PUBLISHED PROJECT REPORT

TRL Limited

PUBLISHED PROJECT REPORT PPR101

THE CHARACTERISTICS OF SPECIAL ORDER VEHICLES

Version: 1.0

by W McMahon

Prepared for: Project Record: **HA Framework Contract 3/359: Task 41**
Client: **Highways Agency**

	Approvals
Project Manager	
Quality Reviewed	

This report has been produced by TRL Limited, under/as part of a Contract placed by the Highways Agency. Any views expressed are not necessarily those of the Highways Agency.

TRL is committed to optimising energy efficiency, reducing waste and promoting recycling and re-use. In support of these environmental goals, this report has been printed on recycled paper, comprising 100% post-consumer waste, manufactured using a TCF (totally chlorine free) process.

CONTENTS

1 Introduction 1

2 Background 1

2.1 Vehicle types in the UK 1
2.2 Designing and assessing structures for abnormal loads 2

3 Overview of SO vehicles (2000 - 2005) 2

3.1 General 2
3.2 Vehicles requiring a Special Order permit by reason of weight 3
3.2.1 Gross weight 3
3.2.2 Number of axles 4
3.2.3 Summary of 'heavy' SO vehicles 5

4 Detailed review of SO vehicle movements (2004 & 2005) 6

4.1 Overview of SO vehicles (2004 & 2005) 7
4.2 Vehicle types 10
4.3 Details of vehicle types 11
4.3.1 Gross weight 11
4.3.2 Number of trailer axles 12
4.3.3 Trailer axle weight 12
4.3.4 Vehicle configurations 12
4.3.5 Axle spacing on trailer units 14
4.3.6 Trailer axle width and lateral wheel spacing 15
4.3.7 Pressure exerted on ground surface by trailer units 16
4.3.8 Details of tractor units 17
4.4 Vehicle dimensions 20
4.4.1 Vehicle width 20
4.4.2 Vehicle length 22

5 Consultation with industry and highway authorities 23

5.1 Form of model 23
5.2 Notification data 23
5.3 Gradients 23
5.4 Speed 23
5.5 Axle weight 24
5.6 Load distribution 24

6 Conclusions 24

7 Recommendations 25

Acknowledgements 26

1 Introduction

The Highways Agency has recently commissioned Atkins and TRL to develop standard loading models for Special Order (SO) vehicles for use in the design and assessment of bridges and other highway structures.

The aim of the work is to develop a number of model vehicles that replicate the loading produced by the SO vehicles that are actually using the highway network at the present time, as well as covering the loads that are likely to be generated by future SO movements. If standard loading models can be developed to cater for the effects of the majority of SO vehicles, then structures on identified heavy load routes can be designed or pre-assessed for these vehicles. This should expedite the process of clearing movement requests for SO vehicles and may also reduce the number of structures requiring strengthening. The model vehicles developed through this project will be implemented through revisions to BD86, BD37 and the UK National Annex to the Eurocode BS EN 1991-2.

In order to develop model vehicles that replicate the loading produced by real SO vehicles, it is first necessary to collect information on the range of physical characteristics associated with SO vehicles. This includes factors such as the gross weight of a vehicle, its individual axle weights, the spacing between axles, and the dimensions of the vehicle. This report presents the findings of the data collection phase of the project. It provides a broad summary of the characteristics of SO vehicle movements during the period 2000 to 2005, and a more detailed review of SO vehicle characteristics in the years 2004 and 2005.

2 Background

2.1 Vehicle types in the UK

Road vehicles in the UK are categorised for regulatory purposes into three broad groups as defined below:

1. ***Vehicles complying with the Road Vehicles Construction and Use (C&U) Regulations and the Authorised Weight (AW) Regulations.***

   This group includes cars, light goods vehicles, and rigid and articulated heavy goods vehicles up to a gross weight of 44 tonnes, with a maximum axle weight of 11.5 tonnes. These vehicles can move freely on the highway network and are not subject to permit and notification requirements. They are often referred to as ‘normal’ traffic to distinguish them from the ‘abnormal’ vehicles described below.

2. ***Vehicles complying with the Motor Vehicles (Authorisation of Special Types) General Order (STGO) Regulations.***

   This group includes vehicles that do not comply with the C&U and AW Regulations such as those used for carrying or drawing abnormal indivisible loads. These vehicles can have axle weights up to 16.5 tonnes and a gross weight of up to 150 tonnes. They are generally referred to as ‘STGO vehicles’ and their movement has to be notified to the appropriate authorities in accordance with STGO Regulations.

3. ***Special Order (SO) vehicles.***

   These vehicles do not comply with the C&U, AW, or STGO Regulations. They are the largest and/or heaviest type of abnormal load and a Special Order (SO) permit is required from the Highways Agency before such vehicles can travel. Special Order (SO) vehicles are those exceeding 6.1m in width, or 30m in length (rigid), or 150 tonnes in weight.

This project is concerned with the third, and heaviest, of the categories described above - the Special Order vehicles. Several hundred Special Orders are issued every year. They specify the route of the movement, and any special cautions or manoeuvres, and are normally valid for six months. SO vehicles weighing more than 150 tonnes are limited to a speed of 12 mph, and large slow loads usually require a police escort for all or part of their journey; the escort is required to close roads where appropriate and to direct traffic. Since January 2004 some of the more routine escorting tasks, which do not require police direction, have been undertaken by the hauliers themselves or private escort companies.

The loads carried by SO vehicles tend to be wide and heavy objects such as electricity transformers, castings, industrial distillation columns and bridge sections, but can also include lighter, longer loads such as wind turbine blades or large girders. The number of SO load movements in any given year can depend on several factors, such as the number of power stations being renewed or dismantled, and the shipping of parts between facilities specialising in one particular operation (e.g. casting or painting) within the manufacturing process.

2.2 Designing and assessing structures for abnormal loads

The current suite of design and assessment standards for highway bridges includes standard highway loading models that cater for the effects of vehicles which comply with the AW and STGO Regulations. However, these models do not cover the load effects generated by SO vehicles.

In the case of an SO vehicle, structures on the notified route are checked for their adequacy to support the vehicle. The checking process can range in complexity from a simple comparative assessment of the SO vehicle against the HB rating for a structure, right up to a full structural assessment. Structures which are deficient may require strengthening to carry the SO vehicle if a suitable alternative route cannot be found. This approach can result in considerable delays and costs to the industry, as well as imposing an administrative burden on highway authorities.

The aim of this project is to develop standard loading models to cater for the effects of the majority of SO vehicles that are likely to move on the highway network. If this can be achieved then the structures on identified heavy load routes can be designed or pre-assessed for these model vehicles. This will enable the load capacity of structures on heavy load routes to be expressed in terms of the standard loading models that can be accommodated, thereby simplifying the process of clearing movement requests for SO vehicles. Thus the development of standard loading models for SO vehicles should increase the efficiency with which heavy load movements are managed, and should reduce the associated costs to both the authorities and the haulage companies.

3 Overview of SO vehicles (2000 - 2005)

3.1 General

In order to develop a loading model that accurately represents the load effects due to SO vehicles, it is first necessary to determine the critical load effects generated by real SO vehicles. Therefore it was necessary to collect information on the range of vehicle weights and configurations that fall within the SO category.

The management of abnormal load movements is the responsibility of the Highways Agency's Abnormal Indivisible Loads (AIL) Team, which maintains an electronic database containing details of all SO vehicle movements. To gain a clear understanding of the characteristics of these vehicles, TRL obtained information from the database on all SO vehicle movements for the years 2000 to 2005. There were 1,767 SO vehicle movements during this period, with gross weights ranging from 30 tonnes to over 2,500 tonnes. The number of SO movements recorded each year ranged between 247 and 356[1].

3.2 Vehicles requiring a Special Order permit by reason of weight

Vehicles can be categorised as ‘abnormal’ because of their weight and/or their dimensions, but with regard to the development of a loading model it is clearly the vehicles that are abnormal by reason of their weight that are of greatest significance. Therefore further analyses were undertaken to identify the ‘heavy’ SO vehicles within the database, i.e. those vehicles which had a gross weight greater than 150 tonnes or which had one or more axles greater than 16.5 tonnes[2].

Of the 1,767 vehicles within the database, some 463 (26 per cent) were categorised as Special Order because of their weight. This is an important and encouraging finding as it suggests that the load effects of approximately three quarters of SO vehicles might well be covered by the standard loading models already in existence (i.e. the HB model in BD 37 and the SV models in BD 86) as these cater for the effects of vehicles up to 150 tonnes.

The remainder of this report deals only with SO vehicles which weigh more than 150 tonnes.

3.2.1 Gross weight

Of the 463 ‘heavy’ SO vehicles within the database, there were four extremely heavy loads which weighed in excess of 1,000 tonnes. These comprised a railway bridge (1,219 tonnes) which was moved in Ashford and three ship sections (weighing between 1,825 and 2,872 tonnes) which were moved within Barrow-in-Furness. Further investigation found that these exceptional loads travelled a few hundred metres at most from their construction sites and therefore it was decided to remove them from the analyses because they were not representative of the SO vehicles which travel on the highway network.

The range of weights from the remaining 459 vehicles in the database is shown in Figure 3.1. It can be seen that although there were a number of SO movements which weighed more than 500 tonnes, the vast majority of movements were of a lesser weight. About 92 per cent of all movements weighed less than 400 tonnes, 79 per cent weighed less than 300 tonnes, and 64 per cent weighed less than 250 tonnes.

It is interesting to note that, in terms of gross vehicle weight, the heaviest of the loading models for STGO vehicles (as defined in BD 86) is the SV-Train, which has a gross weight of 192 tonnes. Given that some 42 per cent of the ‘heavy’ SO vehicles in the database weighed less than 200 tonnes, it would appear that the SV-Train may be representative of a reasonable number of the SO vehicles at the ‘lighter’ end of the weight range.

[1] The total number of movements undertaken annually is likely to be slightly higher than that recorded in the database because a small proportion of SO permits deal with repeat movements (e.g. the transportation of a bridge in several sections spread out over a few days). Where this is the case, only the details of the heaviest movement within the group are input to the database.

[2] In fact, it was found that all of the ‘heavy’ vehicles weighed more than 150 tonnes. There were no vehicles which weighed less than 150 tonnes but had axle weights exceeding 16.5 tonnes.

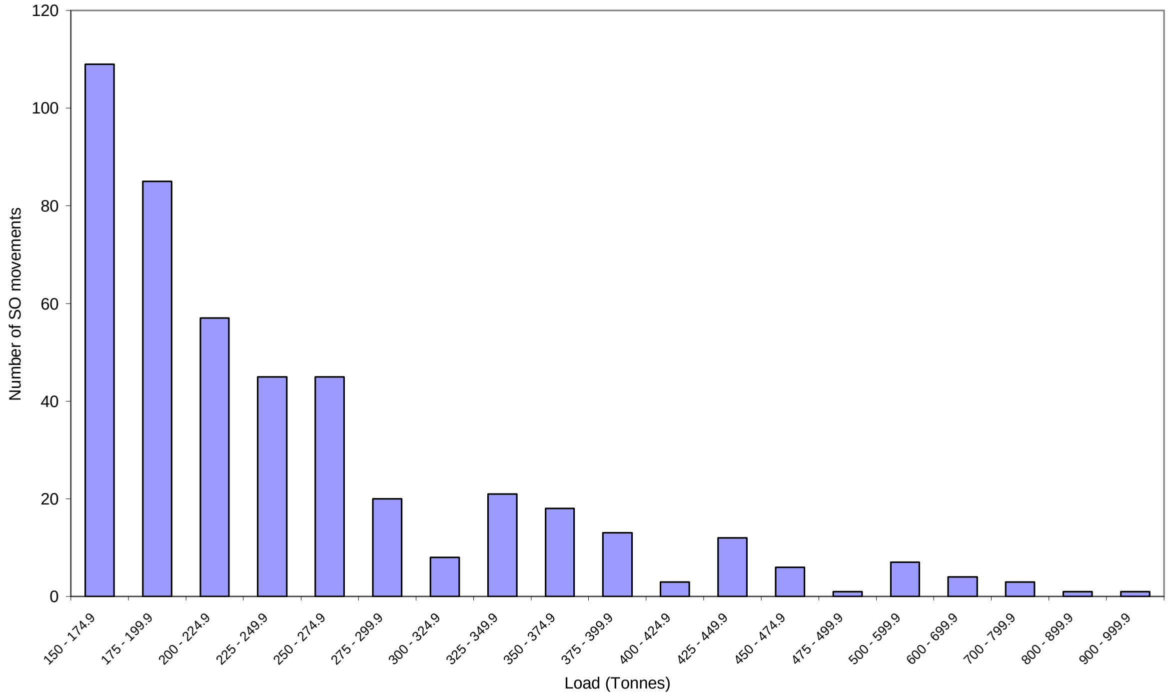


Figure 3.1 Gross weights of SO vehicles (2000 – 2005)

At the other end of the weight range (i.e. between 500 and 1000 tonnes) analyses showed that the majority of the vehicles did not, in all probability, move any great distance and therefore such loads are unlikely to have crossed many bridge structures. The database did not contain information on the actual length of each journey but it did record the starting point and destination of each load movement. It was found that all of the vehicles which weighed more than 550 tonnes had the same town or industrial complex listed as the start and end point of the journey. For example, four particularly heavy vehicles, with weights of between 628 and 950 tonnes, were associated with the movement of bridges within Bradford, Leeds, Hull and Wetherby. Whilst it is not clear exactly how far these loads were moved within each town, it is anticipated that a bridge construction/demolition site will be located as close as possible to the actual bridge site because of the difficulties associated with the movement of such large and heavy loads. Of the other movements in excess of 550 tonnes, almost all of them took place within the Immingham docks complex and nearby power stations. The loads, which included reactors, boiler modules and a de-aerator with weights of between 550 and 816 tonnes, would have travelled a few kilometres at most.

The heaviest vehicles that travelled between different locations were found to be between about 520 and 535 tonnes. Given that every vehicle heavier than this moved only a very short distance, it would seem that the likely upper weight limit for vehicles which travel a substantial distance on the highway network is of the order of about 550 tonnes[3].

The data suggest, therefore, that the loading models developed for SO vehicles would need to cater for SO vehicles with weights of between 150 and 550 tonnes.

3.2.2 Number of axles

As shown in Figure 3.2, the number of axles on which the SO loads were moved varied quite widely from 4 to 32; the most common number of axles for an SO vehicle was 14, but there was also a significant number of vehicles with 10, 12 and 20 axles.

[3] Perhaps not surprisingly, this finding corresponds well with the general experience of the staff in the AIL team who manage these loads.

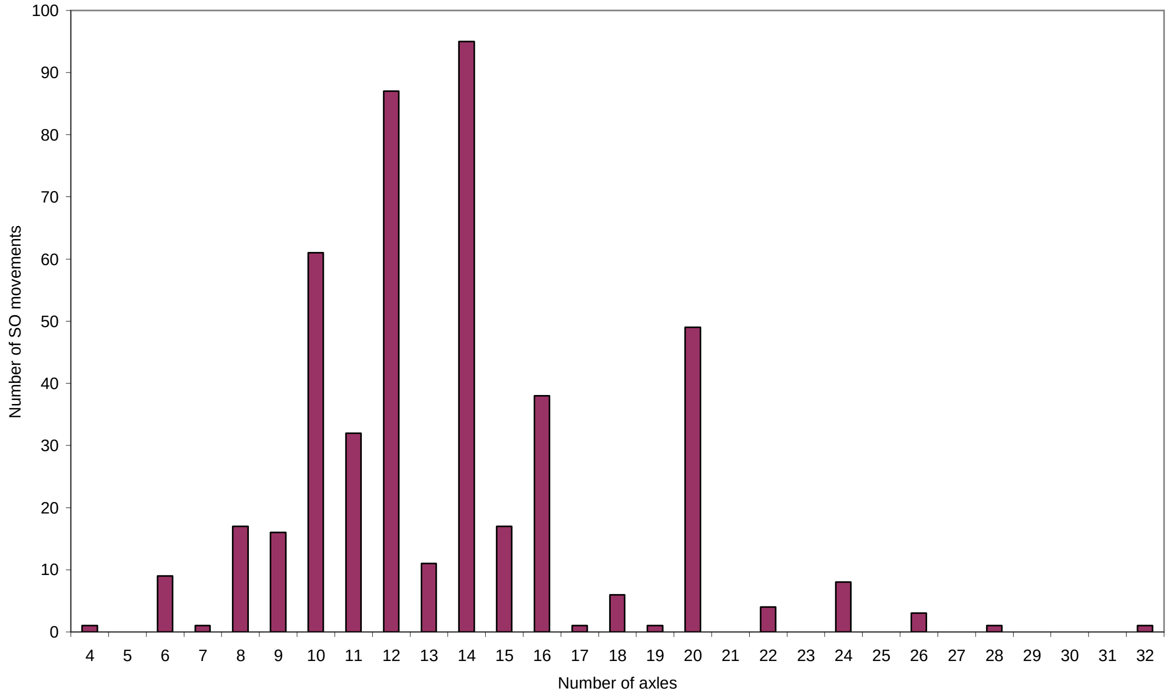


Figure 3.2 Number of axles on SO vehicles (2000 – 2005)

The number of axles used to transport an SO load depends on the type of vehicle used and this, of course, depends on the weight and size of the load. There were four distinct types of vehicle identified within the database and these are discussed in more detail in Section 4.2. However, it is worth pointing out that, perhaps not surprisingly, the vehicles having the greatest number of axles were those that moved the heaviest loads. For example, the 28- and 32-axle vehicles were used to move ship sections, reactors, and transformers, all of which weighed more than 500 tonnes and were transported a very short distance within a port or industrial complex.

For vehicles that moved a reasonable distance on the highway network, the greatest number of axles required was 26. These 26-axle vehicles were used to move transformers between Ellesmere Port and Stafford, and the gross vehicle weights ranged from 440 to 525 tonnes. Most of the 24-axle vehicles also travelled on the highway, transporting generator stators, transformers, and castings. The gross weights of the 24-axle vehicles ranged between 355 and 518 tonnes, and the routes commonly travelled were between Ellesmere Port and Stafford, and between Sheffield and Goole.

At the other end of the spectrum, a small proportion of loads were moved by vehicles with fewer than eight axles. These movements were undertaken by one particular type of vehicle - the self-propelled modular trailer (SPMT) - which is capable of moving heavy loads on as little as four axles, although such vehicles can have up to 12 or 13 axles. Because of their ability to move heavy loads on a small number of axles, SPMT vehicles are capable of generating extremely heavy axle loads, but again it must be emphasised that such movements tend to occur within a port or industrial complex and cover a very short distance.

3.2.3 Summary of 'heavy' SO vehicles

From analyses of the Highways Agency's database of SO movements during the period 2000 - 2005, it was possible to identify the broad characteristics of the SO vehicles that travel substantial distances on the highway network. These vehicles ranged in weight from 150 to about 535 tonnes and had between 8 and 26 axles. It is the load effects generated by these vehicles that the SO model will have to cater for.

The database contained vehicles that were far heavier than 550 tonnes, as well as vehicles that had more than 26 axles or fewer than 8. However, these were associated with movements that occurred within port areas, industrial plants, or bridge construction sites. Although exceptions are always possible, it seems reasonable to suppose that extremely large loads (such as bridges and ship sections) will be constructed as close as possible to their intended destinations due to the difficulties associated with moving such large loads. The information obtained from analyses of the database and associated documentation would appear to support this supposition, because it was found that any load greater than about 550 tonnes did not travel very far at all on the highway network, and most were a matter of a few hundred metres. These findings also agree with the experience of staff from the AIL Team who were of the opinion that the maximum load that travelled any significant distance on the highway network was of the order of about 550 tonnes.

4 Detailed review of SO vehicle movements (2004 & 2005)

The database maintained by the Highways Agency's AIL Team contained general information on SO movements such as:

- The start point and destination of the journey
- The type of load (e.g. transformer, casting, bridge deck)
- The dimensions of the vehicle
- The gross weight of the vehicle
- The number of axles

However, to determine the magnitude of the load effects generated by a vehicle, it is necessary to have more detailed information such as the weight of each axle and the spacing between axles. As shown in Figure 4.1, the specific information required includes:

- The number and weight of the tractor units
- The number and weight of the trailer units
- The number and weight of individual axles
- The spacing between axles, i.e.
    - The spacing between the axles of the tractor units
    - The spacing between the axles of the trailer units
    - The distance between the trailer units
    - The distances between the tractor and trailer units

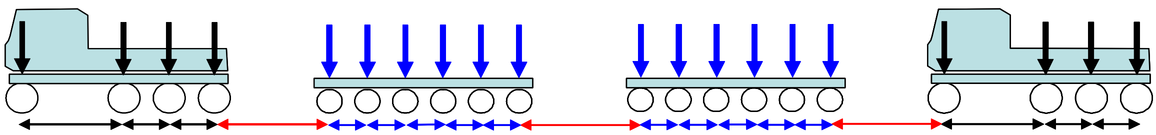


Figure 4.1 Information required to develop SO loading model

In addition, it is important to know the number and arrangement of wheels along the breadth of an axle in order to determine the lateral distribution of the load so that any local effects due to individual wheel loads can be determined. A schematic representation of a typical axle arrangement on an SO trailer is given in Figure 4.2, which shows that a typical axle comprises eight wheels (in four twin-wheel arrangements).

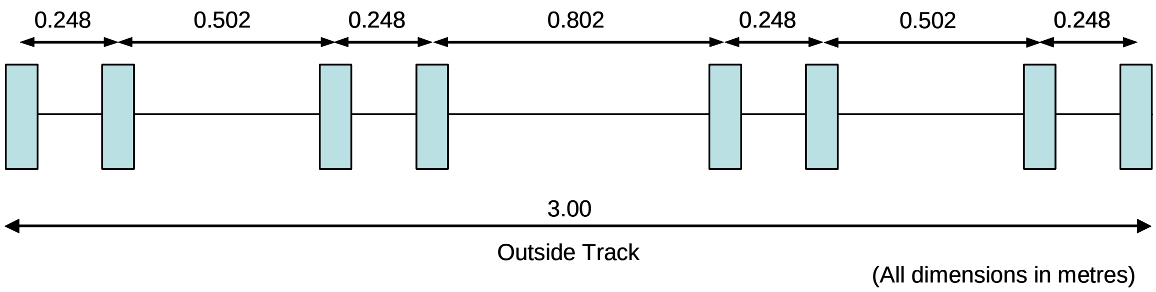


Figure 4.2 Typical lateral wheel load arrangement for SO trailer units

To obtain the data necessary to develop the SO loading model, TRL staff visited the offices of the Highways Agency's AIL Team to examine the documentation associated with the management of SO vehicles. By interrogating the correspondence and drawings within the files, it was possible to collect the data required to develop the model.

As described in Section 3, during the period 2000 - 2005 there were some 463 SO movements which weighed more than 150 tonnes. Unfortunately, the documents which contained the data required to develop the model were only readily available for the years 2004 and 2005. During this period there were 132 SO movements which weighed more than 150 tonnes, and the details of these vehicles were input to an electronic database for further analysis.

Thus the SO load model will be developed from data on the weight and configuration of SO vehicle movements during 2004 and 2005, and a summary of the characteristics of these vehicles is given in the remainder of this Section.

4.1 Overview of SO vehicles (2004 & 2005)

A summary of the 132 SO vehicle movements that occurred in 2004 and 2005 is given in Table 4.1. It can be seen that the gross weights of the vehicles (i.e. including the weight of any tractor units) ranged from 152 to 628 tonnes, and the average weight of an SO vehicle was about 243 tonnes. The range of gross vehicle weights associated with SO vehicles is shown in Figure 4.3. The figure shows that the majority of vehicles (78 per cent) were less 350 tonnes, but there were between six and nine movements in each of the heavier weight categories up to 550 tonnes.

	Gross vehicle weight (Tonnes)	Number of axles	Axle weight (Tonnes)
Minimum	151.8	4	10.9
Maximum	628.0	22	52.3
Mean	242.7	14	17.2

Table 4.1 Summary of SO movements (2004 & 2005)

During 2004 and 2005 there was only one vehicle which weighed more that 550 tonnes; this was the movement of a newly constructed bridge and the gross vehicle weight was 628 tonnes. As discussed in Section 3, in common with the other loads weighing more than 550 tonnes, this bridge was moved only a very short distance from its construction site to its intended destination.

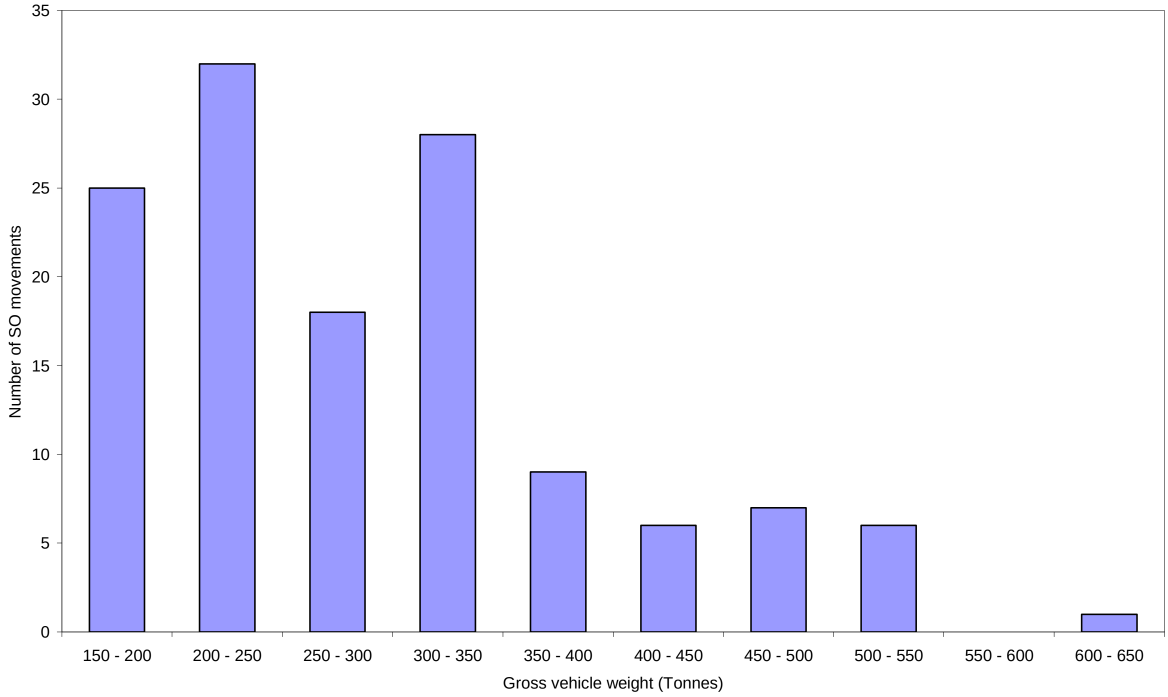


Figure 4.3 Gross weight of SO vehicles (2004 & 2005)

The number of axles on which the loads were moved is shown in Figure 4.4. It can be seen that the number of axles varied quite widely from 4 to 22. The most common number of axles for an SO vehicle was 14 but there were also significant numbers of vehicles with 12 and 20 axles. As already discussed in Section 3.2.2, the use of self-propelled modular trailers (SPMT) accounts for the SO loads moved on four and six axles.

The range of axle weights on the trailer units (i.e. excluding tractor axles) is shown in Figure 4.5. In general, the axle weights of most SO vehicles ranged from 11 to 23 tonnes, with the most common axle weight being 16 tonnes. However, it can be seen from the figure that there was a substantial number of axles that weighed over 25 tonnes, and these were all due to the axle weights of the SPMTs. The axles of these vehicles were generally well over 20 tonnes in weight and ranged up to a maximum of 52 tonnes[4]. This explains why, at 17.2 tonnes, the average axle weight for all SO vehicles might appear a little high in comparison to the range of axle weights shown in Figure 4.5.

[4] However, it should be noted that the heaviest axles were 'double-width' in that they comprised two normal axles placed side-by-side. This is discussed in more detail in Section 4.3.3.

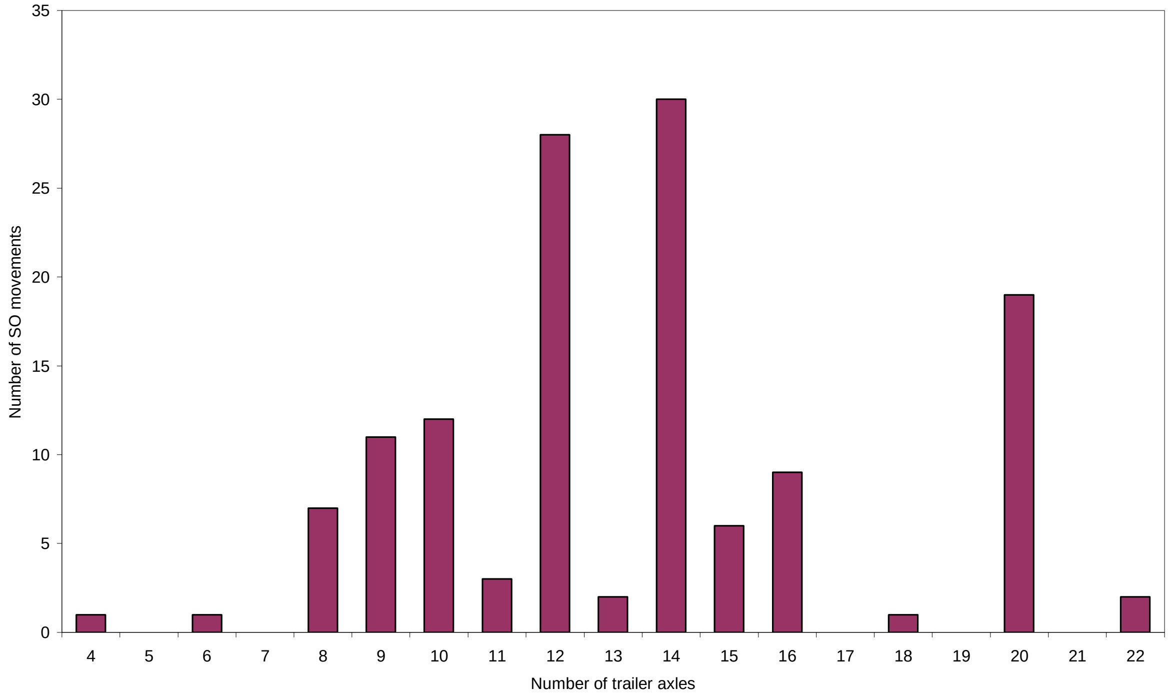


Figure 4.4 Number of axles on trailer units of SO vehicles (2004 & 2005)

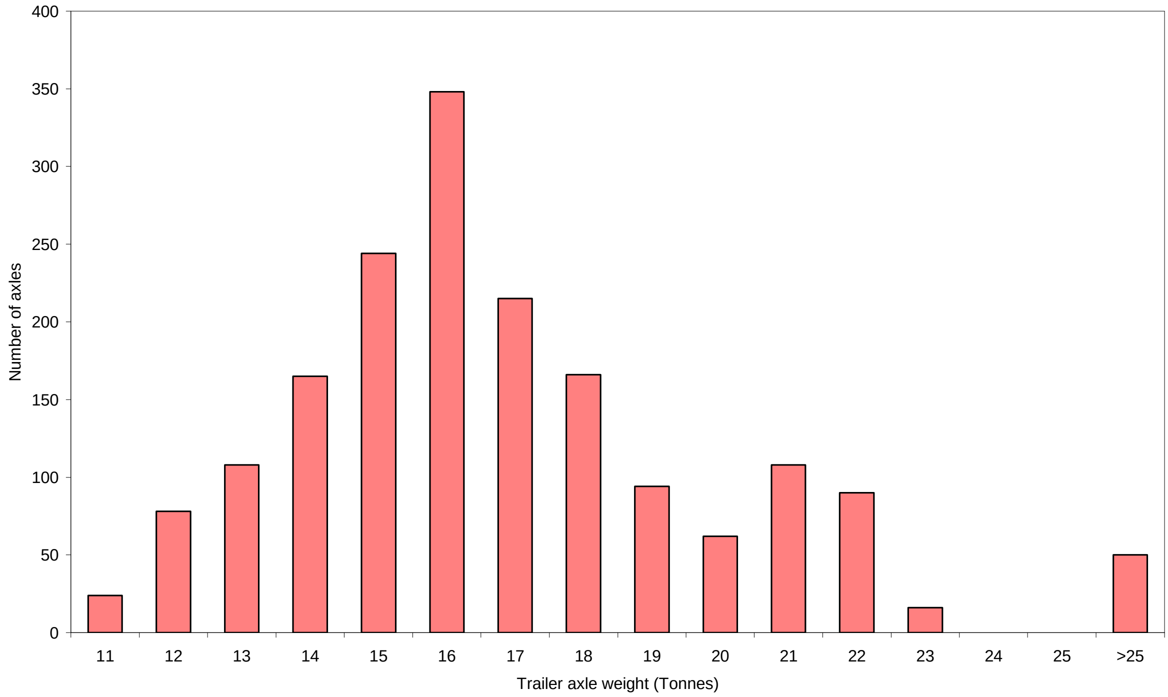


Figure 4.5 Distribution of axle weights on trailer units of SO vehicles (2004 & 2005)

4.2 Vehicle types

To understand the wide range of vehicle and axle weights which were found within the overall population of SO vehicles, it is necessary to examine the different types of vehicle within it. There were four types of vehicle within the database:

- Articulated tractor and semi-trailers
- Draw-bar trailers
- Girder frame vehicles, and
- Self-propelled modular trailers

Views of the different vehicle types are given in Appendix A.

An example of an articulated tractor and semi-trailer arrangement (hereafter referred to as artic & semi) is shown in Figure A1. The load being transported sits on the trailer unit but the artic & semi arrangement is designed such that some of the loading bears onto the axles of the tractor unit. As shown in the figure, the trailer is usually joined to the tractor by a coupling that pivots over the rear axles of the tractor. Examples of an artic & semi arrangement range from a car towing a single axle trailer to a tractor towing a trailer with a 50ft wind turbine blade.

As shown in Figure A2, a draw-bar trailer is one that is pulled and/or pushed by one or more tractors by means of a length material (commonly formed from steel). The load being transported sits on the trailer and its weight is borne entirely by the trailer axles: no component of the trailer's weight may be borne by the tractor(s) otherwise it is classed as an artic & semi arrangement. Examples of this type of arrangement can vary from a car towing another car (in neutral) to extremely heavy load movements where three tractors are pulling and one is pushing a multi-axle trailer. In the case of heavy loads the tractor unit must have ballast loaded onto the rear axles to provide enough traction to pull/push the load.

As shown in Figure A3, a girder frame type vehicle is used when there is a wish to spread the weight of the load onto two separate sets of axles or where it is necessary to 'sling' the load lower than would be the case if it sat directly on top of a trailer. Depending on the arrangement of the tractor units, girder frame vehicles are classed as either a draw-bar arrangement or an artic & semi arrangement. Nonetheless, the documentation usually distinguished between girder frame vehicles and these other arrangements, and so this approach has been adopted in the analyses. Girder frame vehicles are typically used to transport transformers (due to their weight) or wind turbine tower sections (due to their height).

A self-propelled modular trailer (SPMT) is a tractor and trailer combined and an example of such a vehicle is shown in Figure A4; generally these vehicles are controlled by an operator walking alongside the vehicle with a remote control. A version with a mounted seat has been used to allow for travel at speeds greater than walking pace. The self-propelled module typically consists of six to eight axles and these can be combined by either joining the units directly or by placing a rigid section between two modules. SPMTs are generally used in factory or construction yards to move very large and prefabricated structures. If a SPMT is pulled or pushed by another vehicle it becomes either a draw-bar trailer or an artic & semi depending on the arrangement.

The number of movements of each type is shown in Table 4.2. The most common type of vehicle was the draw-bar trailer, which was used for just over half of all SO movements within the database. The girder frame and the artic & semi arrangements accounted for about 20 per cent each of the total number of movements, while SPMTs accounted for 10 per cent of movements. The physical characteristics of the various vehicle types are discussed in more detail in the following sections.

Vehicle type	Number of movements (2004 & 2005)
1. Draw-bar trailer	67 (51%)
2. Girder frame	25 (19%)
3. Articulated tractor & semi trailer	27 (20%)
4. Self-propelled modular trailer (SPMT)	13 (10%)
Total	**132**

Table 4.2 SO vehicle types (2004 & 2005)

4.3 Details of vehicle types

General details of the various vehicle types are given in Tables B1 to B4 of Appendix B, whilst the distributions of gross vehicle weight and axle weight for each vehicle type are shown, respectively, in Figures C1 and C2 of Appendix C. The physical characteristics of the different vehicle types are discussed below.

4.3.1 Gross weight

The data given in Appendix B show that the gross weights of draw-bar trailer vehicles ranged from 173 tonnes up to 536 tonnes, and the mean weight of this vehicle type was just under 290 tonnes. The maximum gross weight associated with girder frame vehicles was similar (at 523 tonnes) to that for draw-bar trailers, but the mean weight of girder frames was considerably higher at 376 tonnes. In contrast, the gross vehicle weights of the artic & semi arrangements were far lower than the draw-bar or girder frame vehicles, with a maximum recorded weight of 271 tonnes and a mean weight of just over 200 tonnes.

These differences are highlighted in Figure C1, which shows that draw-bar trailers were used to transport a wide range of loads, but with most lying in the range 200-325 tonnes. In contrast, the weight distribution of the girder frame vehicles was much tighter, with all but one movement being between 300 and 525 tonnes. This explains why the mean weight of the girder frame vehicles exceeded that of the draw-bar trailer vehicles by about 87 tonnes, even though both vehicle types were capable of carrying loads at the heavier end of the weight range.

The figure also shows that artic & semi vehicles had a much tighter distribution of weights compared to the other vehicle types, and the weights were situated at the low end of the range for SO vehicles, with most being between 175 and 200 tonnes.

The gross weights of the SPMTs ranged from 178 to 628 tonnes with a mean of about 258 tonnes. As discussed previously, most SPMT movements (and in particular the heavy ones) involved only very small distances, i.e. several hundred metres. Examination of the documentation relating to SPMT movements showed that the *longest* distances travelled by such vehicles (in 2004 and 2005) were between 4 and 8km, and these journeys were made by vehicles with gross weights of between 250 and 300 tonnes.

It is also worth noting that there were two distinct weight ranges for girder frame vehicles, which reflects the two particular configurations that such vehicles take: one configuration has 14 trailer axles (comprising 2 no. 7-axle trailers) and the other has 20 trailer axles (comprising 2 no. 10-axle trailers). Not surprisingly, the longer and larger trailers tend to be used for the heavier loads. The various configurations exhibited by the SO vehicles are described in more detail in Section 4.3.4.

4.3.2 Number of trailer axles

The number of trailer axles on draw-bar vehicles ranged from 8 to 22, and the average number of axles per movement was 14. Although a substantial number of movements used 14 axles, the most common number of axles was in fact 12, usually in the form of 2 no. 6-axle trailers. In contrast, the girder frame vehicles always had one of two configurations - either 14 or 20 axles as described above.

The artic & semi vehicles tended to have fewer trailer axles than the draw-bar or girder frame vehicles, with an average of 11 axles per movement. However, the average value is slightly misleading as there were only two such arrangements in the database; the most frequently used arrangement was nine axles, usually in the form of a single line of nine equally spaced axles. The smaller number of axles associated with these vehicles is in keeping with the fact that they tended to move lighter loads than the other types of SO vehicle.

The SPMT vehicles in the database had up to 13 axles but could move SO loads on as few as four axles. However, by far the most common number of axles for these vehicles was 12, usually in a single line of 12 equally spaced axles.

4.3.3 Trailer axle weight

The distributions of trailer axle weight for the various vehicle types, as shown in Figure C2, were similar to those already discussed for gross weight. The axle weights from draw-bar trailer vehicles covered a wide range of values from 11 through to 23 tonnes, with a mean value of 16.6 tonnes. By comparison, the distribution of axle loads from girder frame vehicles was tighter, with all of the axles falling between about 15 and 21 tonnes, and thus the mean axle weight for these vehicles was higher at 17.6 tonnes.

As with the gross weight data, the axle weights of the artic & semi vehicles were distributed towards the low end of the weight range, with a mean value of 14.2 tonnes, which was significantly lower than either the draw-bar trailer or girder frame vehicles.

It has already been shown that SPMT vehicles moved a wide range of loads, some of them extremely heavy, and on relatively few axles. This is reflected in the axle weight data, which ranged from 15 to 52 tonnes. The majority of the SPMTs had axle weights in excess of 20 tonnes, and the mean axle weight was almost 25 tonnes. However, there are a couple of important points to bear in mind when considering these axle weights. The first, which has already been mentioned, is that these vehicles did not usually travel very far. (Therefore it is unlikely that they will have crossed many bridges, although they may well have passed over buried structures such as culverts and drainage pipes.)

The second point is that most of the axles which weighed more than 20 tonnes were ‘double-width’ axles in that they comprised two separate axles placed side-by-side, thereby forming a 5.34m wide axle, rather than the single 2.43m wide axle used for smaller or lighter loads. Thus the axle loads were high in comparison to other vehicle types but, because the loads were distributed over two axles, the individual wheel loads were not necessarily much greater than the wheel loads generated by the heavier examples of draw-bar trailer and girder frame vehicles. There were, however, a couple of exceptions to this within the database. These related to SPMT movements with loads of 26 and 27 tonnes on standard single-width axles (thereby generating loads of about 6.5 tonnes per twin wheel arrangement). However, the loads being moved were a road bridge and a rail bridge and again the distance travelled was no more than a few hundred metres.

4.3.4 Vehicle configurations

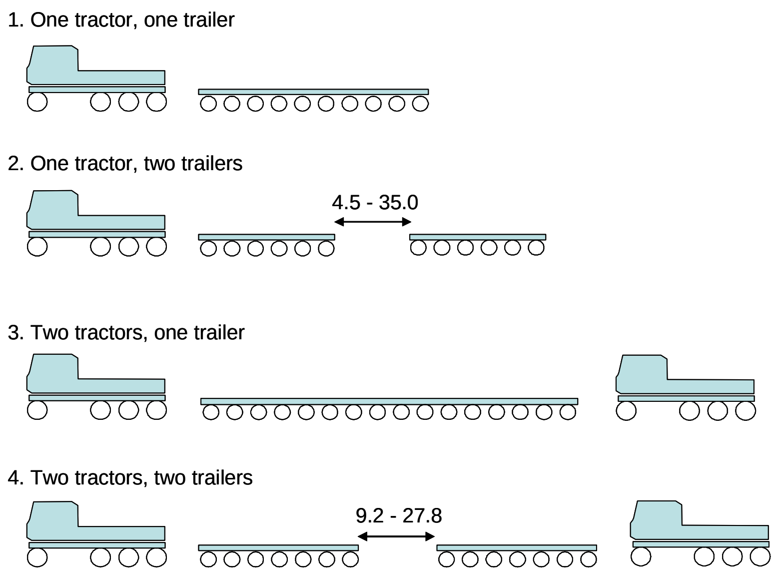
The physical characteristics of the vehicle types have been described above, but a closer examination of the data showed that, for draw-bar trailers and girder frames, there were distinct configurations of vehicles within the general vehicle type.

Draw-bar trailers

Draw-bar trailer vehicles are formed from a combination of tractor and trailer units, and four separate configurations were found within the database:

1. One tractor pulling one trailer
2. One tractor pulling two trailers
3. Two tractors (one pulling, one pushing) with one trailer
4. Two tractors (one pulling, one pushing) with two trailers

These configurations are shown schematically in Figure 4.6, along with details of the physical characteristics of each configuration. The figure shows that the number of movements were broadly similar for each configuration; half of all draw-bar vehicle movements required only a single tractor while the other half required two tractors. Perhaps not surprisingly, the movements involving a single tractor unit were considerably lighter than those which required two. As shown in Figure 4.6, the range of trailer weights for Configurations 1 and 2 (i.e. one tractor) were much smaller than for Configurations 3 and 4. The trailer loads pulled by a single tractor were, on average, about 85 tonnes lighter than those requiring two tractor units.



Configuration		No. of movements	No. of trailer axles	Axle weight (Tonnes)		Trailer weight (Tonnes)	
				Range	Mean	Range	Mean
1.	1 tractor 1 trailer	17	8 - 16	13.8 - 23.1	17.0	152 - 240	190
2.	1 tractor 2 trailers	16	10 - 20	10.9 - 18.1	14.3	160 - 272	187
3.	2 tractors 1 trailer	13	10 - 22	11.6 - 21.6	16.4	172 - 440	264
4.	2 tractors 2 trailers	20	10 - 20	13.0 - 22.3	17.7	164 - 440	282

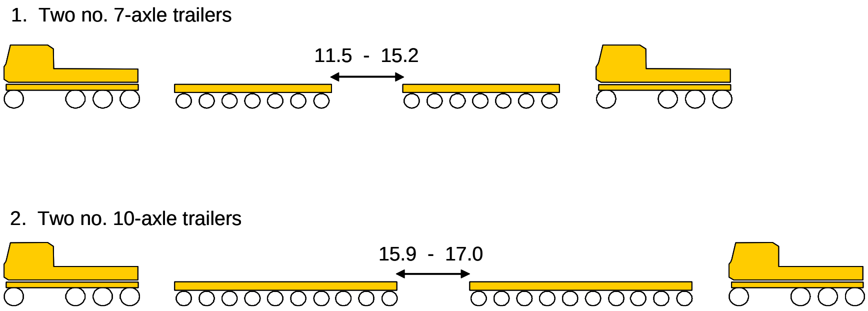
Figure 4.6 Draw-bar trailer configurations

In terms of individual axle weights, there was not a great deal of difference between Configurations 1,3, and 4 with mean values of between 16.4 and 17.7 tonnes. However, with a mean weight of 14.3 tonnes, the axles associated with Configuration 2 were considerably lighter. This is probably a reflection of the types of load carried by Configuration 2, which were light enough to require only a single tractor but long enough to require two trailer units separated by distances of between 4.5 and 35 m. Naturally, the individual axle weights resulting from the transport of relatively long and light loads will be smaller than those resulting from the transport of heavier, more compact loads.

Girder frame vehicles

Unlike the draw-bar trailer vehicles, the girder frame vehicles always had two tractor units to move the load (one pulling and one pushing). This is part of the reason why, on average, the gross weights of these vehicles tended to be higher than the draw-bar trailer vehicles.

There were two distinct configurations of the girder frame vehicle – one having 14 trailer axles and the other having 20 trailer axles. These configurations are shown schematically in Figure 4.7, along with details of the physical characteristics of each configuration.



Configuration		No. of movements	Axle weight (Tonnes)		Trailer weight (Tonnes)	
			Range	Mean	Range	Mean
1.	2 x 7-axle trailers	16	15.3 - 18.6	16.9	214 - 256	237
2.	2 x 10-axle trailers	9	16.5 - 21.4	18.4	330 - 427	368

Figure 4.7 Girder frame configurations

The figure shows that the 14-axle configuration was the most common, accounting for 64 per cent of all girder frame movements. The loads moved by the 20-axle configuration were considerably heavier than those moved on 14 axles: the mean trailer weight for a 20-axle movement was some 131 tonnes greater than the mean trailer weight for a 14-axle movement. In addition the axle weights on the 20-axle configuration were, on average, 1.5 tonnes heavier than those on the 14-axle configuration.

4.3.5 Axle spacing on trailer units

The axle spacing on the trailer units of SO vehicles ranged between 1.35m and 1.9m, but as shown in Table 4.3 there was a relatively small number of configurations, and two or three of these were seen on a regular basis. The axle spacing on the SPMTs was generally 1.4m, whilst for artic & semi vehicles it was mostly 1.5m. The axle spacing for girder frame vehicles was commonly 1.6m whilst the for draw-bar trailers the axle spacing was generally between 1.5 and 1.6m.

Trailer axle spacing (m)	Number of SO movements				**TOTAL**
	Draw-bar trailer	Girder frame	Artic & semi-trailer	SPMT	
1.35	0	0	2	0	**2**
1.40	0	0	0	10	**10**
1.50	31	0	24	1	**56**
1.55	17	6	1	2	**26**
1.60	14	18	0	0	**32**
1.90	4	1	0	0	**5**

Table 4.3 Range of axle spacing found on SO trailer units

4.3.6 Trailer axle width and lateral wheel spacing

As well as notifying the Highways Agency of the axle weight and spacing on SO vehicle movements, the documentation provided by the haulage company usually contains information on the width of the axles supporting the load, the number of wheels on each axle, and the lateral spacing between the wheels. Examination of the data showed that, for SO vehicles as a whole, there were ten different axle configurations used during 2004 and 2005. Details of these configurations are given in Table 4.4, which shows that the outside track (see Figure 4.2) ranged between 2.38 and 4.275m. Theoretically at least, it would be possible for all but one of the SO axle configurations to fit within one notional lane[5] although in practice it is likely that many of the vehicles would encroach into a second notional lane due to the dimensions of the load being moved. (The dimensions of the vehicles are discussed in more detail in Section 4.4.)

A few of the axle configurations had only four wheels[6], but in general most SO loads were supported by axles having eight wheels, arranged in four separate twin-wheel arrangements. A view of a typical axle from an SO vehicle is given in Figure 4.8 below.

Figure 4.8 Trailer axle with four twin-wheel arrangements

The number of movements on each of the axle configurations is shown in Table 4.5, and it can be seen that Configurations 1, 2 and 3 were the most commonly used. All of the girder frame vehicles used four twin-wheel arrangements, as did all but one of the draw-bar trailers and most of the artic & semi vehicles. Five of the artic & semi vehicles used Configuration 8, which comprised two twin-wheel arrangements. All but one of the SPMT movements used Configuration 10 which comprised

[5] In design and assessment standards, notional lanes are those notional parts of the carriageway used solely for the purposes of applying specified live loads. Generally, the maximum width of a notional lane is taken to be 3.65m

[6] Usually associated with SPMTs and artic & semi arrangements.

four single wheels more or less equally spaced along the axle. Where a very heavy load (such as a bridge) was to be moved a short distance by SPMT, two lines of axles would be located side-by-side, forming 'double-width' axles which carried weights from 20 to 52 tonnes.

Axle configuration	Lateral spacing between wheel (or twin wheel) centres (m)			Number of wheels	Outside track (m)
1	0.730	1.050	0.730	8 (4x2)	3.000
2	0.735	1.085	0.735	8 (4x2)	2.990
3	0.950	1.160	0.950	8 (4x2)	3.650
4	1.222	1.222	1.222	8 (4x2)	4.275
5	0.925	1.330	0.925	8 (4x2)	3.650
6	0.630	1.140	0.630	4	2.380
7	0.500	1.800	0.500	8	3.000
8	0.620	1.210	0.620	4	2.750
9	0.720	0.865	0.720	8 (4x2)	2.750
10	0.620	0.860	0.620	4	2.430

Table 4.4 Lateral wheel spacing configurations

Axle configuration	Number of SO movements			
	Draw-bar trailer	Girder frame	Artic & semi-trailer	SPMT
1	31	0	15	1
2	10	6	0	0
3	17	18	0	0
4	3	1	0	0
5	1	0	0	0
6	3	0	0	0
7	1	0	0	0
8	0	0	5	0
9	0	0	6	0
10	0	0	0	10

Table 4.5 Number of movements using each axle configuration

4.3.7 Pressure exerted on ground surface by trailer units

It has been shown that SO loads are carried on groups of closely spaced axles with up to eight wheels on each axle. This ensures that the load is reasonably well distributed over the plan area of the trailer or axle group (bogie), and therefore by taking the sum of the axle weights and dividing it over the plan area of the trailer/bogie, it is possible to calculate the 'pressure' exerted by the trailer/bogie. As shown in Figure 4.9, the plan of the trailer/bogie can be determined from the product of the outside track and the wheel base, both of which can be obtained from the database.

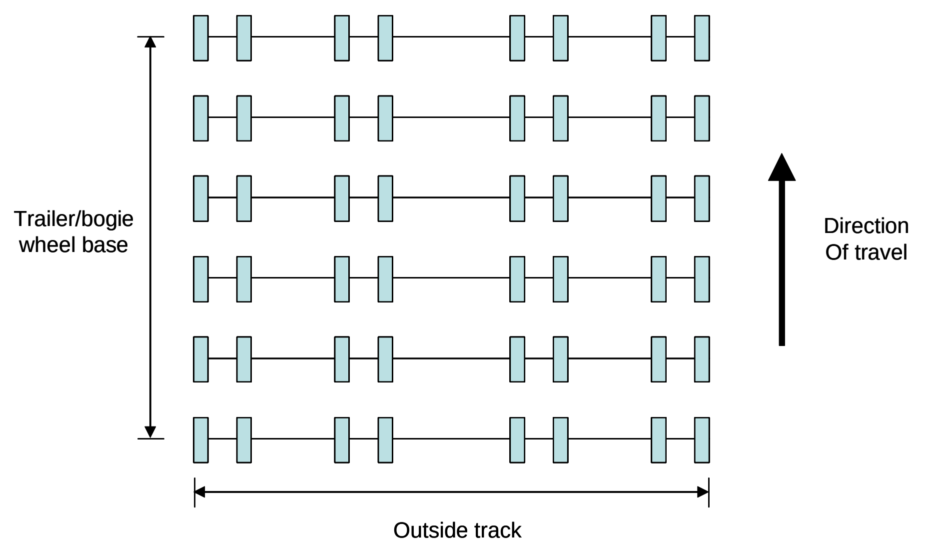


Figure 4.9 Plan area of trailer/bogie

The trailer/bogie pressures were calculated for each of the vehicles within the database, and the results are summarised in Table 4.6.

As might be expected, the highest pressures were exerted by the SPMTs because these vehicles could have very heavy axles at a relatively close spacing of 1.4m. The maximum pressure of 99.6 kN/m^2 was due to a single-width (2.43m) four-axle bogie which had axle weights of 25.9 tonnes. Although there were SPMTs with considerably higher axle weights, these comprised double-width axles (5.34m) and therefore the pressure was reduced accordingly.

For the other three vehicle types, the trailer/bogie pressure ranged from about 25 to 56 kN/m^2, while the mean values for the various configurations were between 34 and 39 kN/m^2.

	Pressure exerted by trailer/bogie (kN/m^2)							
	Draw-bar trailer				Girder frame		Artic & semi	SPMT
	1 Tractor 1 Trailer	1 Tractor 2 Trailers	2 Tractors 1 Trailer	2 Tractors 2 Trailers	2 x 7-axle	2 x 10-axle		
Min	27.4	32.7	26.6	25.4	25.4	30.8	26.0	30.8
Max	43.1	49.0	48.1	54.2	42.7	39.9	55.6	99.6
Mean	36.0	37.8	36.3	36.5	35.6	34.3	38.7	58.1

Table 4.6 Summary of pressures exerted by trailer units of SO vehicles

4.3.8 Details of tractor units

The notification forms completed by the haulage company and sent to the HA usually contain details of the tractor units which are required to move the load. It was found that the SO loads were almost always moved either by a single tractor unit (pulling) or by two tractor units (one pulling, one pushing). There are occasions when three or more tractors may be required to move a load but these additional tractors are not necessarily recorded on the notification forms. This is discussed in more detail in Section 5.

Of the 132 vehicle movements within the SO database, details of the tractor units were available for 114 of them. Of the remaining 18 movements, 13 were SPMTs (which do not have separate tractor units) and tractor details were not available for five vehicles - one drawbar trailer, two girder frame and two artic & semi vehicles. The range of tractor configurations found within the database is given in Table 4.7.

The table shows that the tractor units had either three or four axles and ranged in weight from 33 to 54 tonnes, although most weighed between 40 and 48 tonnes. The front (steer) axle was the lightest, generally weighing between 7 and 9 tonnes, whilst the two rear axles were the heaviest, weighing between 10 and 16 tonnes.

In terms of axle spacing, there were 16 different tractor configurations, five of which were 3-axle configurations and eleven of which were 4-axle configurations. In addition, there were a number of 4-axle configurations which had identical axle spacing but different axle weights; these are shown in the table as sub-configurations (a), (b), (c) etc. It is not clear whether these sub-configurations represent the same tractor unit being subject to different levels of loading, or whether each sub-configuration represents a different type of tractor unit. The former situation could well be the case for artic & semi arrangements where the tractor axles bear some of the load, but this should not be the case for draw-bar arrangements.

The table shows that, in total, there were 29 distinct combinations of axle weight and spacing within the database (five no. 3-axle configurations and 24 no. 4-axle configurations). Half of the movements required only a single tractor (pulling) while the other half required two (one pulling, one pushing). In all cases where two tractors were used, the tractor units were identical in terms of gross weight, axle weight and axle spacing. The majority of SO movements (85 per cent) used 4-axle tractor units.

Although there was a wide range of tractor configurations within the database, it can be seen that some were more common than others. For example, Configuration 5 was by far the most common type of 3-axle tractor used for draw-bar trailers and was the only type used for girder frame vehicles. Interestingly, the girder frame trailers moved by 3-axle tractors were all of the 14 axle (2 x 7) type; the larger 20 axle (2 x 10) trailers that tended to carry the heavier loads were always moved by 4-axle tractors.

Of the 4-axle tractors, Configuration 16 was the most frequently used for draw-bar trailers (although 9(b) and 10(a) were also used quite regularly) and this was the only type used for girder frame vehicles. In contrast the artic & semi vehicles were pulled by a wide range of tractor configurations, which is perhaps not surprising given that the tractor units are designed to bear a portion of the load and thus the tractor axle loads could vary from one journey to the next. Indeed Table 4.7 shows that the heaviest tractor units (i.e. those weighing 50 tonnes or more) were associated with artic & semi vehicles.

In general, the heaviest loads were moved by 4-axle tractor units whilst the 3-axle tractors were used for lighter loads. This is illustrated in Table 4.8, which compares the mean weights of the trailers moved by 3-axle and 4-axle tractors. The table shows that where the vehicle was pulled by a single tractor unit - i.e. artic & semi arrangements and draw-bar trailers with one tractor - the mean weights of the trailers pulled by 4-axle tractors were, respectively, 15 and 7 tonnes heavier than those trailers pulled by 3-axle tractors. The difference was even more apparent where two tractors were used; for girder frame vehicles and draw-bar trailers (one pull, one push) the mean weights of the trailers moved by 4-axle tractors were, respectively, 75 and 87 tonnes more than those moved by 3-axle tractors.

Config. No.		Tractor details			Axle weight and spacing							No. of movements (Pulling)				No. of movements (Pushing)		
		No. of axles	Wheel base (m)	Gross weight (Tonnes)	Axle 1 (Tonnes)	Space 1 (m)	Axle 2 (Tonnes)	Space 2 (m)	Axle 3 (Tonnes)	Space 3 (m)	Axle 4 (Tonnes)	Drawbar trailer	Girder frame	Artic & semi	Total	Drawbar trailer	Girder Frame	Total
1		3	4.47	35	7.0	3.05	14.0	1.42	14.0	-	-	1	-	-	**1**	-	-	**0**
2		3	4.60	39.7	8.5	3.20	15.6	1.40	15.6	-	-	-	-	2	**2**	-	-	**0**
3		3	5.20	43	13.0	3.80	15.0	1.40	15.0	-	-	-	-	2	**2**	-	-	**0**
4		3	5.31	33	7.0	3.91	13.0	1.40	13.0	-	-	1	-	-	**1**	-	-	**0**
5		3	6.95	40	9.5	5.05	15.25	1.90	15.25	-	-	10	6	1	**17**	7	6	**13**
6		4	4.55	35	7.5	1.85	7.5	1.35	10.0	1.35	10.0	-	-	1	**1**	-	-	**0**
7	(a)	4	4.68	43	7.5	1.98	7.5	1.35	14.0	1.35	14.0	-	-	1	**1**	-	-	**0**
	(b)			47	8.0	1.98	8.0	1.35	15.5	1.35	15.5	-	-	2	**2**	-	-	**0**
8		4	4.80	40	8.0	1.90	8.0	1.50	12.0	1.40	12.0	-	-	1	**1**	-	-	**0**
9	(a)	4	5.01	40	8.0	2.25	10.0	1.36	11.0	1.40	11.0	1	-	-	**1**	1	-	**1**
	(b)			42	8.0	2.25	10.0	1.36	12.0	1.40	12.0	9	-	-	**9**	4	-	**4**
	(c)			50	8.0	2.25	12.0	1.36	15.0	1.40	15.0	-	-	1	**1**	-	-	**0**
	(d)			50	9.0	2.25	11.0	1.36	15.0	1.40	15.0	-	-	1	**1**	-	-	**0**
	(e)			53	9.0	2.25	12.0	1.36	16.0	1.40	16.0	-	-	2	**2**	-	-	**0**
	(f)			54	9.0	2.25	15.0	1.36	15.0	1.40	15.0	-	-	1	**1**	-	-	**0**
10	(a)	4	5.13	40	8.0	2.53	10.0	1.30	11.0	1.30	11.0	12	-	-	**12**	5	-	**5**
	(b)			46	8.0	2.53	10.0	1.30	14.0	1.30	14.0	2	-	-	**2**	1	-	**1**
11	(a)	4	5.32	35	7.5	2.6	7.5	1.36	10.0	1.36	10.0	1	-	-	**1**	-	-	**0**
	(b)			38	8.0	2.6	8.0	1.36	11.0	1.36	11.0	2	-	-	**2**	1	-	**1**
	(c)			42	8.0	2.6	8.0	1.36	13.0	1.36	13.0	6	-	-	**6**	1	-	**1**
12	(a)	4	5.35	35	7.5	2.55	7.5	1.36	10.0	1.44	10.0	-	-	1	**1**	-	-	**0**
	(b)			43	9.0	2.55	8.0	1.36	13.0	1.44	13.0	-	-	1	**1**	-	-	**0**
	(c)			44	8.0	2.55	8.0	1.36	14.0	1.44	14.0	-	-	2	**2**	-	-	**0**
13	(a)	4	5.45	36	8.0	2.6	8.0	1.45	10.0	1.40	10.0	-	-	2	**2**	-	-	**0**
	(b)			36.8	6.6	2.6	6.2	1.45	12.0	1.40	12.0	-	-	1	**1**	-	-	**0**
14	(a)	4	5.54	44.5	7.25	2.75	7.25	1.35	15.0	1.44	15.0	-	-	2	**2**	-	-	**0**
	(b)			46	8.0	2.75	8.0	1.35	15.0	1.44	15.0	-	-	1	**1**	-	-	**0**
15		4	6.39	40	8.0	3.65	12.0	1.37	10.0	1.37	10.0	2	-	-	**2**	-	-	**0**
16		4	7.09	48	8.0	1.90	8.0	3.45	16.0	1.74	16.0	19	17	-	**36**	14	17	**31**
											Total	**66**	**23**	**25**		**34**	**23**	
											Grand total				**114**			**57**

Table 4.7 Details of tractor units

Vehicle type	Mean trailer weight (Tonnes)		
	Vehicles with 3-axle tractor units	Vehicles with 4-axle tractor units	All vehicles
Artic & semi	145.5	160.0	158.0
Girder frame	224.7	299.6	283.9
Draw-bar (one pull)	185.6	192.5	191.4
Draw-bar (one pull, one push)	203.3	290.6	272.6

Table 4.8 Mean weights of trailer units moved by 3-axle and 4-axle tractors

4.4 Vehicle dimensions

4.4.1 Vehicle width

The relation between gross vehicle weight and width is shown in Figure 4.10. It can be seen that most SO vehicles were between 2.5 and 9m wide. There were a few loads which were greater than 10m in width, but further investigation found that these were due to the movement of bridge sections by SPMTs over very short distances within Leeds, Lockerbie, and Berkhamstead. A more detailed view of the data, for widths up to 10m, is given in Figure 4.11. The figure shows that the artic & semi arrangements and the girder frame vehicles had well defined ranges; the former were between 2.5 and 4.85m in width and weighed no more than about 270 tonnes, whilst the latter almost always exceeded 300 tonnes in weight and were between 4.7 and 6.1m wide. In contrast the draw-bar trailer arrangements were used to transport loads with a much wider range of weights and widths.

Also shown on the figure are the 3.65m wide notional lane widths assumed in design and assessment standards. It can be seen that artic & semi arrangements with weights of up to 271 tonnes could fit within one notional lane and therefore, theoretically, it would be possible for normal traffic to occupy the adjacent lane(s) on a dual carriageway or motorway. Although this may not occur in practice for SO vehicles, it may still have to be considered during the development of the model.

With the exception of the 271 tonne artic & semi vehicle mentioned above, all other vehicles which weighed more than 250 tonnes were wide enough to encroach into the second notional traffic lane, and several draw-bar trailer movements were even wider. As already described, most of the particularly wide loads were moved only a very short distance (within the same location) by SPMTs; the widest load that moved between different locations was an 8.9m wide industrial fabrication which moved about 5km from Billingham to Middlesbrough by draw-bar trailer. The widest loads that moved any significant distance on the highway were heat exchangers and dephlegmators with widths of between 6.4 and 7m, which were moved between 40 and 45km by draw-bar trailer between Ellesmere Port and the Wrexham area.

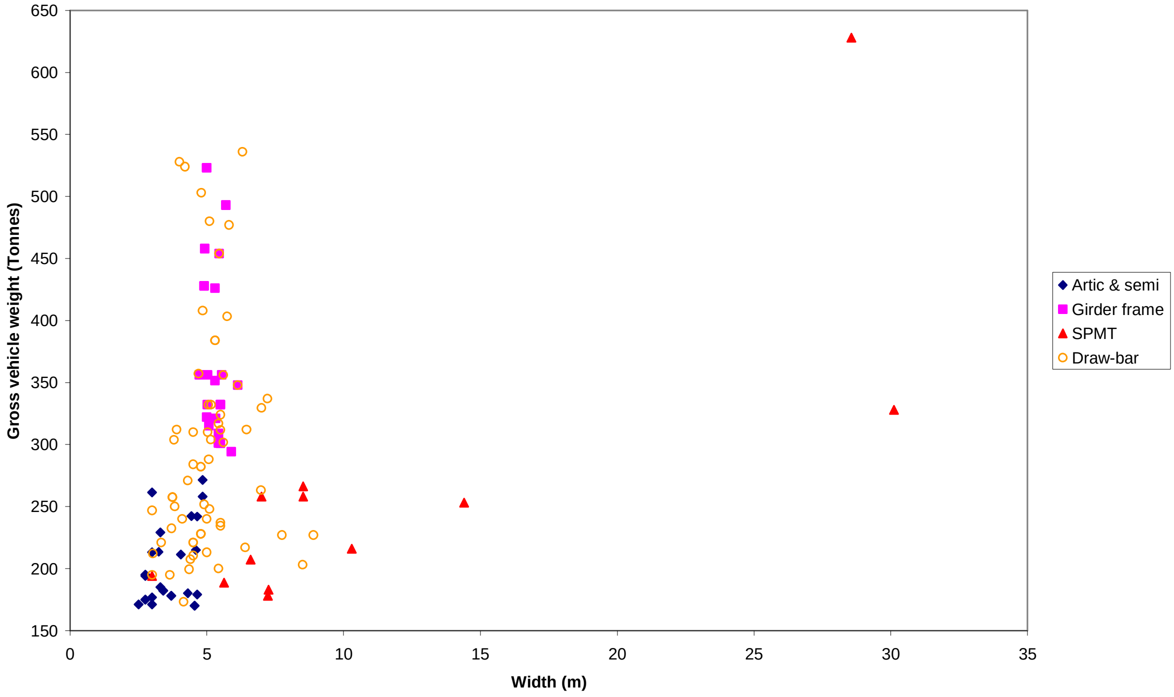


Figure 4.10 Relation between gross vehicle weight and vehicle width

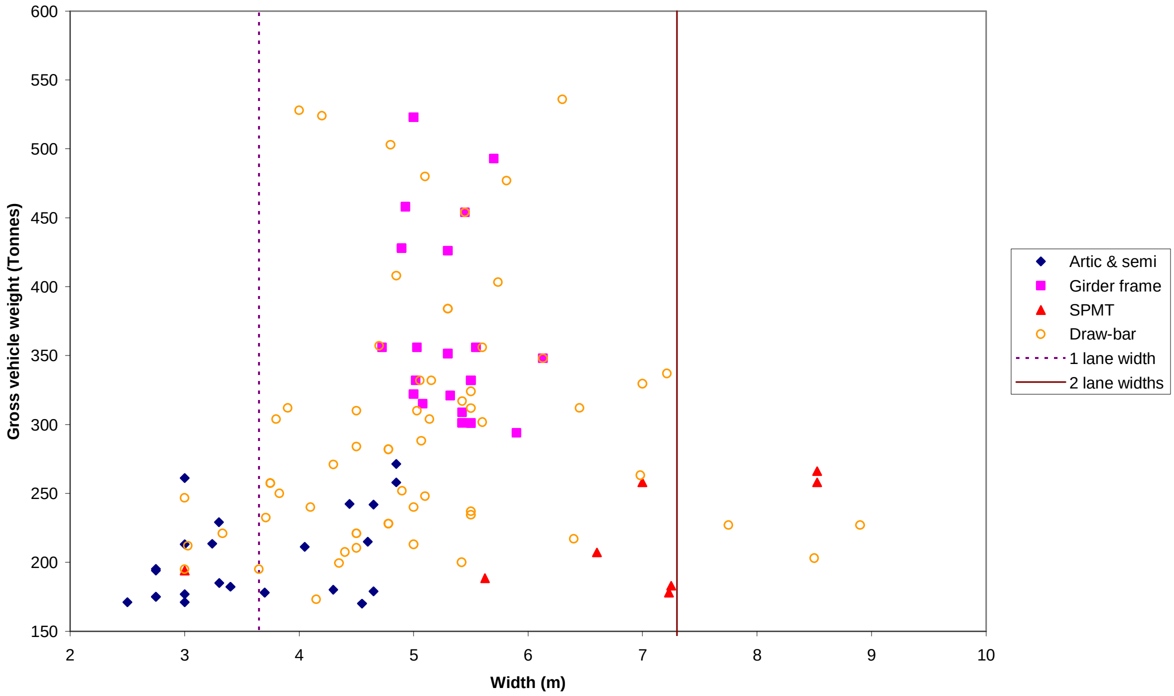


Figure 4.11 Relation between gross vehicle weight and vehicle width (up to 10m width)

4.4.2 Vehicle length

The relations between gross vehicle weight and overall length are shown in Figure 4.12, where it can be seen that the SO vehicles varied in length between 16 and 76m.

As with vehicle width, the data for the artic & semi and girder frame vehicles exhibited a reasonably well defined pattern, whereas the draw-bar trailer vehicles exhibited the full range of weights and lengths. The artic & semi vehicles, which were relatively light compared to the other types of vehicle, had an overall vehicle length of between 21 and 37m, whilst the girder frame vehicles exhibited three distinct lengths of approximately 60, 65 and 76m. Perhaps not surprisingly, the longest girder frame movements were also the heaviest (427 - 523 tonnes), and these were associated with the 2 x 10 trailer configurations, as described in Section 4.3.4, with a distance of 16m between the trailers. The two shorter configurations (60 and 65m) were associated with the 2 x 7 trailer configurations, with distances of either 11 or 15m between the trailers, and these carried loads of between 294 and 356 tonnes.

Although there are no clear trends within the data, it can be seen that, in general, vehicles weighing less than 270 tonnes tended to be artic & semi or draw-bar trailer vehicles with lengths of between 21 and 30m. Vehicles with gross weights greater than 270 tonnes tended to have lengths greater than 30m, and loads greater than 310 tonnes were associated with vehicles longer than 44m. With two exceptions, any vehicle weighing more than 425 tonnes was associated with a vehicle length of 76m. The two exceptions were draw-bar trailer vehicles with lengths of 45 and 55m and weighing 528 and 524 tonnes respectively; however these were both associated with the movement of castings within Sheffield (probably within the same industrial unit).

Most of the 76m long vehicles (both girder frame and draw-bar) moved between different locations and several moved a reasonable distance on the highway. For example, a number of 76m long vehicles weighing between 450 and 500 tonnes travelled distances of between 50 and 70km. The loads moved were usually transformers but they also included generator stators and quad boosters.

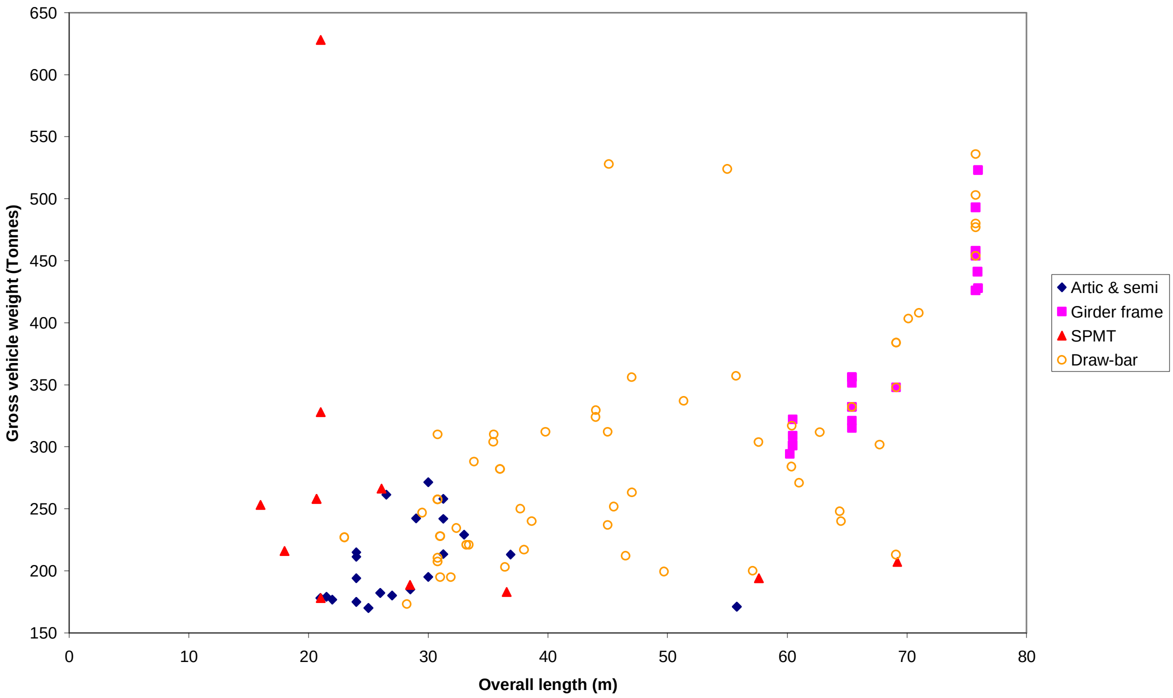


Figure 4.12 Relation between gross vehicle weight and overall vehicle length

5 Consultation with industry and highway authorities

The collection of data on the physical characteristics of real SO vehicles is essential to the development of a loading model, but it is by no means the only information required. To produce a model that accurately represents the load effects of real SO vehicles, it is also necessary to obtain information on the more practical and operational aspects of SO movements.

To obtain this information, a one-day workshop was held at TRL with the aim of consulting representatives of the haulage industry and the highway authorities. The workshop was attended by representatives of the Road Haulage Association and the Heavy Transport Association, along with staff from the Highways Agency, the Scottish Executive, the Welsh Assembly, and the CSS Bridges Group. The Project Team described the background to workshop and the aims of the project, and this was followed by a wide ranging and informative discussion on aspects of SO vehicle movements that require consideration during the development of the model. The issues that arose in the discussion are summarised in the following sections.

5.1 Form of model

The project will proceed initially on the basis of developing a model to cover each of the vehicle types described in Section 4.2. It was agreed that, at this stage, mobile cranes are unlikely to require consideration in the model as they rarely exceed 150 tonnes. (This was confirmed by the lack of mobile cranes in the SO database compiled by TRL).

Because there are various configurations within each vehicle type, it may be necessary to produce more than one model vehicle for each type. However, the general point was made that, from a practical point of view, the fewer the number of model vehicles the better and this will be borne in mind by the Project Team.

5.2 Notification data

The notification forms sent to the HA usually contain details of the tractor units which are required to move the load. This is almost always notified as one tractor (pulling) or two tractors (one pulling, one pushing). However, the industry representatives pointed out that there are occasions when three or more tractor units are required to move the load for at least part of the journey, and the additional tractor units will not necessarily be included on the notification forms. This is an important point with regard to the potential loading on structures, and the effect of additional tractor units will need to be considered as part of the model development process.

The notification forms held by the HA AIL Team provide a great deal of the data required to develop the SO model (e.g. axle loads and spacing). However, there is a paucity of information on the spacing between tractor units and trailers. This parameter can be estimated when developing the model, but it was agreed that it might be useful to consult formally with the industry (through a questionnaire) to obtain this, and any other, relevant information missing from the database.

5.3 Gradients

The need for additional tractor units is usually associated with particular stretches of a route where the gradients are relatively steep. The general point was made that it would be beneficial to both the industry and the authorities if such sections of the highway network were identified.

5.4 Speed

The issues surrounding the current and future travelling speed of SO vehicles were discussed in some detail. With regard to current travelling speeds, it was thought reasonable to assume a speed of 12mph (the current limit) for a substantial number of SO movements, such as draw-bar trailers.

However, it was pointed out that SO vehicles can move at speeds greater than 12mph, and abnormal loads in Europe regularly move faster than in the UK. Therefore it may be sensible to assume that in future loads will move faster than 12 mph, particularly as the authorities also want to minimise the level of congestion associated with abnormal load movements

Therefore the development process for the model will consider the effects of dynamic loads from SO vehicles.

5.5 Axle weight

The question was asked whether the axle loads declared by the haulier were always correct, i.e. how much scope was there for axle loads to change in the time between the notification of the movement and it actually taking place. The industry representatives stated that the axle weights declared by the haulier are based on the total weight of the load, which is given to the haulier by the client. If the real weight of the load is different from that provided by the client, then of course the axle weights will differ accordingly, but there is little that the haulier can do about it.

The model may have to consider the possibility of the overloading of axles compared to their declared weights. The discussion touched on instances where the actual load turned out to be heavier than expected, but it was difficult to get a feel for the frequency and magnitude of any overloading. TRL has recently completed a project on the roadside weighing of abnormal vehicles, and the results of this project will be examined to determine whether it provides relevant information on the overloading of abnormal vehicles.

5.6 Load distribution

The discussion also touched on the issue of load distribution along the axles of a trailer. On the notification forms, the axle weights of a trailer or bogie are nearly always assumed to be equal (e.g. a load of 100 tonnes on 10-axle trailer would result in a loading of 10 tonnes per axle). The question was asked as to whether this was the case in practice.

The haulage industry endeavours to equalise the axle loads as much as possible, given the shape and centre of gravity of the load, but clearly there will be occasions where some axles are heavier than others. Again, it was difficult to be precise about any likely differences in axle weight but it was thought the TRL research project referred to in Section 5.5 above may provide some relevant information on load distribution which can be used in the development of the model.

6 Conclusions

This project involved the collection and analysis of data on SO vehicle movements, and the creation of a database containing the information required to determine the loading imposed by these vehicles. The main findings of the analyses were as follows.

- There were over 1700 Special Order (SO) vehicle movements in the 6-year period from 2000 to 2005. In general, the Highways Agency receives notification of between 250 and 350 SO movements each year.
- The SO vehicles ranged in weight from 30 to over 2500 tonnes.
- Approximately 26 per cent of these movements require a Special Order permit because they are ‘heavy’, i.e. they weigh over 150 tonnes.
- Although a small number of these ‘heavy’ vehicles can weigh well in excess of 1000 tonnes, the majority of such movements are of a lesser weight. Approximately 92 per cent of heavy movements between 2000 and 2005 weighed less 400 tonnes, and 64 per cent weighed less than 250 tonnes.

- The heaviest vehicle weights that moved any substantial distances on the highway network were of the order of 500 - 550 tonnes. Vehicle weights greater than this tend to be associated with the movement of very large loads (such as replacement bridges or ship sections) over very short distances. These movements usually take place within the confines of a port complex or industrial plant.
- A detailed review of SO movements during 2004 and 2005 showed that, in general, there were four types of vehicle:
    - Self-propelled modular trailer (SPMT)
    - Articulated tractor and semi-trailer
    - Draw-bar trailer
    - Girder frame vehicle
- The self-propelled modular trailers were primarily used to transport large (and sometimes very heavy) loads over short distances within an industrial plant and its surrounding area. The other three vehicle types were used to transport loads which had to be moved any substantial distance on the highway (although draw-bar trailers and girder frames were also used on occasion to move heavy loads over short distances).
- Articulated tractor and semi-trailer vehicles were used to transport relatively 'light' SO loads such as motorway gantry signs, small furnace chambers, and press frames. These vehicles ranged in weight from 170 to 271 tonnes, with a mean weight of 200 tonnes. The weights of the trailer axles were found to be between 11.1 and 17.6 tonnes, and the mean value was 14.2 tonnes.
- The girder frame vehicles were used to transport heavy and relatively compact loads, such as transformers and generator stators. The girder frame vehicle enabled the height of the load to be kept below the available headroom of the bridges on the route. The weights of these vehicles ranged between 294 and 523 tonnes, with a mean value of 376 tonnes. The maximum recorded axle weight was 21.4 tonnes, and the mean axle weight for these vehicles was 17.6 tonnes.
- The draw-bar trailers could be used to transport the full range of SO loads. The weights of these vehicles ranged between 173 and 536 tonnes. The maximum recorded axle weight was 23.1 tonnes, and the mean value for these vehicles was 16.6 tonnes.
- It was found that some articulated tractor and semi-trailer arrangements and some draw-bar trailer vehicles were narrow enough to fit within one notional lane. The heaviest load that could fit within one lane was an articulated tractor and semi-trailer weighing 271 tonnes.
- Apart from this one vehicle, all vehicles weighing more than 250 tonnes would have encroached into a second traffic lane. A few vehicles were wide enough to have required three traffic lanes but these were moved only a very short distance by draw-bar trailer or SPMT within a town or industrial complex.

7 Recommendations

- The Highways Agency maintains a database of SO vehicles which contains general information such as the type of load, the start and end points of the journey, the gross weight of the vehicle, and the number of axles. With regard to determining the loading imposed by such vehicles, it would be useful to maintain a database in the format established by TRL which records all the individual axle loads and spacings associated with tractor and trailer units.

- It would be useful to ensure that the distance travelled by each SO vehicle is recorded in the database. Ideally this would include a measure of the proportion of the journey undertaken on local and national routes.
- Any load (such as a bridge or ship section) which is being moved a very short distance (say less than one kilometre) should be flagged within the database so that it can be distinguished from those vehicles which travel on the highway network.
- Most of the data required to calculate the load effects generated by SO vehicles can be obtained from examination of the notification documentation supplied by the haulage company. However, the forms could be modified to improve the collection of data in three areas
    - The distance between the rearmost axle of the pulling tractor and the first axle of the trailer unit.
    - The distance between the rearmost axle of the trailer unit and the front axle of the pushing tractor (where applicable). This information is essentially required for calculating load effects from the vehicle train and can be critical for some continuous span structures.
    - Whether the load will require more than two tractors. (It is known that three or more tractors may be required for some loads or for certain uphill stretches of the route but at present such details are not provided within the notification documents).
- The focus of this project was the physical characteristics of SO vehicles, but it was clear from the data provided by HA that a few routes (such as Stafford to Ellesmere Port and Wrexham to Ellesmere Port) are frequently travelled by SO vehicles. A more comprehensive analysis of the routes used by SO vehicles would identify such key routes, and would allow resources to be focused on the assessment of structures on those routes. This in turn would expedite the management and administration procedures for a substantial number of SO movements.
- On these key routes, it would also be useful to identify those stretches where more than two tractors are likely to be used, so that this can be taken into account when assessing the load carrying capacity of any structures located on these particular stretches.

Acknowledgements

The work described in this report was carried out in the Structures and Materials Group of TRL Limited. The author is grateful to Dr Richard Woodward who carried out the quality review and auditing of this report.

The data collection and analyses could not have been undertaken without the significant help provided by Andrew Cook, Chris Cottell and Stephen Reilly of the Highways Agency’s Abnormal Indivisible Loads (AIL) Team. The author would like to thank them for providing access to their database and for taking the time to answer a number of questions that arose during the analyses.

The project team would also like to thank Peter Wynn and Jim Parkinson (representing the Road Haulage Association) and Tony Lovell (representing the Heavy Transport Association) for attending the workshop on abnormal loads and providing a valuable insight into the practical and operational aspects of Special Order vehicle movements.

Appendix A Examples of Special Order vehicles

Figure A1 View of an articulated tractor and semi-trailer with a close-up of the coupling

Figure A2 View of a draw-bar trailer with a close-up of the draw-bar

Figure A3 View of a girder frame vehicle with a close-up of the unloaded girder set

Figure A4 View of a self-propelled modular trailer

Appendix B Details of vehicle types (2004 & 2005)

	Gross vehicle weight (Tonnes)	Trailer weight (Tonnes)	Number of trailer axles	Trailer axle weight (Tonnes)
Minimum	173.1	151.8	8	10.9
Maximum	536.0	440.0	22	23.1
Mean	289.2	233.2	14	16.6

Table B1 Draw-bar trailers

	Gross vehicle weight (Tonnes)	Trailer weight (Tonnes)	Trailer axle weight (Tonnes)
Minimum	294.0	214.0	15.3
Maximum	523.0	427.0	21.4
Mean	376.0	283.9	17.6

Table B2 Girder frame vehicles

	Gross vehicle weight (Tonnes)	Trailer weight (Tonnes)	Number of axles	Trailer axle weight (Tonnes)
Minimum	170.0	124.0	8	11.1
Maximum	271.4	222.9	15	17.6
Mean	200.8	158.0	11	14.2

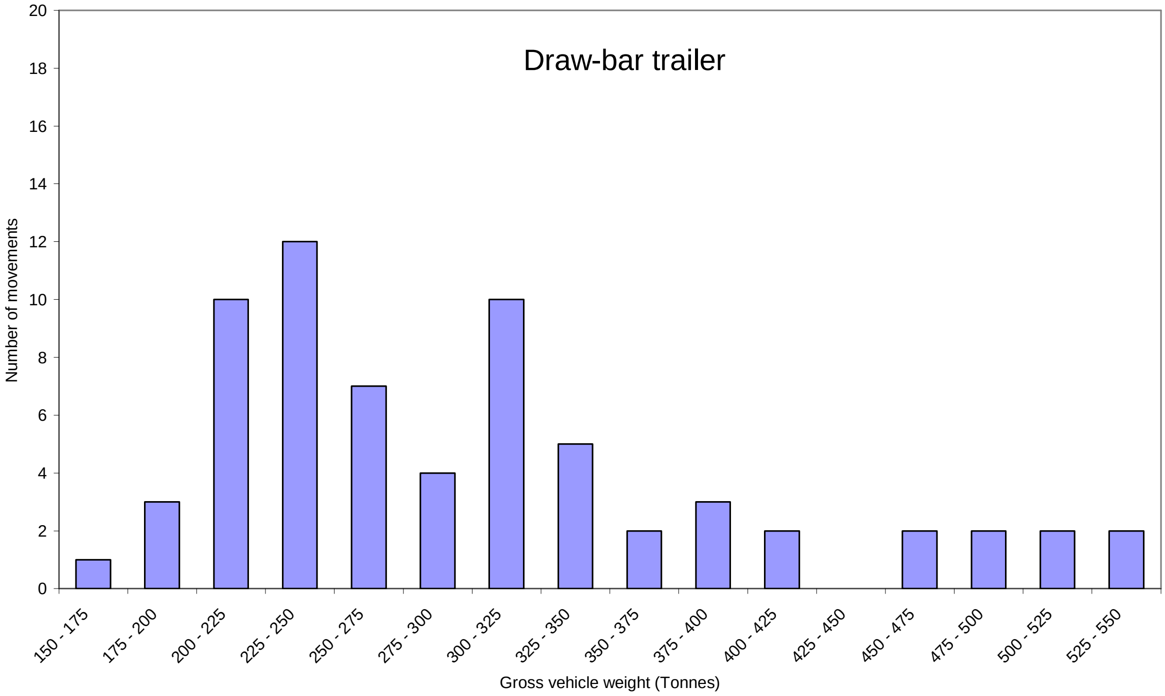
Table B3 Articulated tractor & semi-trailers

	Gross vehicle weight (Tonnes)	Number of axles	Axle weight (Tonnes)
Minimum	178.0	4	14.7
Maximum	628.0	13	52.3
Mean	257.6	12	24.8

Table B4 Self-propelled modular trailers

Appendix C Distribution of gross vehicle weights and axle weights

Figure C1 Gross weights of vehicle types



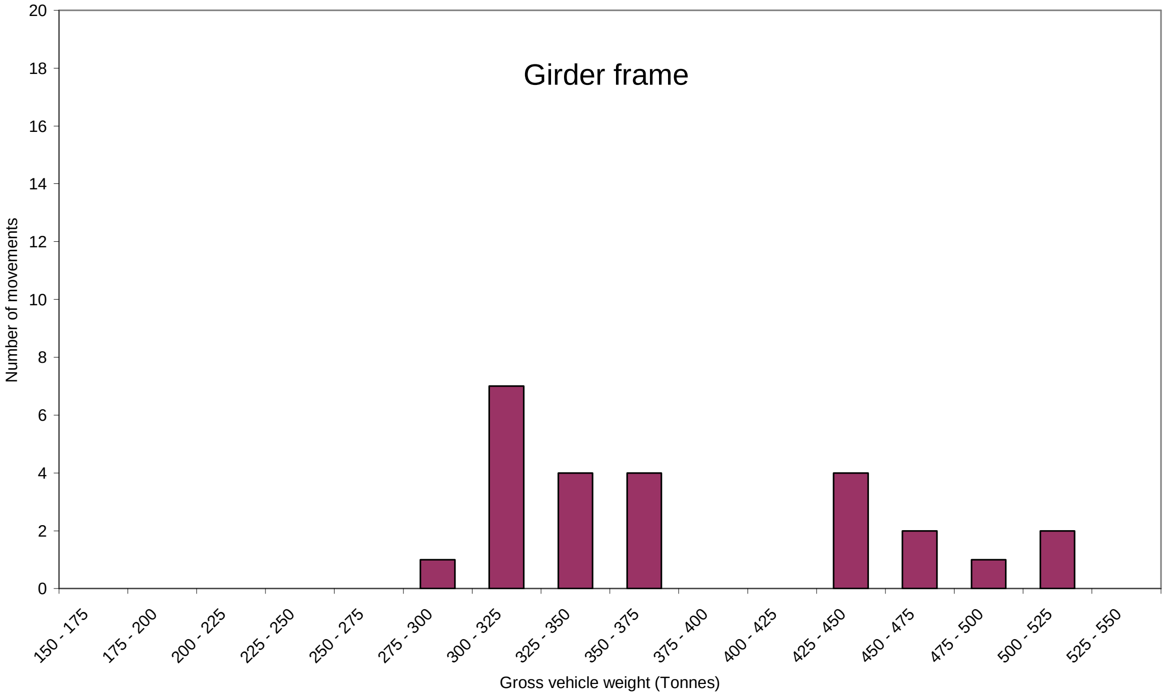
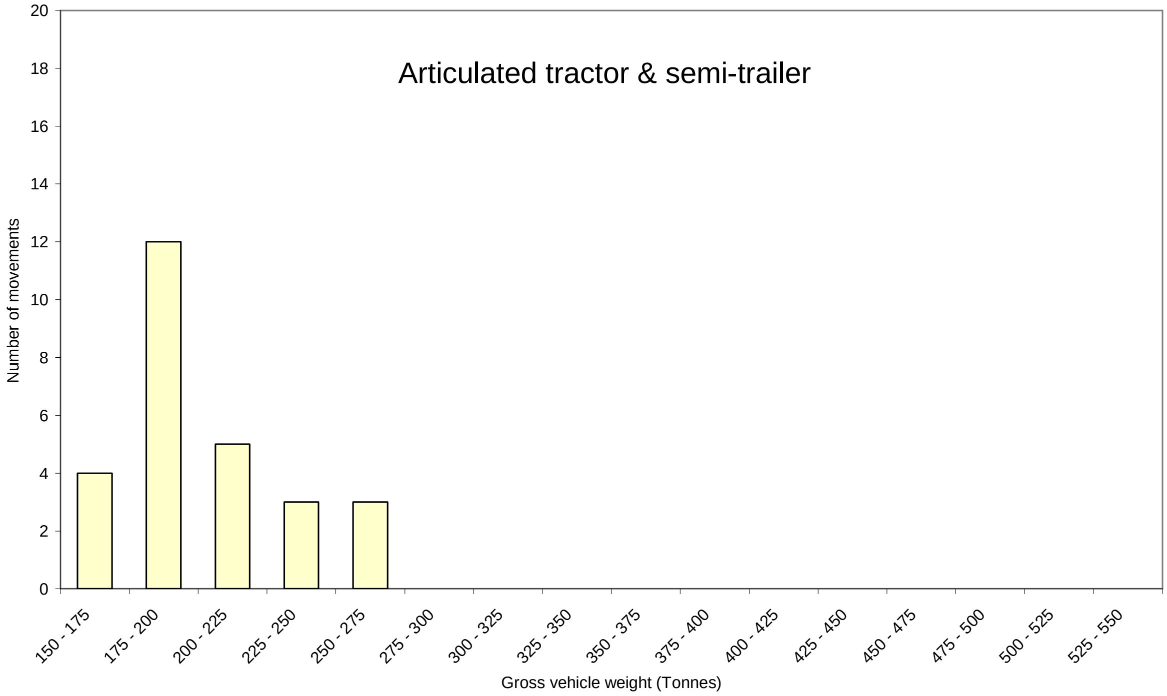


Figure C1 (*cont*) Gross weights of vehicle types



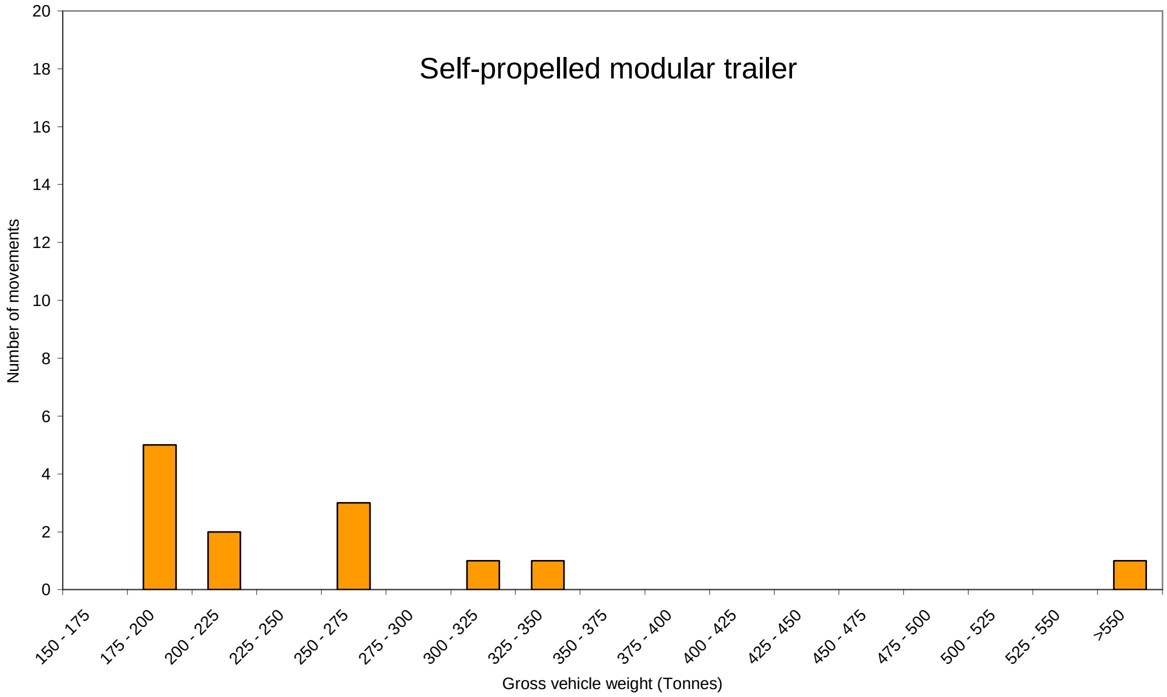
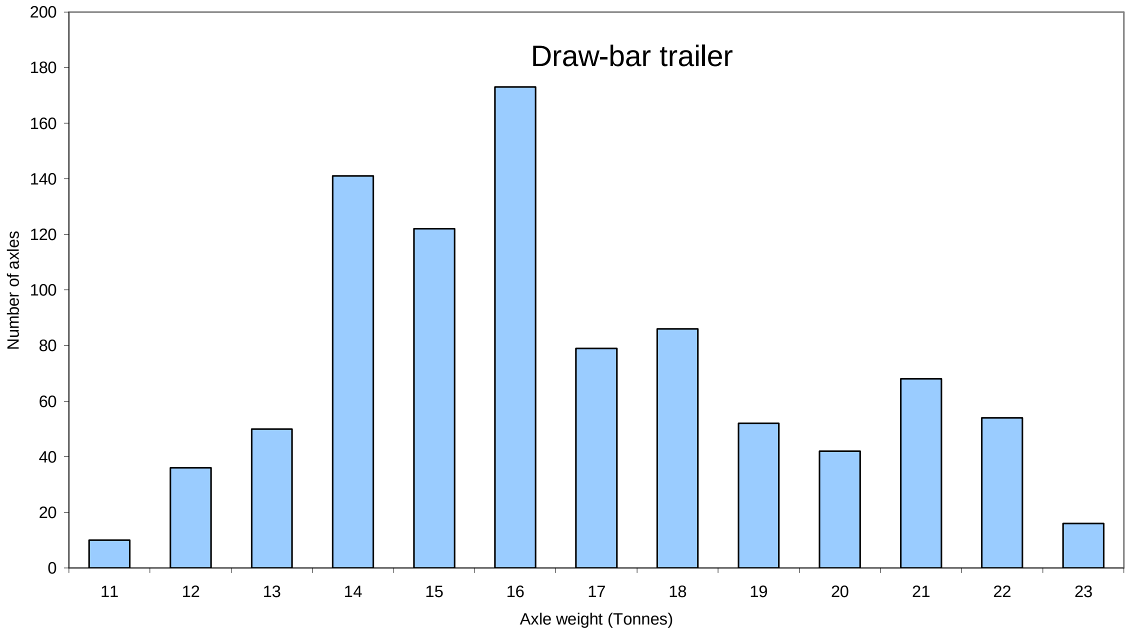


Figure C2 Axle weights of vehicle types



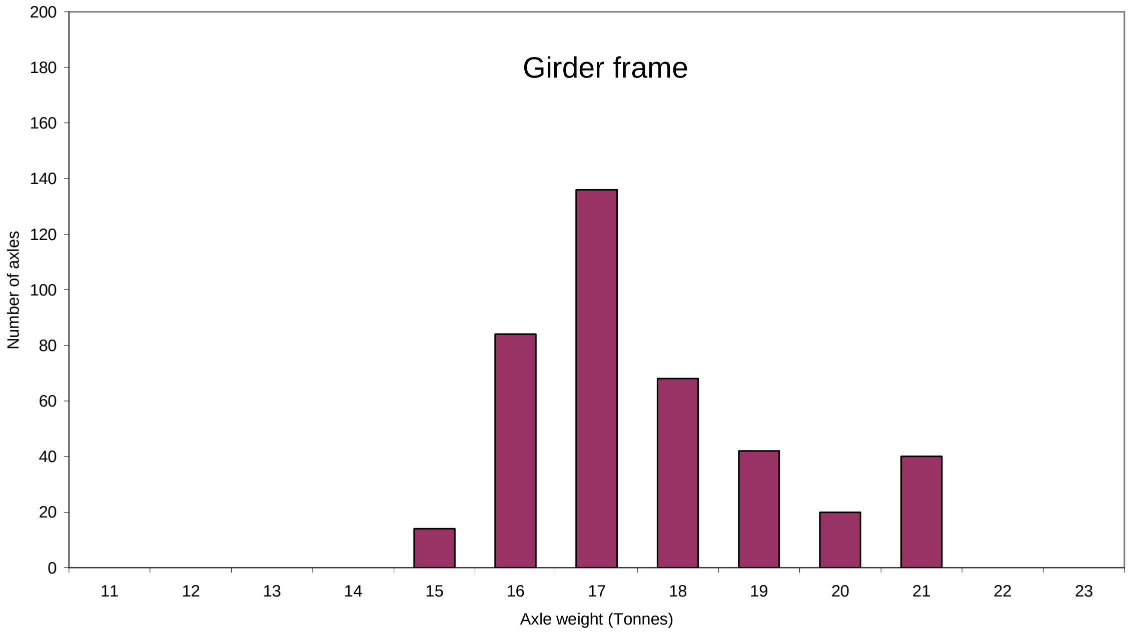


Figure C2 (*Cont*) Axle weights of vehicle types