefore necessary to develop a new traffic load model and to develop a new safety check in which present day and future loading due to other traffic is taken into account.

3 OABT (OPTIMALIZATION OF THE ADVICE FOR EXCEPTIONAL HEAVY VEHICLES)

The number of applications dealt with by the Civil Engineering Division of RWS has risen dramatically in the last decade. In 1993 there were 150 applications for vehicles above 100 t, this number has shot up to almost 1300 in 2003 and 1500 in 2005. This fact and lobbying by the transport branch were the main reasons to carry out the project OABT in the period 2000 – 2002. One of the most important findings of this investigation was the necessity to develop a new traffic load model. Commissioned by and under the supervision of the Civil Engineering Division of RWS, a new model was developed by TNO (Netherlands Organization for Applied Scientific Research) and is referred to in this paper simply as the Traffic Load Model 2004.

3.1 Traffic Load Model 2004 (TLM2004)

The following criteria, amongst others, were taken into consideration in the development of the traffic load model:

- during the passage of exceptional heavy vehicles the structure must comply with the safety regulations laid down in the Dutch codes;
- the traffic load model must be independent of the structure type and it's dimensions;
- the traffic load model must incorporate the number of traffic lanes;

TNO used data from the (freight) traffic measurements for the WIM location on the A16, the main highway between the ports of Rotterdam and Antwerp, for developing the TLM2004. This traffic data (Spectra RVB) is characteristic for highways in the Netherlands.



Figure 3 Spectra of total weight and axle loads for traffic on the A16

A probabilistic traffic flow model was constructed, comprising traffic intensities, lorry distances and lorry speeds, based on the WIM measurements for the A16. This model was constructed by:

- performing a Monte Carlo simulation on a standard bridge using all the possible vehicle combinations obtained from the WIM-measurements for the A16;
- analyzing the chance of occurrence of a certain load combination;
- comparing this chance of occurrence with the prescribed chance of occurrence in the Dutch code;
- converting this load combination to a uniformly distributed load with the same effect as the "real vehicle combination".

In summary, the traffic flow model describes the uniformly distributed load per traffic lane, dependent on the length of the structure and the number of lanes of traffic on the structure.

A similar approach was used to determine the traffic model describing the load due to other traffic to be combined with an exceptional heavy vehicle. The only difference was, since the heavy vehicle load is calculated separately, that the position of the heavy vehicle on the structure was left empty and unloaded in the Monte Carlo simulation. The chance of occurrence of such an "empty space" was taken into account.

The TLM2004 determines the uniformly distributed load, dependent on the length of the structure and the numbers of lanes of traffic on a structure, to be applied for other traffic alongside the load of the exceptional heavy vehicle.

In the TLM2004 all vehicles are assigned a length of approximately 12 meters. This is not the actual length of a vehicle but the length over which the vehicle transfers the load to the

structure. All vehicles (and/or axle groups) in the model travel at a center-to-center distance of 18 meters. The space between vehicles is therefore 6 meters.

In the TLM2004 the following parameters are used:

- span length
- levels of reliability (SLS or ULS)
- trend in time
- lane configuration (e.g. S, SF, SMF, SMFF, SFFS, SMFFMS)

(S = slow lane; F = fast lane; M = middle lane)

In the model, the loads for normal traffic are given for the ultimate limit state (ULS) and the serviceability state (SLS). The loads are calculated for various combinations and traffic lane combinations. In the verification, two load combinations are checked:

- (1) exceptional heavy vehicle as the dominant load alongside other traffic
- (2) other traffic as the dominant load alongside the exceptional heavy vehicle.

Length L	Dominant	Not-dominant	
[m]	qd [kN/m]	qd [kN/m]	
20	146	47	
50	84	28	
75	67	24	
100	60	24	
150	49	23	
200	45	23	



table 1: example of ULS loads qd with traffic lane configuration SMF



In most cases when the exceptional heavy vehicle is considered simultaneously with other traffic on a structure, the second (2) load combination is the critical load case. In the model the standard bridge is a single span structure. Obviously the effective span length L is equal to the span length. For statically indeterminate structures the effective span length is the length of the combined lines of influence.

3.2 Pilot transport corridor

The RDW wanted to determine a boundary weight below which permanent permits could be issued. For vehicles above the boundary weight applications would still have to be evaluated by the Civil Engineering Division. The RDW proposed to investigate a set of 8 common heavy vehicles between 100 and 140 t to determine if any of these vehicles could be issued with permanent permits. The corridor proposed for these 8 heavy vehicles was the entire highway A16 running between the port of Rotterdam and the Belgium border close to the port of Antwerp. The length of the corridor is about 56 km and it contains about 100 structures (6 steel bridges, 94 concrete culverts, small tunnels and bridges). A preliminary investigation reduced the number of structures to be checked to 34 characteristic structures.



Figure 5: individual structure vs. allowable total weight of the vehicle

3 load combinations were considered:

- Combination A: exceptional heavy vehicle (in figure 5 type VC-2a (128 t)) situated in the slow lane. Other traffic is situated in front, behind and next to the vehicle.
- Combination B: exceptional heavy vehicle situated in the slow lane. Other traffic is situated only in the lane next to the vehicle;
- Combination C: exceptional heavy vehicle situated in the most favorable lane without any other traffic.

Figure 5 shows that the results of combinations A and B are almost identical. The total length of the heavy vehicle VC-2a is approximately 25 meters, with the empty space in front of and behind the vehicle there is no other traffic present on most of the structures.

Figure 5 shows that there is little correlation between the structures, but that critical structures can be identified for all vehicle types. For structures 4, 10, 19 and 20 no other traffic can be allowed in combination with most of the heavy vehicle types. Structures 4, 10, 14, 19, 31 and 32 are shown to be critical in combination C, without other traffic.

The conclusions for the pilot transport corridor were that:

- for most vehicle types the boundary weight had to be reduced to 80 t;
- some vehicles (like type VC-2a) could only be allowed to pass without other traffic;
- the effect of other traffic was more dominant than in the traditional evaluation method and in future all evaluations had to be made using TLM2004;

- critical structures can be identified for the evaluation of stretches of highway.

With an extra recommendation, since reducing the boundary weight would lead to an extra 15,000 requests to be assessed by the Civil Engineering Division:

- to start developing a computer program to coherently and rapidly assess the applications for exceptional heavy vehicle permits using the TLM2004 and a database containing the characteristics of all critical structures.

4 THE SAAB SYSTEM

As a direct result of the conclusions and recommendations of the OABT research study the SAAB (Standardization Processing Applications for Exceptional Heavy Vehicles) was developed. The SAAB system was developed with the "look and feel" characteristics of Windows® and is programmed in Visual Basic® version 6. All the functions can be called up via the menu-bar and/or buttons of the system. When the system is opened the buttons and the menu choices are visible in the toolbar.



The SAAB-system has the following main functions:

- basic information
- structure registrations
- route sections
- heavy vehicles

Without going into too much detail about the SAAB-program a few of the main features will be explained in the following paragraphs.

Figure 6 The SAAB program

4.1 Basic information

The system is subdivided into a number of general functions:

- management of traffic lanes. In this function the loading due to other traffic can be specified, e.g. table 1 of this paper. In table 1 the loads for the year 2004 have been specified. New measurement data, annual trends and possible different kinds of road network (international, provincial, municipal) may all be reason to change this basic setup.
- management of standard vehicle configurations. Experience over the past few years has shown that particular vehicle configurations reappear in the applications from time to time. This function makes it possible to save standard vehicle configurations
- management of structure registrations. Although the Netherlands is a relative small country, it is densely populated and has a relative high number of highways (ca. 3500



km), secondary roads and canals. For this reason the highways have a relatively high number of tunnels, culverts and bridges (> 4000 concrete structures). Of these structures about 1000 have been registered using the traditional method. All the relevant information for the structure (e.g. idcode, name, highway, influence lines for the relevant lanes for moments, shear force and reaction forces) is stored in a database. As this information is not altogether obsolete in the SAABsystem much of this information can be transferred to the SAAB-system database.

Figure 7 structure characteristics: influence lines

4.2 <u>Route sections</u>

When an operator applies for a permit to drive with a heavy vehicle from A to B a transport route must be determined. Many transport routes already exist in the SAAB-system. The new transport route may overlap or supplement an existing transport route. For this reason it was decided to compile transport routes from smaller route sections. These route sections, complete with the accompanying structures, must be present in the system. To facilitate the input of route sections the SAAB-system contains the function "compilation of route sections".

4.3 <u>Vehicle configuration and transport route</u>

This function combines a certain heavy vehicle configuration, either a standard heavy vehicle or new configuration, with a transport route, compiled from existing route sections.

Transportconfiguratie		Transport	K
	Configuratie	Transport Transport Route	1
Identificatie van de transportconfiguratie : BB2-160	Zoeken	Identiticate I Lontigurate 5523-120	
	Toevoegen	Verwijderen	
	Verwijderen	C periode Analyse	
<u>୦ ୦୦ ୦୦୦ ୦୦୦</u>	Adimon	Route Id. Omschrijving Uitvoer	1
I	Toevoegen	12R1 KP Pr. Clausplein - KP Gouwe	
as nr hoh assen aslast X-ordinaat type as		15L7 KP Valburg - KP Deil	
2 3400 120.0 3400 DI	verwijderen	16R3 KP Ridderkerk KP Klaverpolder Sluiten	
3 1,350 120,0 4,750 DL	Verwijderen alle assen	IL/ KP Azelo - KP Beekbergen	1
4 4,000 160,0 8,750 BB 5 1,500 160,0 10,250 BB		KW-id omschrijving A B C A B C	
6 1,500 160,0 11,750 BB	Annuleren	38A-104 / 1 Viadukt over de Middelweg 86.4% 86.4% 129.9% 111.6% 182.9% 38A-112 / 2 Zuideliik viadukt over de spoorlin Gouda - Alphen 77.1% 77.1% 128.1% 101.8% 101.8% 180.4%	
7 10,200 160,0 21,950 BB 8 1,500 160,0 23,450 BB	Akkoord	32D-105 / 1 Viadukt over de Amersfoortseweg 834% 834% 117,5% 108,9% 108,9% 165,4% 32D,108 / 1 Viadukt over de Woudenbergewen 834% 83,4% 117,5% 108,9\% 108,9\%	
9 1,500 160,0 24,950 BB	Help	39H-116 / 1 Noordelik viadukt over de Wageningsestraat =prc 64,3% 65,3% 134,6% 78,0% 79,7% 189,5% 2001	
	Skiten	Soft-110 / 2 Zuidelijk vladukt over de Karel Doormaniaan 88 6% 103,6% 280,0% 104,5%	
		334-30371 Noordelijk vladukt over de spoorlijn Deventer-∠u 17224 17224 123,58 161,08 161,08 182,44 33A-110/2 Ecoduct 0,0% 0,0% 0,0% 0,0% 0,0% 0,0%	
Selecteer een actie	18-2-2004	Selecteer een actie 13-10-2004	-

Figure 9 Vehicle configuration

Figure 8 Analysis results

4.4 <u>Analysis of the structures</u>

When the transportation route is satisfactory the calculation process can be started. The function "Analysis" is used for this. During the calculation process, all the structures present in the transportation route are calculated independently. Almost all the structures are calculated for two reliability levels (ULS and SLS for the three load combinations specified in paragraph 3.2.

The results of the calculation are compared with the stored design values. The results are shown in tabular form in colour. The colours have the following meanings:

- Red; the bearing capacity of the structure is insufficient.
- Green; the bearing capacity of the structure is sufficient.
- Grey; there is no information available with which to perform the calculation.

At the same time, the relationship between the available capacity and the required capacity is shown as a percentage in the cells. This gives an insight into whether or not the structure can be used.

The time necessary for the calculation process is dependent on the number of structures. For the computer on which the SAAB system was developed, the calculation for a route with 75 structures took about 80 seconds.

5 CONCLUSION

On the basis of the results the following conclusions can be drawn regarding the system SAAB:

- The SAAB system has been developed as prototype assessment system and the system is now available for wider use. The system has been validated and the (output) results are reliable.
- The system is not yet fully operational. To make the system fully operational, so that all the functions are fully utilized, it will need to be developed further, perfected and scaled up as necessary.
- The SAAB database was compiled during the project and contains a relatively limited number of the structures relevant for exceptional heavy vehicles in the national highways. The emphasis was placed on heavy vehicles in the range from 80 to 100 t.

References

- [1] VROUWENVELDER A., and others., "General Safety Considerations and modelling of traffic loads for bridge structures". *TNO-report 98-CON-R1813*. March 2000. pp.76 (in Dutch).
- [2] WIT M. DE., and others., "Coping with exceptional transportations over bridges and viaducts". *TNO report 2000-CON-DYN-R2100*. March 2001. pp.59. (in Dutch).
- [3] WIT M. DE., and others., "Calculation model one-off exemptions for exceptional transportations". *TNO-report 2001-CON-DYN-R8048*. September 2001. pp.68. (in Dutch).
- [4] WIT M. DE., "Supplement to calculation model exceptional transportations". *TNO report 2003-CI-R0150*. 17 November 2003. pp.20. (in Dutch).
- [5] DJORAI M.H., and others., "Standardisation Dealing with Applications for Exceptional Transportations (SAAB)". *Final Report (including four workgroup reports)*. Construction Department, Directorate for Public Works and Water Management. August 2004. pp.28. (in Dutch).
- [6] BOSCH F.H.W.M.VAN DEN, WEESIE E.J.M., "Weighing is Knowing, Research study to an operational better and more simple maintenance system for exceptional heavy transports" *Twijnstra en Gudde report* 1 July 2003, pp. 29 (in Dutch).
- [7] WEESIE E.J.M., BOSCH F.H.W.M.VAN DEN, "Cost-Effectiveness Analysis SAAB-system" *Twijnstra en Gudde report* 31 January 2005, pp. 29 (in Dutch)