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Executive summary

This report is intended to provide a summary of findings related to the feasibility of running a Longer Heavier Vehicle (LHV) trial in Great Britain (GB), and the potential design of such a trial, if it were to be permitted. LHVs are commonly defined as goods vehicles up to 25.25m length and up to 60 tonnes weight. This report is supported by a series of earlier documents including; an initial Feasibility Report (2022) highlighting potential policy options and areas for further investigation; an extensive Literature Review (2022) incorporating insights from around 50 published and unpublished documents relating to worldwide LHV trials; and a Stakeholder Report (2023), detailing the outputs from an industry survey assessing potential demand.

The study concludes that a GB trial of LHVs is technically feasible but requires significant up-front investment by government with some uncertainties remaining. In the short term at least, such a trial would need to start with limited options for LHV configurations, weight (54-56t) and height (4.2m). These constraints would significantly reduce, but not eliminate, the substantial immediate benefits that could be realised. To gain the greater decarbonisation and economic benefits that would be available if additional weight, height and route access could be shown to be viable, would require additional work. DfT, roads authorities, and the industry would need to regard this a 10-15 year journey of expanding LHV use cases.

LHVs are now used in many countries both within and outside Europe. For some (e.g. Sweden, Finland) this has been a gradual evolution in standard practice over many decades. Others (e.g. the Netherlands, Germany, Denmark, Belgium) have first undertaken extensive in-service trials of 5 to 12 years in duration before full legalisation. A few (e.g. Spain, Argentina) have progressed to legalisation after only brief feasibility studies and pilots of around 2 years in duration. The resulting regulatory conditions when legalised vary considerably from being quite light touch to quite cautious and restrictive. All countries using them consider that after trials and legislation they have achieved gains in efficiency, with reductions in traffic, emissions, casualties, and costs, though the methodologies and data available to validate these claims are variable.

Initial work in 2022 on the feasibility of LHVs in GB identified some areas where more investigation was required. This second phase focussed on those issues, including the potential influence on infrastructure (e.g bridges and vehicle restraint systems), road safety, and modal shift. The scale, duration, cost and complexity of any trial is also a factor in assessing feasibility. Detailed mathematical analyses of bridge loading (considered to be the most challenging barrier to a trial), extensive engagement with National Highways over a wide range of subject areas and the scoping and content design for a trial, if it were to be permitted, has all been undertaken in this phase of work. The approach has been to

consider what it would be feasible to trial in the short term. A ‘path of least resistance’ to a trial that minimises the lead time has been sought, and this has involved restricting the scope in some areas, notably LHV weights. The work then aimed to identify future analyses, interventions and measures that, if a trial were permitted, could enable the scope to be subsequently expanded to overcome the identified barriers in a better way over a longer time period.

Any national trial would be subject to the approval of a robust safety case by the national roads authorities. This study has found that is only likely to occur, in the short term at least, if the permitted Gross Vehicle Weight (GVW) were to be limited to 54-56t GVW (depending on configuration) and the overall height of vehicles was also limited to around 4.2m. If such a trial were to be implemented, the scope limitations would mean the benefits would be substantially smaller than with an implementation at 60 tonnes with unrestricted height. Even with this restricted scope, significant immediate benefits are achievable. However, such a trial would be substantially more complex than the longer semi-trailer (LST) trial in terms of initial creation, trial approvals and subsequent management. Some uncertainties remain as to exactly what roads authorities will require to approve a safety case and, assuming that is resolved, significant effort would be required to approve individual routes, vehicles and operators in compliance with the safety case. Ensuring it met all the objectives for feasibility, safety, infrastructure, monitoring and evaluation would require a commitment to sustained investment by government and private sector for at least 7 years.

The identified restrictions and uncertainties strongly affect the cost benefit analysis. As such, an analysis sufficient for robust policy Impact Assessment has not yet been possible. This report provides a qualitative explanation of the main benefit and cost contributors and the key variables.

If the DfT decided to proceed with a GB trial of LHVs at 25.25m length, 54-56t GVW and 4.2m height, the work reported here shows that a number of major steps would be necessary.

1) The proposal would need to pass the risk assessment process at National Highways to be approved for use on their network, and similar processes may be required to gain approval to access roads operated by Transport Scotland, the Welsh Assembly, and local authorities. Positive ways forward have been identified in discussion with National Highways in most areas, but in at least some they still require independent quality assurance. Full scale impact tests may be required to establish the exact level of risks that LHVs pose to the effectiveness of vehicle restraint systems (roadside barriers). If current very high containment barriers are found to be inadequate this could remain a substantial barrier to the feasibility of a trial. Bridge loading is also critical. Even with the proposed GVW limitation, some long span bridges could be overloaded if filled with fully loaded LHVs, but permission to use these long span bridges is necessary for LHVs to be viable at significant scale. Structural assessment of those bridges to identify whether they have capacity exceeding the minimum required may resolve this problem but is

very costly. Operational controls to limit the number of LHVs that can be on those bridges at risk are feasible, but it is not certain this would be accepted by the National Highways risk assessment process. Ultimately, data from a trial, if permitted, could be used to resolve this specific problem if it were confidently shown the probability of the traffic on the bridge, including LHVs, exceeding the minimum load standard was sufficiently small to be tolerated.

2) Potential long-term benefits could be substantial in sectors where LHVs can be used, but LHVs at 54-56t and 4.2m height will not be able to be used everywhere. Operators are only likely to invest if they have regular flows where they know they can utilise the additional equipment regularly, where routes can be approved, and sufficient space is available at origin and destination. They will also only use them where the shipment size and the density of goods means that the cost of the transport is significantly lower than it would be on existing vehicles (including standard length, LSTs and tall trailers). For low density goods (i.e. those that are limited by the volume capacity of the vehicle and not the weight capacity), existing HGVs (including LSTs) operating at a maximum height of around 4.9m will likely remain the cheapest solution, such that these commodities may not move to LHVs at only 4.2m tall. However, for higher density goods LHVs at 54-56t GVW will likely be cheaper than standard 44t vehicles. These loads are likely to move to LHVs, subject to the other operational constraints and the maximum capacity increase will depend on configuration and related unladen weights. For example, a 44 tonne HGV may carry up to around 30 tonnes of payload, whereas an LHV type A at 55 tonnes GVW may carry up to around 37.7 tonnes of payload, an increase of around 26%.

3) The costs of running a trial, if permitted, are expected to be significant. The amount of bridge assessment that will be required is a major variable; for some bridges, operational controls to limit the number of LHVs passing over a specific bridge at the same time would be a far cheaper alternative approach. However, there are still substantial costs involved in approving individual routes as suitable for LHV use, as well as approving operators and vehicles for use in any trial, enforcing compliance with the trial conditions, and the monitoring and evaluation required to assess results. Whilst the absolute benefit and cost values are uncertain, we can state that:

- before any trial could be approved, there would be a substantial up-front investment by government at the tax-payer’s expense, to carry out certain specialist infrastructure assessments (to support the safety case) and prepare trial support processes and resources.
- the benefits of using LHVs are potentially substantial and are proportionate to the level of take up, with value being delivered both to the businesses involved and wider society. However, the gains would accrue only to the subset of businesses who were able and willing to take on the new vehicles and associated trial conditions, whilst a disproportionate amount of the costs, would fall on the taxpayer, unless some cost-benefit balancing mechanism were introduced.

If the ‘core’ trial above were to be permitted, then there may be potential in future to expand the scope of the trial and create significant additional benefits, subject to the feasibility of removing certain technical barriers and the benefits outweighing the cost:

- Removing the height restriction in line with existing UK HGVs: This may be the biggest measure that could be taken to increase the usage of LHVs and extend the benefit to the lower density goods sector. To investigate this would require vehicle simulation and/or testing to assess whether LHVs at c4.9m introduce any additional risks (e.g. dynamic stability) and, if so, to identify trial or regulatory controls that could mitigate that risk.
- Increasing the permitted LHV GVW to the 60t allowed in most European countries, would increase the benefits in the weight constrained sector. Achieving this would be challenging and costly and may involve extensive analysis of bridge loading conditions in the real world, beyond regulatory minimum standards. Success is far from certain.
- Increasing the range of operations that can access increased capacity, for example, through permitting a wider range of vehicle configurations, improving manoeuvrability to access more routes, engaging with more road authorities to approve more routes etc.
- Providing a mechanism to support other innovative freight technologies. For example, a scheme for vehicles longer and heavier than standard could potentially provide a mechanism whereby the additional weight of battery powertrains could be spread over greater length, thus allowing equal or better payload while minimising the infrastructure impact.

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1. Introduction

Introduction

1 Introduction

In many parts of the world, using goods vehicles with higher cargo capacity has been highlighted as a way to significantly improve the efficiency of road freight transport. In Europe, the basic premise is that two vehicles of 25.25m length and 60 tonnes weight can replace 3 standard HGVs, thus significantly reducing cost, casualties, energy use and emissions per unit of goods moved. DfT commissioned an investigation into whether a trial of such vehicles was feasible in the UK and the results of a preliminary study were published (Knight, Smallwood, Brand, & Dickson, 2022).

It was found that other countries identified substantial benefits to adopting larger vehicles, none had stopped using vehicles after a trial, and pathways to a feasible trial were identified in the UK. However, the study also identified a range of areas where additional work was required to establish the technical feasibility and in the case of bridge loading it was considered that if the issues couldn't be resolved it would render a trial infeasible. It also identified that managing a commercial trial safely and without additional wear and tear on infrastructure could also be substantially more complex and expensive than earlier trials of longer semi-trailers. Five potential policy options were identified:

0. Do nothing – no trial to be undertaken.
1. Route based risk control – vehicle controls are relatively light; risks are managed by limiting access only to safer roads.
2. Vehicle based risk control – vehicle configurations are more restrictive, and specifications pushed towards state of the art to allow more roads to be safely accessed.
3. Rules based risk control – where access is granted according to more complex and sophisticated performance based standards to match vehicle performance to road suitability.
4. Hybrid of options 2 and 3 – intended to identify a 'path of least resistance' to a trial, which may be quite limited in scope but possible to implement more quickly, and then in parallel to explore expanding the trial to larger scale based on step by step development of rules/requirements for new 'use cases' over time.

The DfT therefore decided to undertake a further phase of feasibility work to better inform Government decision making. The objectives were to:

- Establish with more confidence the technical feasibility of the trial, and the controls and requirements that would be required if a decision was made to proceed to ensure safety and infrastructure protection.

- Identify the Monitoring and Evaluation requirements that would, if a trial were to be permitted, ensure that it could properly inform future decisions about whether or not to legalise after the trial.

To minimise complexity, the approach to the work has assumed any decision to proceed to trial implementation would be in accordance with policy option 4, unless the evidence uncovered suggested a different approach was necessary. This report provides a summary of the findings.

The vehicle configurations under consideration are illustrated in Figure 1, below.

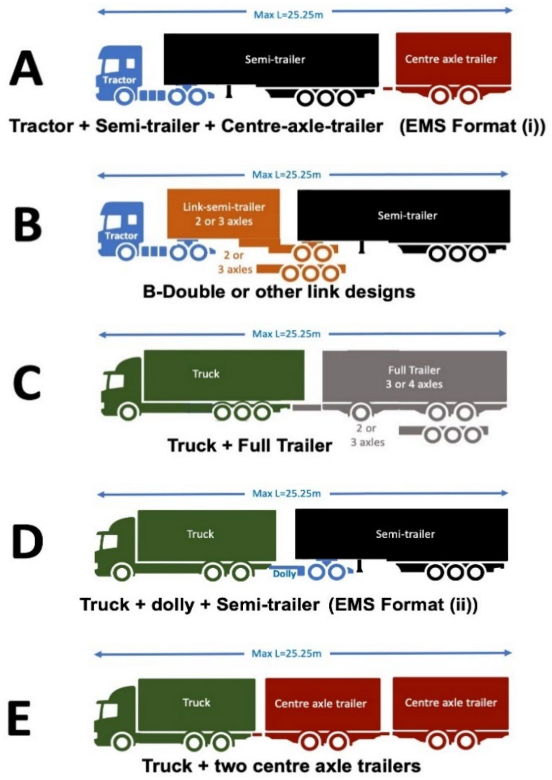

Figure 1: Core LHV configurations at 25.25m & <=60 tonnes. Source: Adapted from (Aarts, et al., 2010)

Based on a lack of data identified concerning the use of LHVs in a UK ‘double deck’ configuration at up to 4.9m tall, the scope for this work was based on the principle height would be limited to around 4 or 4.2m, where (Knight, Brand, & Smallwood, LHV Trial Feasibility Study: Literature Review, 2022) identified that considerable experience already exists.

2.

Bounding the feasibility study

2 Bounding the feasibility study

DfT have made no decision on whether a GB trial of LHVs will take place or not. This feasibility study is designed to inform DfT's thinking on the issues that would need to be considered in making such a decision. To do this, the study team needed to agree in very broad terms, what should be assumed was meant by a trial, whilst leaving space for a variety of different options within that general boundary. In short, bounding "what the study is assessing" as feasible or not.

Having such a high-level set of bounding assumptions ensured we could:

- Explain what we meant by a GB LHV Trial when talking to stakeholders.
- Maintain some consistency in assumptions across our work.
- Explore cases and new options that might suggest different a trial concept, whilst acknowledging that the scenario would involve expanding or changing these bounding assumptions, which could then lead to different conclusions.

For the purpose of this Stage 2a project only, the bounding assumptions were that we were assessing the feasibility of a GB Trial of LHVs where:

- vehicle configurations would be broadly as in **Figure 1**, being at or near 25m in length and likely to be on 8 or more axles and GVWs not greater than 60t. (actual max GVW subject to infrastructure assessment).
- vehicles would be in commercial operation (not just empty running tests).
- operators, vehicles and routes would be subject to robust pre-operational approvals.
- robust monitoring would be in place for trial compliance and evaluation purposes.

3.

Is it feasible to run a trial?

3 Is it feasible to run a trial?

3.1 Introduction

In order to consider the potential feasibility of running an LHV trial, a number of high-level questions were posed to frame the assessment of whether a trial could meet the objective of maintaining safety standards and infrastructure protection. These objectives have been considered using a process of risk assessment based around a National Highways standard (GG104). A series of potential risk controls and mitigations have been developed. A detailed draft safety case has been developed and it is intended to be suitable for a preliminary submission to the National Safety Control and Review Group (NSCRG) at National Highways if a decision was made to proceed with further work on LHVs.

Alongside this, work has explored the potential take up of LHVs and the potential associated benefits to business and society under certain illustrative scenarios of the potential migration of cargo from standard vehicles to a growing number of LHVs during some hypothetical phases, as shown in Table 1.

Table 1: Illustrative development stages

Pre-REGULATION	Pre-REGULATION	Post-REGULATION
PILOTS	TRIAL + TRANSITION	NEW REGULATION
2 yrs	7yrs + 1	10 years

The initial two-year period presumed that a small number of restricted pilot operations, limited to 3-6 routes and operators, would help to validate the safety case for the major roads authorities and allow refinement of the concept trial design and documentation and the development of an associated impact assessment.

A trial of 7 years was then assumed, with an additional ‘transition’ year during which trial results are finalised and new regulatory policy options scrutinised, before a decision on whether to proceed to implementation of allowing LHV operations outside trials. This period is presumed not to be long enough for a fully mature LHV market demand to develop and so the number of LHVs has been estimated based on broad indications of demand for the vehicles under trial conditions, from a survey of operators interested in LHVs.

Following a trial, it is assumed there will be a period of post-implementation growth of LHV use. However, this would be subject to new legislation based on a final impact assessment which itself would be subject to post-implementation review, by default after 5 years.

In breaking down the question of whether a trial is feasible, the sections which follow use a set of high-level questions that could potentially be used in future to evaluate any such a trial, derived from a similar set applied to the GB trial of Longer Semi-trailers (See section 4.2 for more details)

3.2 What would operators use LHVs for?

Considerations

In order to assess the feasibility of a trial of LHVs, we need to understand the level of demand for these vehicle configurations and the nature of the work for which operators would like to use them.

Study Approach

The Literature Review (Knight, Brand, & Smallwood, LHV Trial Feasibility Study: Literature Review, 2022) found that LHVs are used in many countries, including across Europe, for longer-haul, repeated journeys where the goods density makes it feasible to operate an LHV within the GVW limit set for LHVs in each country (varying from 40 tonnes in Germany to 76 tonnes in Finland).

A GB operator survey has been undertaken, firstly with an initial group of operators who had been involved in the recently completed trial of longer semi-trailers. This was later expanded to include a wider range of operators and detailed results are available from (Brand, Hahne, & Smallwood, 2023). The survey produced 123 responses, of which 97 were from operators who indicated they would have a use for LHVs and 26 from those who did not. While we invited operators who were unlikely to use LHVs to provide responses, we anticipated that they would be less likely to respond and so the proportion of responses in each group cannot be taken as an indication of the proportion of all GB haulage operators who would use LHVs.

Following on from the survey, we invited operators to submit ‘Use Case Examples’ (UCEs) which asked for much more detail for specific routes on which they might realistically run LHVs. For these UCEs we collected detailed data about the likely routing as well as goods types and actual weights of the existing HGVs performing the work, so that we could scale it up to potential LHV GVWs.

Outputs

<u>Operator Survey:</u>

Of the 97 operators who did see a use for LHVs in their work:

- 93% anticipated uses on Long Haul (>60 miles/100km) work, with about half of that number also seeing regional opportunities (15-60 miles / 25-100km). However, a significant minority (22 operators) also saw opportunities in short haul work (<15 miles/25km).
- More than half of the operators anticipated hauling mixed pallets or raw materials - both of which are often characterised by regular operations between repeated locations. Another quarter of the operators noted FMCG, industrial products, waste

packaging and biomass as likely cargos. Some, (~20%) were interested in LHVs for mail/parcels or hazardous materials.

- The most common types of work anticipated were Palletised Trunking and other work between national or regional distribution centres (both >60% of respondents), with a substantial interest (>50%) in movement of supplier goods to DCs and industrial sites. 20-25% of respondents anticipated use to and from railheads or ports and retail sites.

Use Case Examples (UCEs)

We received 43 complete UCEs from around 15 companies. Whilst the details of these UCE routes were collected on the condition that they remain commercially confidential, they provided some useful insights that were used in further developing the thinking on a feasible trial. The UCEs:

Covered the entire country – even in this relatively small sample, we had cases routing on all the major motorway links and across all regions.

Contained a wide variety of route types - many involved significant operation beyond the Motorway Network. This included segments of the APTR (All Purpose Trunk Road) network, much of which is dual carriageway, but the start or end of some journeys also required use of some single carriageway A road.

Included two cases of very short haul movements between industrial sites, where the trip is made many times every day.

Included a wide range of cargo types, body types and potential LHV configurations, although for the latter, most operators had a 'preferred' configuration and acceptable alternatives.

About a third of the cases submitted were from companies proposing configurations shorter than the EMS standard of 25.25m. These operators were exploring whether the DfT would consider, as part of an LHV trial, incorporating heavier but not longer (or not much longer) vehicles at higher than 44t, with additional axles. While these would be perfectly valid applications of increased capacity, it was apparent from early in the work that increasing weight without length would present different challenges for bridges and, to limit complexity in the required analysis, it was decided to restrict the scope only to those that spread additional weight across the full 25.25m. Increased weight over a length between 16.5m and 25.25m could be considered separately in the future. (See further discussion under "Trial Expansions' in 4.5).

Of the 'valid' UCEs, around half of the operators stated that their interest in LHVs was to some degree dependent on there being no height limit (as is the case for other trailers in GB) as they would be replacing existing tall or dual-deck 13.6m trailers or even Longer Semi-Trailers. A height limit for LHVs would remove much of the

marginal benefit of such a replacement, whilst having to accept the additional restrictions of LHVs compared with existing HGVs.

The dependence of operator's interest in LHVs on height, not just weight limits, informed later work considering what additional evidence would be required in future to assess whether or not LHVs at unrestricted height could be considered of at least equivalent safety performance.

3.3 What are the potential savings realised in LHV journeys?

The most common description of the potential savings offered by LHVs is '3 for 2' – that 2 EMS length LHVs can carry the same cargo as 3 standard articulated HGVs – a nominal saving of 33% in the number of trips required.

This common 'rule of thumb' is valid for the length of road occupied by the vehicles and also to some extent the costs related to drivers, maintenance, capital costs, but several factors can change the net savings, for example:

- **Maximum permitted GVW for the LHVs** and the vehicles they replace. If the percentage increase in maximum GVW for LHVs, compared to existing large HGVs, is less than the percentage increase in cargo deck length, then the market for LHVs will be less attractive to those carrying the highest density cargoes.
- **Maximum permitted height for LHVs** and the vehicles they replace. This is very specific to GB, where heights are not legally limited, but are fixed at not greater than 4.9m by clearance under bridges on the trunk network. This has opened up a much larger market for dual-deck trailers in GB compared to most other countries where all vehicles are height limited – often at ~4.2m. If the maximum height of LHVs was to be less than 4.9m, then the market for LHVs will be less attractive to those carrying the lowest density cargoes.
- **The nature of the load carried** and the ability to efficiently utilise the capacity increase. For any goods vehicle, there will be an optimum density of load that exactly fills the available payload mass and the volume. All other densities can at best fill by only one parameter. Depending on payload mass and volume changes, some types of goods will benefit from a larger capacity increase than others and the balance of the quantities of different types of goods carried is strongly linked to national and regional economies so can vary between countries and regions. As an example, if large individual load units are considered, one object (such as a steel roll) might weigh 18 tonnes such that only one can be carried on a standard vehicle, making it a 'partial load' if carried on a 44 tonne artic with 29 tonne payload. However, two could be carried on an LHV, an increase in capacity of 100% and a reduction in required trips of 50%. If a similar large load unit weighed 25 tonnes, then it would still not be possible to carry two on an LHV so the increase in capacity would be zero.

- **The change in costs per vehicle km**. For example, a heavier vehicle will burn more fuel per vehicle km than a lighter one so the cost of operating the vehicle will increase per vehicle km, but by less than the decrease achieved by reducing vehicle km by the nominal 33%. This means the benefit in terms of operational costs and external costs (e.g. emissions, casualties etc) will differ from the nominal rule of thumb to some extent.

Due to infrastructure concerns (covered later in section 3.5.2) this study is primarily focused on a core trial scenario for LHVs with 54-56 tonnes GVW and a maximum height of 4.2m.

3.4 What are the resulting potential reductions in emissions?

Considerations

The reduction in distance travelled to deliver a fixed amount of cargo should result in reduced fuel use and related emissions, as well as reductions in other air quality metrics, even if the emissions per km for LHVs are slightly higher than for the vehicles they replace.

The Study Approach

LHVs will have a higher fuel use per km, but not so great that it would offset by the reduction in distance travelled to move the same loads as standard HGVs. In the literature review published during the earlier phase of this feasibility study (Knight, Brand, & Smallwood, LHV Trial Feasibility Study: Literature Review, 2022) European studies were cited where the next saving in fuel and emissions from using LHVs to replace standard trailers was around 12% per tonne-km of goods delivered.

Full emissions modelling was beyond the scope of this feasibility study, although some estimates based on simple fuel use multipliers was included in the assessment of benefits (see section 3.10). In reality, over the time period anticipated, if a trial were to go ahead, it is to be expected that a small number of the vehicles could be either battery or fuel cell electric vehicles (if not during the trial period itself but certainly in the post-trial evaluation period). This shift has not been explicitly analysed to avoid complexity, but even where a battery electric LHV replaces a battery electric HGV there will be an energy efficiency benefit. For as long as the grid is not zero emission, this will imply an emissions reduction and the reduction in total energy demand will allow quicker decarbonisation of the grid.

Outputs

There is potential for use of LHVs to yield CO2e savings comparable to the 12% noted in other studies – which would represent a substantial reduction in harmful emissions over the life of an extended trial and the longer term if there is sustained long-term commitment from industry to invest.

The way forward

If a trial of LHVs were to proceed, the more refined emissions modelling should take place during the trial design phase, taking into account more specific use cases, perhaps from pilot operations, so that it can reflect average speeds, weights and other factors. This modelling could then be extended into any trial period, updating the assumptions with actual trial data.

3.5 Will LHVs cause more or less damage to road infrastructure or to other assets?

3.5.1 Introduction

A range of potential impacts on road infrastructure and assets was identified during Phase 1 of this study through the literature review and early engagement with road owners and regulators. Bridges and Vehicle Restraint Systems were identified as the key topics for further analysis and engagement in Phase 2. Whilst the other factors were not seen to require additional analysis at this stage, they were further discussed to identify specific risks and potential mitigations.

3.5.2 Bridges

Considerations

The consideration here is that the increased mass of LHVs could result in the overload of bridges causing premature wear and/or ultimately the collapse of a bridge with potentially catastrophic consequences. There are over 5,020 bridges recorded on the National Highways database and analysis of bridge vertical loading has proven to be one of the major parts of this feasibility study.

Study approach

A comprehensive analytical review of the bridge vertical loading was undertaken in regular consultation over methods and next steps with the National Highways Structures team. The full technical detail of this assessment is reported by (Rodger & Ash-Edwards, 2023).

It was agreed with National Highways that a **least risk approach** should be taken when determining the most appropriate and safest benchmark, for individual bridge spans, of which a bridge structure is made up, to pass the analysis, with two key components:

- The effects that an LHV produces in bridge structures would be no more onerous than those that the standard CS454 (National Highways, 2022) requires in-service bridges to be capable of withstanding, based on the range of currently permitted HGVs of up to 44 tonnes. CS454 requires assessors to consider both single vehicles, which are considered to be moving at speed and subject to dynamic axle loading (momentary increases in load as an axle bounces over slight bumps and undulations in the road surface), and convoys of slow moving or stationary vehicles that are nose to tail with only small gaps between and are not subject to dynamic axle loading.

- For long span bridges, the option to assess according to “ALL model 2”, which is based on a statistical model of the distribution of real world mixed traffic loads was removed. The absence of UK statistical data to determine the likely traffic mix of LHVs with other traffic on the network and the average load weights that will be associated with LHVs meant that assessments of all spans of bridges had to be undertaken based on the conservative assumption that all LHVs would be fully laden to their maximum Gross Vehicle Weight.

In development of the LHV bridge vertical loading models the following steps were undertaken:

- Realistic worst case axle loads were developed for LHVs type A, B and D, to cover a range of different axle spacing arrangements. This used published data from vehicle and trailer manufacturers to determine the likely distribution of the gross vehicle weight across each axle associated with the LHV types, each using a different configuration of axles.
- Information for all the bridges on the Strategic Road Network (SRN) was provided by National Highways. This data was used to determine a range of bridge span configurations that would represent the bridge stock on the SRN.
- Mathematical models were created in Microsoft Excel that then moved the vehicle across a line beam, to represent bridges of different span arrangements and lengths; to calculate the loads induced in the bridges by the LHVs, and to compare them against those induced by the assessment code traffic loads.
- The initial model calculated the impact of vehicles with a GVW of 60t and then the process was repeated to model GVW limits reducing by increments of 1t, down to 54t, to create a matrix of outputs for LHV configurations A, B and D.
- A relatively small sample of bridges could not be analysed due to various issues in span configuration and data availability. Masonry arch bridges in particular were not checked in the analysis.

Outputs

The results were that at **60 tonnes** GVW LHVs produced loads that were in excess of the assessment traffic loads for at least some bridge spans. There were two problem areas generally: bridge spans around 25m and long span bridges in excess of around 60 metres. In both cases, it was the shear load on the bridge that the LHV was exceeding. Shear load relates to the total load on the bridge structure.

It was found that an LHV at **54-56 tonnes** (depending on LHV configuration) would not exceed the minimum load defined by the assessment codes for approximately 98% of bridges, meaning that the loading they induced was no more onerous than a 44 tonne articulated vehicle. The problem with shorter (c25m) bridges was eliminated entirely. The study found that for a configuration type B 56 tonne LHV, a sample of different bridge configurations with spans of one, two, three, four and five, did not exceed the assessment live loading. However, there were issues for very long span bridges, such as the Humber, Severn, and Dartford Crossing, where the loads defined by the assessment code were exceeded. The reason for this was the conservative assumption in the least risk approach that all vehicles in the convoy are LHVs, all fully loaded by mass. If the loads imposed by a convoy of 25.25m LHVs at 54-56 tonnes were compared to a convoy of 16.5m at 44 tonne articulated HGVs occupying the same length of bridge deck, then the total load in the LHV scenario would be less than for the standard HGV scenario. However, long span bridges are not designed for a convoy of fully loaded standard HGVs, the bridge codes acknowledge a mix of traffic and a mix of loading conditions for those vehicles. This results in a minimum load that is lower than implied by a line of worst case vehicles but that is still extremely unlikely to be exceeded in real service. It is the uncertainty of what effect LHVs would have on that statistical probability that led to the agreement with NH engineers that the least risk approach should be taken.

The way forward

One underlying assumption is that trial operations could be approved route by route. It is also possible that operators could be asked to declare the frequency of movements for a stated time period, or to comply with additional conditions such as the time of day or days of the week when the route can be operated. This may allow the trial to be controlled in a way that ensures a long convoy of fully laden LHVs can never arrive simultaneously on a bridge where the minimum assessment load could be exceeded.

It may be possible that a large proportion of individual bridges on the trunk road network can be designated by National Highways as safe to pass, based on the work already done, for:

- LHV D at GVW 54 tonnes.
- LHV A at GVW 55 tonnes.
- LHV B at GVW 56 tonnes.

If a trial is permitted, then on this basis the route assessment process must allow the identification of any bridge structure where further work is required to clear them for the use of LHVs. Those bridges could then be assessed in stages:

Stage 1: Are LHV loads less than assessment code loads? Undertake the same desktop calculation comparing LHV loads to the assessment loads in CS454, considering that all LHVs will be fully loaded to GVW on longer spans. This should be undertaken for each specific bridge identified (rather than for a category of bridge as done in research to-date). A suitable tool similar to that used in this feasibility study would need to be designed in a form that could be used by route assessors, who cannot be assumed to be bridge loading specialists.

If LHV loads exceed the minimum assessed loads, then move to stage 2.

If not, clear the bridge for safe passage and add it to the list of approved bridges.

Stage 2: Desktop assessment of whether the capacity of the bridge exceeds the minimum standard set by CS454. This will involve in-depth consideration of the available documentation for the specific bridge, including but not limited to; when was it built and to what design code; have routine reviews identified any change in condition; when was it last assessed and to what level of capacity?

If the project safety control and review group (PSCRG) considers that the evidence clearly shows a capacity greater than required by the minimum standard and sufficient to support LHV loads, then clear the bridge for safe passage and mark it as approved on the relevant database.

If not, then move to stage 3.

Stage 3: Demand Assessment. Consider the level of demand for LHV operation over the particular structure.

Where demand is for only a small number of vehicle movements, so that it is unlikely to offer sufficient economic gain to justify substantial investments, then move to stage 4a – consider operational limitations.

Where there is substantial demand and economic gain sufficient to justify the cost, then move to stage 4b – structural assessment of bridge, while considering Stage 4a in parallel if needed to avoid unnecessary delay.

Stage 4a: Operational restrictions. Work with PSCRG/NSCRG and the applicant as necessary to consider whether imposing operational restrictions such as limiting total numbers, time of day, distance to vehicle ahead etc can sufficiently ensure safety while remaining manageable for the operation with good compliance. As more operators joined the trial, this analysis would need to be done at an aggregate level across all operators wishing to use a route across the relevant bridge at similar times of the day.

If an arrangement can be agreed, clear the route as safe (with restrictions) and mark it accordingly in the database.

If not, reject the application and mark as not suitable for LHV without structural assessment.

Stage 4b: Structural bridge assessment. Undertake full assessment of the bridge to whatever load standard is needed to ensure suitability for a convoy of fully loaded LHVs. If the bridge passes, clear for safe use. If it fails, move to stage 5.

Stage 5: Bridge strengthening. Assess the costs and benefits of strengthening the bridge so that it is capable of taking LHV loads. Bridge strengthening is expensive and will be designed to last decades whereas the assumed trial duration would, if it proceeds, be only 7 years. As such it is considered highly likely that this would only be a commercially viable option during any subsequent period of full legalisation. If bridge strengthening is not viable then the application from the haulier should be rejected and the rejection marked in the route database as unsuitable for LHV operation without strengthening.

Although there is some uncertainty in the bridge structural data, approximately 400 trunk road bridges have not yet been proven acceptable or unacceptable under the agreed conditions of the analysis undertaken to date. However, it is considered highly likely that in route-by-route assessment of individual structures this number would be reduced significantly and that additional assessment during Stage 2b would reduce it further. This means that, subject to appropriate controls and agreement by National Highways, the cost of structural bridge assessment could be substantially lower than the worst case. Indeed, it could be that DfT would choose to limit trial routes such that any bridge reaching Stage 4b in the process above would initially bar the route from acceptance unless a very special case were made for its analysis. If operational restrictions could also be accepted by National Highways and operators for some of the remaining bridges then the number of residual bridges and inspection costs could potentially be reduced.

3.5.3 Vehicle Restraint Systems

Considerations

A vehicle restraint system (VRS) is a road safety measure that contains and redirects vehicles that would otherwise have left the carriageway, reducing the severity of accidents for occupants and the public and protecting otherwise vulnerable infrastructure from damage. It is designed and installed on the verge and central reservations of roads and includes the parapets of bridges.

The key consideration for VRS is associated with the increased LHV vehicle weight, that at any given speed, increases the kinetic energy compared with a standard HGV. When colliding with another object of comparable mass or a rigid fixed barrier, the additional energy can increase the crash forces causing more damage. In the case of a collision with a vehicle restraint system, this could mean an increased risk of penetrating through the barrier.

Study approach

The literature was reviewed on this subject (Knight, et al., 2022) and discussed with VRS experts in National Highways, and additional information was obtained from searches of collision data on road and rail as well as from on-road pilot studies closely tracking a standard HGV travelling on two routes that had been proposed as potential ‘use cases’ for an LHV trial.

Outputs

VRS that are designed to contain and redirect heavier HGVs tend only to be installed to protect vulnerable and/or high risk locations such as bridges where the supporting pier may be weak, or the parapets of bridges over railway lines. The evidence and experts agreed that of the vehicles that VRS are currently designed and tested to contain, the worst case is a 30 tonne rigid vehicle, not the 38 tonne articulated vehicle the standard also requires. This is thought to be because the articulation point allows the load to be spread across two separate, and smaller impacts. LHV configurations in scope all have 2 articulation points instead of 1 in standard articulated HGVs. This may mean that impact forces are distributed across even more impacts on different parts of the barrier compared to a rigid or single articulated vehicle. However, there is a risk that this extra flexibility could increase the chance that an LHV that does not penetrate the barrier, but instead rolls over the top of it. The overall interpretation is that the probability of an LHV not being contained by a VRS is not reliably known. It is very clear that an LHV falling onto a railway line in circumstances where a standard HGV would have been contained could be catastrophic. However, the evidence also suggested that substantial risks of HGVs suffering similar collision types are already tolerated, based on the design heights, weights and speeds for VRS tests compared with those permitted in the real world, the fact that not all vulnerable locations are protected by an appropriate VRS and that often, the appropriate VRS might be installed on a bridge structure itself for example, but not on the approach to the bridge. A vehicle leaving the road before the bridge can still result in a vehicle on the railway line which runs under a bridge. This is what actually occurred in the Great Heck rail disaster, which involved a passenger car towing a trailer leaving the road. Despite this level of risk, the probability of incidents appears to be very low, with no incidents identified involving a current maximum size/weight articulated HGV on a railway line.

The way forward

In other European countries that permit LHVs, which tend to use the same European Standard for the testing of VRS, no specific measures to control this risk were identified. Where mentioned in trial reports, the additional risk of penetrating or rolling over a VRS were balanced against a reduced probability of colliding with a barrier, thanks to the expected or observed overall reduction in HGV kms.

When initially considered with National Highways, it was thought that restricting routes to avoid vulnerable locations would be feasible. However, when mapping infrastructure limitations for bridges it was clear that determining these relatively small number of locations on the SRN as inaccessible to LHVs could render a trial uneconomic due to a lack of alternative accessible long haul freight routes. With that option ruled out, it was not possible to agree a way forward with National Highways VRS experts in the time available.

Options for future consideration identified for moving forward include:

- Undertake full scale crash tests. If LHVs are contained by the appropriate VRS then LHVs can be considered no worse than standard HGVs in this respect. If they are not contained, then options to assess and/or mitigate risks could be considered.
- Tolerate the risk on the basis that the probability of occurrence will be very low and further reduced by the reduced vehicle km associated with LHV use.

- Add additional vehicle safety features to further reduce the probability of occurrence. Options for this could include:
    - All LHVs to be fitted with lane departure warning, electronic stability control and Advanced Emergency Braking Systems.
    - As above plus, all operators to be part of the ‘earned recognition’ scheme and vehicles to be fitted with driver inattention monitoring systems.
    - As above plus all vehicles to be fitted with lane keep assist systems and speeds to be limited to 80 km/h to ‘equalise’ kinetic energy with a 44 tonne HGV at 90 km/h (possibly only at geofenced ‘vulnerable’ locations).

These options will need to be considered by the NSCRG process within National Highways, if DfT decide to proceed further with the trial.

3.5.4 Other factors

The following table summarises the considerations and way forward towards a viable trial for the other identified factors.

Table 2: Other factors assessment summary

Factor	Considerations	The way forward
Pavement vertical loading	Heavier vehicles may cause more wear and tear on road surfaces that, if not matched by improved maintenance, would lead to poorer quality road surfaces for other vehicles, which could contribute to collisions. Increasing maintenance would erode economic and environmental benefits	The aggressivity of LHV configurations was within the range of currently permitted vehicles and substantially less than for certain battery electric HGVs. As such, the risk could be tolerated but a trial should monitor weight limit compliance.
Pavement horizontal loading	In addition to the need to support the vertical load of an HGV, the pavement must also support forces that are applied horizontally, to accelerate, brake and turn the vehicle and these can wear or damage the surface.	NH do not currently control horizontal forces and keeping the same maximum axle weight means that effects were expected to be small. Monitor the impact of steered rear axles, if present, because they may reduce horizontal loading below that of standard vehicles.
Vehicle manoeuvrability & accessibility of the road network	GB Regulation requires that all HGVs can turn through 360 degrees with all of the vehicle contained within two concentric circles of radii 12.5m and 5.3m.	Accept the risk of reduced manoeuvrability and control it by initially adopting a highly restricted approach to route approval. Consider the ability of more manoeuvrable vehicles to access a wider range of routes if and when trial expansion is considered.

Factor	Considerations	The way forward
Temporary Traffic Management & diversionary routes	The concept of route restriction to control the risks of LHVs is valid for as long as the planned route remains unchanged. Planned roadworks, incidents and unplanned road closures can all present significant challenges for this concept.	Either begin the trial with limited routes to plan detailed mitigations or limited to LHVs which meet existing 44 tonne HGV manoeuvrability standards.
Smart Motorways	Three key hazards were identified through discussions with road authorities (with almost no direct experience from across Europe); 1. The impact on traffic detection algorithms; 2. The accessibility of emergency refuge areas; 3. The increased implications of an impact with stationary vehicles (an existing concern with the lack of a hard shoulder)	These risks already exist for abnormal loads, with processes to manage them in place. The low number of LHVs expected initially if trials permitted could make these risks tolerable with further assessment based on experience as the trial expands.
Parking availability	It is important that LHV drivers can access suitable parking facilities to take their breaks, and if they were unable to this would create risks of a fatigue related collision.	Planned and emergency parking availability should form part of the route assessment and approval process.
Junctions, level crossings and overtaking	The increased length of an LHV could have implications for the time gap required to clear a road junction or level crossing and for other drivers to overtake.	The potential for junction blocking should be reviewed as part of the route assessment process, with evidence collected during a pilot phase that would either allow the requirement to be safely waived, or to produce a simplified assessment that could be undertaken at scale more quickly.
Driver competence	LHVs more difficult to drive increasing risk of collision.	The option of a new licence class could be held as a long term approach and is in use in countries like Australia, where there are several higher licence classes. For the initial trial stage, the more viable option would be to make LHV training explicitly mandated with evidence and delivery by accredited providers.
Incident response	Incident response – LHVs may be harder for responders to clear from the road after breakdowns or collisions.	Existing processes (e.g. abnormal loads) can manage LHVs, but recovery contracts need to be checked to confirm coverage. Existing towing licenses are valid for 60t.

Factor	Considerations	The way forward
Field of view	There is a potential risk relating to visibility of rear trailer in tight turns, with the potential affect, mainly impacting on cyclists.	Route restrictions to avoid use in dense urban environments and where routes require near side turn across a significant cyclist flow. Encourage use of R46 compliant mirror replacement Camera Monitor Systems (CMS) with dynamic views (e-mirrors, or digital mirrors).
Braking performance	Risk of longer stopping distance or reduced stability under braking.	All elements of combinations (Motor Vehicles, link trailers and trailers) must be equipped with Electronically Controlled Braking Systems (EBS), to ensure minimum reaction times and best possible braking distribution and must be approved to UNECE R13 revision 8 amendment 10 or later.
Dynamic stability	Risk of directional instability in sudden manoeuvres such as lane changes, rollover in similar manoeuvres, steady state cornering or high winds.	Configuration E is the least stable combination and was not a popular option in the operator survey so could be excluded, while permitting all others. It is possible to restrict the trial only to configuration B, as the most stable vehicle and also the configuration that best spreads the load on bridges, however this may limit demand. Electronic stability control is a common requirement in other countries LHV operations. It is proposed that all vehicles and trailers used in LHV combinations are equipped with Electronic Stability Control (ESC).

3.6 Will LHVs increase or reduce casualty frequency or severity?

3.6.1 Introduction

The study and risk assessment defines three categories of population affected:

Workers – National Highways employees or contractors working on the motorway and all-purpose trunk roads.

Road Users – all of the users of the National Highways road network, who are not considered Workers at the time of their use.

Other parties – those who are neither workers nor users but who may be affected by the presence or operation of a National Highways road. For example, those living adjacent to roads, or those using other transport networks such as rail that intersect with the roads.

When considering the impact that LHVs might have on road casualties there are two questions. Will the presence of LHV's increase, maintain or reduce the number of overall casualties on the road network? And what are the additional implications of an individual impact with an LHV?

3.6.2 Will LHVs increase the number or road casualties?

Replacing a proportion of current HGVs with larger LHVs will affect the exposure of any of the affected populations to the risk of collision with a goods vehicle, the frequency of collision per km and the severity of outcome if a collision occurs. Consider for example collisions where a tired or distracted driver allows their vehicle to leave its lane of travel. Thinking first of the probability of occurrence of this incident, the reduced number of vehicle movements associated with increased capacity would be expected to reduce the risk. If industry use only the best drivers in LHVs (e.g. as part of a career ladder) this may mean on average LHV drivers suffer distraction or fatigue less frequently than the average for standard HGVs. However, in contrast, a more complex driving task may increase the risk of fatigue for any given LHV driver. This event could then occur in a number of different circumstances with different consequences. The HGV could drift out of its lane into an adjacent lane and collide with any other road user. The incident could occur in roadworks such that it drifted into the roadworks zone and collided with one or more Workers. Or the vehicle could run off the road entirely and collide with roadside property or travel onto a railway line and collide with a train, such that it affected other parties. Any differences in severity of these possibilities must be considered.

(Knight, et al., 2022) reviewed evidence from scientific literature and found that studies tended to focus on high level outcomes in terms of either casualties or casualty rates per vehicle or tonne km. The studies could be divided into two approaches:

- Engineering predictions of the casualty rate of LHVs, where collisions involving standard HGVs were studied and based on the circumstances, judgements were made as to whether the outcome would be better or worse if it had been an LHV involved. These typically produce a predicted increase in the number of collisions per vehicle km. For example, (Knight, et al., 2008) predicted an increase of 10% if specific risks were not mitigated. Wider modelling by (Knight, et al., 2008) showed that this increase per km would be outweighed by the decrease expected from a reduction in the number of vehicle km, despite considering significant quantities of modal shift from rail in the analysis.
- Post-hoc statistical comparisons of the crash rate of standard HGVs compared with that for LHVs. These studies, across multiple countries, have shown a decrease in the number of collisions per vehicle km, for example (Balint, Fagerlind, Martinsson, & Homqvist, 2014) found LHVs in Sweden were associated with a 21% lower number of serious or fatal collisions per vehicle km than standard length HGVs. When these

lower crash rates per km are combined with the reduction in vehicle km expected from the capacity increase, they suggest very substantial reductions in the total number of casualties (or the rate of casualties per tonne km transported).

Both approaches have advantages and disadvantages. Post-hoc statistical studies are generally considered more reliable because they measure an actual difference not a predicted one. However, they demonstrate an association between parameters and not that the change in one parameter causes the observed difference in another. As such they are open to biases and confounding factors. It is logical that if an operator considers the operation of an LHV more technically difficult than an HGV then they will only pick their safer and easier operations to move. This may mean that the higher risk operations stay on standard HGVs. This could create an apparent difference in crash rate between two groups which is caused by differences in the wider operation (locations, road classes, load types etc), not by the different characteristics of the vehicle. The engineering approach does not suffer this limitation, but it can be very hard to capture the potential for behavioural change. If a trained driver knows that an LHV is harder to drive than a standard one and therefore drives more slowly and defensively in it, this is a genuine, LHV-specific improvement in safety, but would be missed by most engineering analyses.

(European Commission, 2023) reviewed literature and experience in Member States that had implemented the European Modular System. They found that such vehicles do not increase the risk of collisions but in fact slightly reduced it, estimating that the higher capacity vehicles already permitted within the EU had already contributed around €22 million of collision cost savings per year.

It is, therefore, possible to consider the risk assessment as the definition of the safety and infrastructure measures required to ensure the trial falls in the range identified from both the engineering predictions and the measured experience in other countries.

3.6.3 Individual impact severity

Changes to the aggregate level of collision risk, as discussed in the previous section, are clearly extremely important. The defined condition for the trial, if it goes ahead, is that there must be the same or fewer casualties than would otherwise have been the case. The answer above is that can be the case. However, collisions that are prevented cannot be identified and seen. The numbers expected in any trial are sufficiently small that it will likely not be possible to prove a lower rate statistically. The fact that a trial of LHVs could be expected to produce fewer casualties than business as usual, does not mean that there will not be casualties involving LHVs during the trial. It is likely that there will be such casualties. The expectation is that in the ‘do nothing’ scenario, the HGVs that might otherwise have transferred to LHVs would be involved in 4 fatalities and if the LHV trial goes ahead that might become only 3 fatalities. However, all of those fatalities will be highly visible and could and should be subject to significant scrutiny. It is, therefore, also important to consider the effects that LHVs could have in individual cases, and whether they might systematically affect one crash type more than another. This is potentially analogous to the smart motorway situation where analysis considered an aggregate reduction in risk but one particular crash type, directly associated with the policy (collisions with stopped vehicles) could be at greater risk.

The most obvious risk point here is the one identified in relation to the possibility that VRS could fail to contain an LHV in circumstances where it would have successfully contained a standard HGV. This is a very low probability event but could have catastrophic consequences if it occurred. The potential options for mitigation were identified in section 3.5.3.

In addition to this, it has been established that the increased mass of LHVs should make no significant difference to severity in most collisions. However, it could significantly increase the severity of collisions with another heavy vehicle, a rigid fixed object or if it collided with the rear of a queue of light vehicles.

These crash types where an increased risk is possible, within a wider decrease, need to be considered carefully both on an aggregate and an individual level. A transparent and rigorous incident investigation process as part of any trial could also be very beneficial in this respect, and it may be an opportunity for the involvement of the newly formed Road Safety Investigation Branch.

3.7 What special operational requirements will be appropriate for LHVs?

Considerations

In nearly all other trials and later operations of LHVs seen in the literature, the vehicles have been operated under some form of special permission that is separate to the regulation of standard HGVs. We anticipate the same would be true for any GB trial of LHVs both for any trial period and any later operations if permitted.

The study approach

Throughout the potential trial design and exploration of monitoring and evaluation, we collected an extensive list of possible requirements for any trial. Capturing issues as a series of individual discrete requirements statements ensures clarity on the nature and purpose of each requirement and provided a document in which the value of individual requirements can be assessed for inclusion in the final set to be applied to any trial with a clear understanding of the rationale for each requirement and the implications of keeping or removing any individual requirement. Requirements were collated in groups that apply to:

A The whole trial – mainly requirements needed to enable a trial to take place

B Engagement – with operators and other stakeholders

C Routes / Routing

D Vehicles

E Operators

F Monitoring and evaluation

Outputs

The detailed requirements list is too large to include in this report but is summarised here in Table 3 which just shows the title of each requirement in groups A-E. The requirements for M&E are contained in a separate list, discussed later (see section 4.6.2), but many of the items in groups A-E are necessary to enable the later monitoring and evaluation of such a trial. Behind each of these there is a statement of the requirement as it might be applied for a trial and further details of rationale and purpose, so that in any future discussion of whether a requirement is needed or not, these factors can be considered properly.

The way forward

If DfT decides to design and initiate a trial, the full requirements list could be used to both support the safety case (demonstrating risk management processes) and as the starting point for the formal statement of legal and operational terms and conditions for participation in such a trial.

Table 3: Emerging LHV trial requirements

A: WHOLE TRIAL	B: ENGAGEMENT	C: ROUTE Approval	D: VEHICLE Approval	E: OPERATOR Approval
WHOLE TRIAL LEGAL DOCS / ISSUES	**Stakeholder Group Engagement Functions**	**ROUTE APPROVAL PROCESS OBJECTIVES AND DESIGN**	**LEGAL VEHICLE APPROVAL**	**DRIVER TRAINING REQUIREMENTS**
A1: MASTER OPERATOR UNDERTAKING	B1: Engagement with trial enquiries and applications	C1: Overall Route Approval Objective	D1: Proposed LHV is an approved configuration	E1: Develop driver training requirements
A2: MASTER TRIAL CONDITIONS	B2: Engagement with trial participants	C2: Cap on number of approved routes, by stage of trial	D2: LHV on road combination elements all listed on live VSO	**REQUIREMENTS FOR TRIAL APPLICATION PROCESS**
A3: LEGAL VIRES	B3: Engagement with National Roads Authorities (NRAs)	C3: Route Approval process and ongoing management counts total LHV usage on route	**LHV DESIGN CHARACTERISTICS**	E2: Operator application to trial
A4: DfT<> ALB Agreements	B4: Engagement with trial regulatory stakeholders (VCA, DVSA, OTC other)		D3: Permitted Config Types	E3: Application assessment process
A5: DfT <> Roads Authority Agreements	B5: Engagement with trial sponsor (DfT)	C4: Exclude high HGV/VRU related casualty routes	D4: Max GVW	E4: Operator capable and willing to meet trial requirements
A6: DfT<> Agreements with other HMG Depts or their ALBs – including the emergency services	B6: Engagement with other stakeholders	C5: Exclude mode shift	D5: Max Length	E5: Operator disciplinary agreement
A7: NH Safety Control & Review Group (SCRG)	**INDIVIDUAL OPERATOR ENGAGEMENT AREAS**	C6: Exclude routes where bridges are not proven to have capacity to take LHV traffic loading for approved configurations and GVWs	D6: Min Length or Max GVW per metre body length	E6: OP financial and other standing

A: WHOLE TRIAL	B: ENGAGEMENT	C: ROUTE Approval	D: VEHICLE Approval	E: OPERATOR Approval
TRIAL SUPPORT FUNCTIONS	B7: Status of applications and approvals	C7: Requirements in relation to impact with VRS and bridge structures	D7: Min axle spread or max GVW per metre of outer wheelbase	E7: OP data sharing agreement
A8: Trial Management Function	B8: Trial PROCESS non-compliance issues	C8: Routes must be accessible to LHVs at each permitted manoeuvrability level	D8: Defining minimum length and outer wheelbase tolerances	E8: OU signed by representative of company
A9: Trial Engagement Function	B9: Trial DATA events	C9: LHVs must not be permitted to pass through unsuitable schemes for temporary traffic management or diversions	D9: Min Axles (for config)	E9: Registration on 'Earned Recognition' (Optional)
A10: Route Demand, Approval and Hosting Function	B10: Trial Insights	C10: Identify safe parking facilities on route	D10: Max Axle load	**OPERATOR STEPS PRIOR TO ROAD OPS**
A11: Structures Assessment Support		C11: Do not approve routes with unsafe junctions	D11: Max overall height	E10: OP process for route planning and risk assessment
A12: Vehicle Approval Function		C12: Do not approve routes with unsafe level crossings	D12: Manoeuvrability (Optional)	E11: OP process for pass route to drivers
A13: Vehicle Special Order Function		C13: Bridge Vertical Loading Check Process to be agreed by National Ras	D13: Warning signs	E12: OP process to check route compliance
A14: Operator Approval Function		C14: Notify all incident response services of trial, conditions and response plans	D14: Coupling strength	E13: OP process and content of driver training
A15: "Six-Expansions" Programme		-	D15: Braking Systems (towing characteristics)	E14: OP process for driver training compliance
A16: Trial Monitoring and Evaluation Function			D16: Braking Systems (Stopping distance and stability)	E15: OP process for notifying trial management of change to LHV numbers

A: WHOLE TRIAL	**B: ENGAGEMENT**	**C: ROUTE Approval**	**D: VEHICLE Approval**	**E: OPERATOR Approval**
A17: LHV specific regulatory compliance monitoring functions			D17: Advanced Emergency Braking Systems (AEB)	**DRIVER QUALIFICATIONS**
A18: Collision investigation function			D18: Electronic Stability Control (ESC)	E16: LHV drivers' proof of experience & training
TRIAL SUPPORT SYSTEMS			D19: Lane Departure Warning (LDW)	**LHV DRIVING RULES AND BEHAVIOURS**
A19: SYSTEMS TO SUPPORT FUNCTIONS AND DATA MANAGEMENT (See PN A1-2)			D20: Driver Monitoring Systems (DMS) – Optional	E17: LHV drivers stay on planned route(s)
			D21: Lane Keep Assist (LKA) – optional	E18: LHV drivers' actions for unplanned DRs
			D22: Limit speed to 80 km/h – optional	E19: LHVs drivers convoy avoidance rule
			D23: Telematics Data D24: Telematics Data Access	E20: Making or breaking the LHV combination

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3.8 What proportion of the existing national fleet of HGVs and trailers might be replaced by these new vehicles, were numbers not restricted (i.e. post-trial)?

Considerations

The DFT vehicle licensing data for 2020 shows there were ~124,000 HGVs rated >41t GVW on the roads in GB. A useful metric to convey the scale of LHV uptake for policy makers and public communication, is the number of LHVs as a percentage of the GB total fleet.

The study approach

The number of LHVs that might appear on a trial is likely to be relatively modest based on the 2023-23 survey of operators (Brand, Hahne, & Smallwood, 2023) which gave a range (just for the 97 operators who gave responses) of around 600-1700 LHVs for a multi-year trial and 1890-4440 in the long term. These numbers remain highly uncertain as an estimate of national effect because:

- The numbers were calculated as the number of vehicles the 97 respondents that answered would be expected to deploy based on their answers. It ignores any vehicles that may be used by operators that did not reply to the survey and can be considered very conservative in this respect, but to what extent cannot be known.
- The estimates were made at a time when it was expected that the capacity of LHVs would be 60t and there may be no height limit. A height limit of 4.2m and a GVW of 54-56 tonne depending on configuration for a core trial (as explored in section 3.5.2). This factor will tend to produce a very optimistic estimate in light of the trial conditions now expected.

The values for the longer term adoption of LHVs from the survey were compared to other work exploring the DfT CSRGT dataset, with a range of scenarios setting limits on which segments of the data might be amenable to move to LHVs at 54-56t GVW. This exploration gave of range of 2600-6500 vehicles, which is higher than the survey indicated, but this was judged to be reasonable since in the longer term the pool of operators adopting LHVs, once proven by a trial, is assumed to go far beyond the group who responded to the survey.

Outputs

The study explored a range of demand figures around a base scenario assuming 54-56t GVW and a height limit that excludes very tall or dual-deck configurations, with numbers of vehicles and the resulting percentage of the GB Heavy (>41t) articulated fleet.

- 300-750 LHVs by the end of a 7 year trial: 0.35-0.6% of the GB fleet.
- 2600-6500 LHVs by the end of 10 years of post-trial: 2-5% of the GB fleet.

For comparison, in the Netherlands, (after 20 years of use) LHVs represent about 4% of all large HGVs (Knight, Brand, & Smallwood, LHV Trial Feasibility Study: Literature Review, 2022). Other European countries report similarly low numbers of LHVs as a proportion of their HGV fleet, in contrast to the Nordic countries, where decades of infrastructure planning, has led to LHVs hauling 74% of all tonne kms (Vierth, et al., 2008).

The way forward

If a decision is made to progress towards a trial, and more certainty was needed around the demand for LHVs to support an impact assessment of ministerial decision, then, then the LHV fleet size estimates would need to be modelled further or a new operator survey undertaken, based on the actual design and constraints of such a trial as they would affect demand for the vehicles.

3.9 What wider system elements might influence, or be affected by trial of LHVs?

Considerations

If a modal shift from rail or waterway was large enough it could substantially erode or reverse the emissions benefit of LHVs.

Study approach

The literature review undertaken in Phase 1 highlighted a large body of literature which considers the subject of modal split between road and rail and an exhaustive study was not the main aim of this feasibility study. The literature review covers enough studies to identify mode shift as one of the more controversial areas of potential impact for LHVs. Almost any value of predicted mode shift is available somewhere in the literature, from no effect to very large effects in excess of 50%. The previous UK study (Knight, et al., 2008) estimated a range of 8% to 18% based on a combination of elasticity values and theoretical case studies. The more sophisticated and academic analyses (independent of potential 'special interests') have tended to be critical of the theoretical methods used in many studies. These have generally found that mode shift is a genuine risk associated with LHVs but the expected reduction in rail traffic is smaller of the order of 1% to 5%, a level at which studies generally show the efficiency gain within the road mode outweighs the disbenefit of mode shift to produce net benefits.

Outputs

Despite the range of more recent studies suggesting the mode shift expected would be substantially smaller than estimated for the UK in 2008, limitations remain due to a lack of well controlled empirical data.

Some stakeholders in the freight industry have provided input highlighting mode shift as a significant ongoing concern if a GB trial were to progress and responses to EU consultations on similar subjects also suggests strong concerns remain among the rail industry. However, several stakeholders have also pointed toward the advantage that could be gained for intermodal traffic if they were permitted for those operations only. This was also cited as an advantage for a move to permit 48 tonne vehicles for intermodal freight only, but there has been limited demand for that initiative.

The Belgian trial aimed to avoid adverse effects on rail container traffic by limiting the carriage of containers to journeys that started or ended at a railhead.

The potential of excessive mode shift to reverse the benefits of LHVs is another of the main reasons for retaining the “do nothing” option from the start. If a ‘do something option is chosen, then there is a choice to simply trial LHVs and accept the risk that the more moderate studies are wrong. Alternatively, the trial could be designed to allow competition with rail in controlled circumstances only and to more accurately measure the risk to better inform the analyses of this subject and reduce the controversy. This would better inform any potential future decision on whether to permit LHVs beyond a trial and, if so, under what conditions. Finally, the risk of mode shift could be excluded from a trial as has been attempted in Belgium.

The way forward

The project team has assumed that simple acceptance of this risk without any constraint will not be acceptable. The route by route approval process was considered to have strong potential to allow the assessment of the extent of competition any particular road route would pose to rail. This would allow special provisions to be put in place for operators wishing to trial LHVs on this route in order to better monitor the effect on the competing rail route. Alternatively, it would also be possible to decline approval for any route where the assessment suggested scope for competing with rail.

3.10 What are the real-world economics of LHV operations including the costs and benefits to operators and other stakeholders?

Note: A cost benefit analysis that is sufficiently robust to inform a policy impact assessment has not been possible at this time. There remains considerable uncertainty in input estimates, particularly in relation to the trial demand with the proposed scope limitations and cost estimates depend heavily on key decisions around, for example, whether operational controls are adequate to mitigate bridge loading concerns in the short term without expensive structural assessment. For this reason, the discussion of costs and benefits presented here is limited to qualitative discussion of the primary drivers of the CBA and indicative ranges demonstrating the sources and extent of the uncertainty.

Considerations

To determine whether a GB trial of LHVs is worthwhile and affordable, the DfT need an assessment of the costs and benefits not only of the trial itself (including any pre-trial ‘up front’ costs) but also the impact of long-term operation of LHVs if a trial took place and led on to regulation of these vehicles for use beyond the trial. Such estimates need to have acceptable uncertainty ranges.

The study approach and CBA inputs

As outlined earlier, an estimate has been made of the migration of cargos from standard vehicles to a growing number of LHVs over several time periods:

- Pre-REGULATION: 2 year pilots followed by 7 year trial and 1 year transition.
- Post-REGULATION: 10 years of post-trial regulated LHV use.

Estimates of the impacts have been made for the Pre/Post phases above and under four groups:

- Benefits to Business.
- Benefit to Society.
- Costs to Business.
- Costs to Government

Table 4 (overleaf) shows the primary cost and benefit contributors in each group.

Estimates have been explored across the LHV demand ranges shown earlier for a base scenario assuming 54-56t GVW and a height limit that excludes very tall or dual-deck configuration:

- 300-750 LHVs by the end of a 7 year trial.
- 2600-6500 LHVs by the end of 10 years of post-trial operation.

Early estimations of benefits and costs start to give DfT some indication of the broad scale of potential benefits and costs, but these will need to be refined and the uncertainty ranges narrowed, before DfT could commit to launching a trial.

The other key area requiring more work is the estimate of the likely ‘up front’ costs to government, even before a trial could be launched. These are dominated by four items:

- Peer Review of WSP bridge analysis method and results (see 3.5.2) to confirm whether it can be relied upon for a safety case.
- Selected Bridge Assessment costs for a small number of routes to be used for pilots using stages 1-3 of the process described in section 3.5.2. An individual bridge assessment might cost in the region of £100k, so total the costs would vary depending on whether routes can be found that provide useful data but avoid too many bridges requiring individual capacity assessments.
- VRS – Full crash testing and modelling (see 3.5.3)
- Pilots – design and monitor pilots on a small number of routes.

Early estimates of these up-front costs to the taxpayer before any larger scale commercial trial, could be almost £1million, even if pilot routes could be found where only 2-3 bridge assessments were required, but potentially much more depending heavily on the actual extent of the desktop assessment of individual bridges that is required for pilots.

Table 4: LHV Trial Benefit and Cost Contributions

Primary contributors shown in **bold** with the estimated percentage contribution to that benefit of cost group
This table reflects the primary drivers for both a trial and post-trial period, with the exception of the list of items explicitly shown as 'Pre-Trial Costs to Government'.

Benefits to Business	Costs to Business
~30% fewer trips to deliver the same goods, saving • **Driver Costs** • **Fuel** **Tyres,** Repairs and Maintenance • Equipment Renewals • Standing costs	• **Capital investment in specialist LHV elements purchase** (for some configurations) • Costs of compliance with additional regulation (route applications, vehicle approvals, operator compliance, telematics data provision) • Additional training • Potential costs of adjustment to depots
Benefits to Society	**Costs to Government (Taxpayer)**

Reduced HGV impact on:
• **Congestion**
• **Greenhouse Gas emissions**
• Air quality
• Road Damage
• Noise
• Safety
	Pre-trial costs:
	• **Clearance by national roads authorities**
	  ◦ **Complete all assessments required (e.g. Safety Case, design of new procedures across multiple stakeholders including national and local roads authorities**
	  ◦ **Peer review of bridge and other assessments performed in this study**
	  ◦ **Physical testing to support safety case – including Vehicle Restraint Systems**
	• Small scale pilots on limited routes, possibly including limited desktop bridge assessments
	• Preparation of minimum new processes and data management required for trial monitoring and evaluation
	• Regulatory clearance for a trial, including impact assessment and consultation
	• Coordination, policy development and procurement costs.
	Costs during trial
	• **Lost tax revenue (mainly Fuel duty)**
	• **Resources in multiple stakeholder organisations to run systems and processes to support increasing numbers of participants and approvals.**
	• **Individual bridge assessments to open up range of routes open to the trial.**
	• **Annual costs of trial monitoring and evaluation, analysis and reporting**

	• Further work to assess the feasibility and value of any trial scope expansions beyond initial conditions. Associated costs to introduce any such expansions. • [Possible] partial offset of benefits previously claimed for LSTs if replaced by LHV.

The simple mathematics of LHVs replacing standard vehicles means that the ratios of benefit to cost are positive for Business and for Government (the latter through reduced congestion and greenhouse case reduction). However, a very large portion of the benefits accrue to a relatively small segment of the haulage businesses (those who adopt LHVs), whilst a greater proportion of the costs (dominated by lost fuel revenue) falls on government (the taxpayer).

Some other counties have sought to share the benefits and costs more equitably between business and society, to some degree, by transferring some of the regulatory cost burden to business in return for the major benefits they gain from using LHVs.

The way forward

The exploration of benefits and costs developed for this study is a work in progress which would need to be refined and developed before it could provide a robust basis for a l decision on whether go ahead with a trial.

In particular, DfT would need to refine the LHV demand assumptions and the pre-trial cost estimates to narrow the range of uncertainty. Five key areas for attention would be:

1. Updating the assessment of likely demand for LHVs on a trial if it were limited to 54-56t GVW and 4.2m height were the only option available.
2. Alongside (1), confirming the expectation that the vast majority of demand in this scenario would come from the replacement of single deck standard HGVs at a comparable height and ensuring that the estimates in (1) adequately excluded loads already likely to be carried by LSTs and tall trailers that would provide more volumetric or deck area capacity than the LHVs.
3. Considering, with roads authorities, any alternative processes to providing bridge safety assurance that would not require large numbers of individual bridge assessments. This might include approaches that could reliably restrict occupancy of longer bridge spans by multiple LHVs, and testing whether such control would form an acceptable safety case argument.
4. More detailed examination of major estimates, in particular the pre-trial regulatory costs
5. Exploration of the viability of trial expansions in weight or height (and some others discussed in section 4.5.2) and the resulting benefits (i.e. demand increase) and costs. It is quite plausible that a relatively straightforward series of physical tests and/or dynamic simulations could identify stability concerns for tall LHVs that are no greater than already exist for tall HGVs. This would very substantially reduce the uncertainty in demand

estimates because all sectors of the market could benefit from the measure, making it much easier to estimate demand.

These focus areas are interdependent and so would need to be considered in parallel.

3.11 What is the public attitude to LHVs and what public engagement would be necessary alongside any introduction of LHVs?

Considerations

DfT will need to consider the public acceptability of any trial or long term use of LHVs.

The study approach

Direct exploration of public attitudes to LHVs was not in the scope for this feasibility study, in part because until a preliminary design of what a trial might entail is 'on the table' it would be unclear what any survey of public attitudes was asking people to comment on.

That said, comments in the operators' responses in the survey and some experience from other countries, plus a little common sense can be combined to give a general list of the range of public concerns that are likely to be expressed directly or through societal interest groups focused on road safety and freight.

Outputs

Public concerns are likely to include:

- A concern related to safety around existing large HGV's being amplified if larger vehicles are to be permitted. These concerns tend to focus on increased risks to vulnerable road users if the larger vehicles are permitted to share road spaces with them.
- Increased risks to other drivers when sharing the road with LHVs, including issues related to overtaking the larger vehicles, junction blocking, lane discipline and the potential increase in severity in the event of a collision.
- Concerns that LHVs could reduce or reverse the move to put more freight on rail.
- Concerns over the perceived environmental and congestion impacts of allowing bigger lorries on the road network – the public may see the larger vehicles on the road but not the greater number of smaller vehicles they replace.

The public are likely to expect:

- Rigorous controls on where and when LHVs might be used, avoiding or highly restricting areas where vulnerable road users might be present, especially for urban and suburban roads.
- Route approval measures specifically designed to avoid modal shift from rail to road.

- Robust monitoring of route, weight and other regulatory compliance, with rapid feedback to operators in the event of breaches and, potentially, meaningful sanctions in the event of serious or repeated non-compliance.
- Robust evaluation of actual trial performance in comparison to pre-trial projections.
- A commitment from the Department for Transport that similarly strong (or stronger) regulation and compliance processes would be anticipated to continue beyond the trial period.

It is worth noting that these concerns:

- Are largely the same as was raised in other countries where LHVs have been trialled and where, after 10-20 years, LHVs are well regulated and seen as part of ‘normal traffic’.
- Reflect those that will be raised by roads authorities where:
    - National Highways (responsible for the trunk roads in England and Wales) will demand a very detailed safety case before they permit LHVs to be trialled on their roads.
    - Transport Scotland will require similar levels of assurance before they allow a trial to access their network – especially the northern areas beyond the motorway network.
    - Local Authorities will need to approve applications for LHV routes using their roads, where they will be particularly concerned to control any access to urban areas or minor roads which may be determined to be not suitable for any LHV use. However, an authority that has industrial estates as major local employers and economic contributors may see value in investing some time in enabling well controlled use of LHVs.
- All countries have persisted with some form of robust route and other regulation beyond the trial, with the possible exception of the Nordic areas, where the approach has been more focused on improving the primary road network to take the vehicles.

The way forward

DfT will need to consider the appropriate time to engage in a formal exploration of public attitudes. When this is done, care will need to be taken to ensure any survey or other fieldwork can distinguish between responses based solely on a perception of what LHVs ‘might be like’ and those from respondents who have actually seen or shared road space with LHVs in operation.

4.

What might a trial look like?

4 What might a trial look like?

4.1 Introduction

It is considered that the work undertaken to date has been to assess the feasibility of a trial. However, to be confident in the feasibility but also in consideration of the economics of running a trial, and how the results can be used to inform future decision making, it is also important to consider how the trial could be designed. The result of the risk assessment, preliminary trial design activities, and the definition of requirements, the overview of a trial has been based on the assumption that the original policy option 4 (Knight, Smallwood, Brand, & Dickson, 2022), reproduced in section 1, will be adopted.

This defines an approach where it is assumed two streams of activity might be undertaken in parallel:

- Implementation of a limited trial, in a relatively short lead time, with conditions representing the 'path of least resistance' to beginning a trial.
- Collection of use cases outside of the initial trial conditions and assessing the feasibility of expanding any trial to include them.

Several challenges needed to be overcome to reach a position where there is a reasonable chance that the National Highways safety risk assessment process could approve even a limited trial. It is considered that gaining real world experience even in a tightly controlled way, will provide information that helps in assessing the risks of other use cases and taking appropriate action to mitigate risks and remove barriers. As such, it is considered that this may be a quicker path to achieving a safe trial of a wide scope of LHV activity, than trying to solve all of the problems for all of the use cases at once and in advance of any trial starting.

If DfT choose to pursue a trial, there will still be a need for considerable work to prepare for the first commercial operations. As such, a preparation phase has been considered a pre-requisite ahead of the start of any commercial trial.

4.2 Objective Statement and Evaluation Questions

Table 5 (below) gives the objective statement for a potential LHV trial, if a decision was made to proceed. This has evolved slightly since the first phase of feasibility assessment.

Since one of the purposes of a trial is to inform the evaluation, this is also the objective of the Trial Monitoring and Evaluation.

Table 5: GB LHV Trial Draft Objective Statement

The objective of a Longer-Heavier Vehicle (LHV) trial in GB would be to:

- assess whether efficiency gains resulting in NET economic (operator and societal) and environmental benefits, seen in other countries, can be demonstrated in GB,
    - **in** real-world operations,
    - **on** both national trunk and local authority roads,
    - **while,**
        - avoiding increases in infrastructure damage,
        - maintaining safety standards and public acceptability
        - avoiding reverse modal shift from rail to road

If so, the trial should provide evidence to support:

- proposals for any special operational requirements and public engagement that would be needed to support longer term (post-trial) use of LHVs.
- long term demand projections for LHVs under selected policy scenarios.

Below this objective statement, we have also agreed the top-level Evaluation Questions (EQs) that any trial would need to be designed to answer. These questions have also been used as a structure for discussing whether a trial is feasible, across the remainder of the study (and indeed the structure of section 3 of this report.

EQ1 For what type of goods movements do operators use LHVs?

EQ2 What are the (real world) cost savings realised in LHV journeys?

EQ3 What are the resulting (real world) reductions in emissions?

EQ4 Will LHVs be involved in more road casualties, or fewer?

EQ5 Will LHVs cause more or less damage to road infrastructure or to other assets?

EQ6 What special operational requirements will be appropriate for LHVs?

EQ7 What proportion of the existing national fleet of HGVs and trailers might be replaced by these new vehicles, were numbers not restricted (i.e. post-trial)?

EQ8 What wider system elements might influence, or be affected by trial (and any wider adoption post-trial) of LHVs?

EQ9 What are the real-world economics of LHV operations including the costs and benefits to operators and other stakeholders?

EQ10 What is the public attitude to LHVs and what public engagement would be necessary alongside any introduction of LHVs?

Any trial would also need to consider "What (if any) is the mode shift impact?" as a specific market impact.

4.3 Preparation & pilots

The preparatory work for any trial has also been divided into stages:

Foundations

In this stage, should a trial proceed, DfT will need to engage with road authorities in pursuit of formal sign off that the safety case is adequate, through the National Highways National Safety Control & Review Group (NSCRG) and potentially other similar mechanisms at Transport Scotland and local authorities. The main residual risk areas are:

Whether NH will consider operational restrictions on the concurrent use of bridges by multiple LHVs a sufficient mitigation when they are not proven safe according to the establish 'least risk' method.

How to deal with the risk around whether VRS will contain an LHV in the same circumstances in which it will contain existing HGVs. This may require a significant crash test activity to generate more confidence.

This stage would also seek to run a series of scientific on-road pilots to validate the findings to-date to the greatest extent possible and to allow more evidence and refinement in translating the very close scientific analysis and monitoring of example routes that has been undertaken to-date, to the more industrialised processes that will be needed if a commercial trial is undertaken with larger numbers of routes that need assessing and subsequently monitoring. Subject to road authority approval, it may be that if these pilots are considered safe, then the operators involved could be permitted to continue to run them in commercial form, in parallel with the remainder of the preparatory work. This could be considered a form of 'soft start' to the commercial trial, offering opportunities to learn ahead of wider roll out.

Design

This translates the concept design already undertaken into detailed specifications that could be used by DfT, other government agencies and/or contractors to actually build the trial processes and systems. This phase also assumes the creation of an Impact Assessment and public consultation for the trial.

Build

In this phase, the contracts, trial functions, processes and documents will be created in final form, suitable for use in a commercial trial. In addition to this, the IT and database systems required to support those documents and functions will be created, at least to a minimum-viable-product level.

Initial exploration of likely timescales suggests that a conservative and largely sequential approach to these tasks would see this phase of work last around 27 months. However, some substantial tasks (track and laboratory testing) may not be required, depending on the view of the safety case to date and its approval process. Others could be deferred and there is some scope for parallel working 'at risk' if there is sufficient confidence in an outcome of an earlier stage, before it is formally signed off. As such, there is potential to reduce the duration to perhaps 18 months.

4.4 Starting a commercial trial

As well as deciding whether or not to go ahead with a trial, there are also other key decisions that will shape how a trial looks if it does go ahead, discussed in section 5. However, based on the evidence so far and the development of the draft safety case with National Highways, the initial limited use case to be trialled would be likely to operate under a special permit scheme, as with Abnormal Indivisible Loads, and would be expected to have the following characteristics (though details may change as a consequence of Ministerial decisions and/or the progress of the safety case with Highways Authorities).

- Operators would need to be approved to operate LHVs. This would involve contractual requirements to share defined telematics data with the trial management, to commit to defined levels of compliance with conditions, to train drivers and to inform trial management of changes to operations.
- Any vehicles, link trailers, dollies and potentially standard trailers and semi-trailers would need to be approved for use in an LHV combination. It is assumed that VCA would provide the approval service, but recognised that this would add to their remit and require increased funding and human resources, the extent depending on the complexity of approval required. The broad assumptions being used here (section 2) are that LHVs would have to fit several criteria, including:
    - Length: 25.25m (subject to small tolerance), not shorter
    - GVW Max between 54 and 56 tonnes, depending on configuration, and carry this weight on 8 or more axles without exceeding existing maximum axle weight limits.
    - Height: must not exceed 4.2m.
    - Configurations: it may be that only certain vehicle configurations are permitted.
    - Braking systems and couplings: must comply with recent standards adapted to 2 trailer operation and a range of safety equipment will be mandatory. As a minimum, mandatory EBS, ESC, LDW and AEBS is likely, other systems may be required depending on road authority views of the safety case, but
    - Compliance with existing manoeuvrability standards would not be mandatory, recognising that at least some National Highways stakeholders preferred a solution meeting existing standards. If existing standards were required, the complexity of approvals would be increased.
- Each route would need to be approved from origin to destination. This is to ensure suitability in terms of bridge loading, accessibility to vehicles with reduced manoeuvrability, minimising conflicts with VRU traffic, the availability of suitable parking facilities on the road and the potential for additional length to cause issues blocking junctions or level crossing. Once approved in response to an application

from one operator, it would be approved for any approved operator operating vehicles approved as suitable for that route.

- The trial would be extensively monitored, directly via telematics recording of position, route compliance, speed, weight etc as well as obligations to report collisions or other incidents. Disciplinary processes will be available to deal with any poor levels of compliance, up to and including ejection from the trial, over and above any sanctions applicable as a result of any contravention of existing road traffic law.

4.5 Collection of new use cases and trial expansions

4.5.1 Collection and assessment of use cases

It is proposed that in parallel with commencing a trial, an expression of interest would be transparently opened to any operator with any use case that would involve exceeding standard weight or length limits that could bring decarbonisation and/or economic benefits.

As part of this project, we collected a series of prospective use cases from operators. It has already been noted that in these use cases some scenarios were with vehicles that:

- were replacing existing ‘tall’ (4.5-4.9) dual deck trailers and so presumed the same heights would be available for LHVs.
- were loading dense cargo that would require a 60t GVW to be viable.
- exceed the standard 44t GVW, but with lengths significantly shorter than 25.25m appears to be attractive to some parts of industry. It is also possible that some of the short-term issues associated with the introduction of ZEV could be dealt with through the same trial mechanism, allowing additional mass or length to compensate for the heavier weight of batteries (until technical development brings weight parity with diesel), compared with current vehicles but without the adverse consequence, for example, of increased road wear or bridge loading. It could also compensate for the bigger size of hydrogen tanks, which may otherwise compete with payload volume.

These variations to the base scenario conditions set out in section 4.4 are considered here as potential **expansions** of that base case.

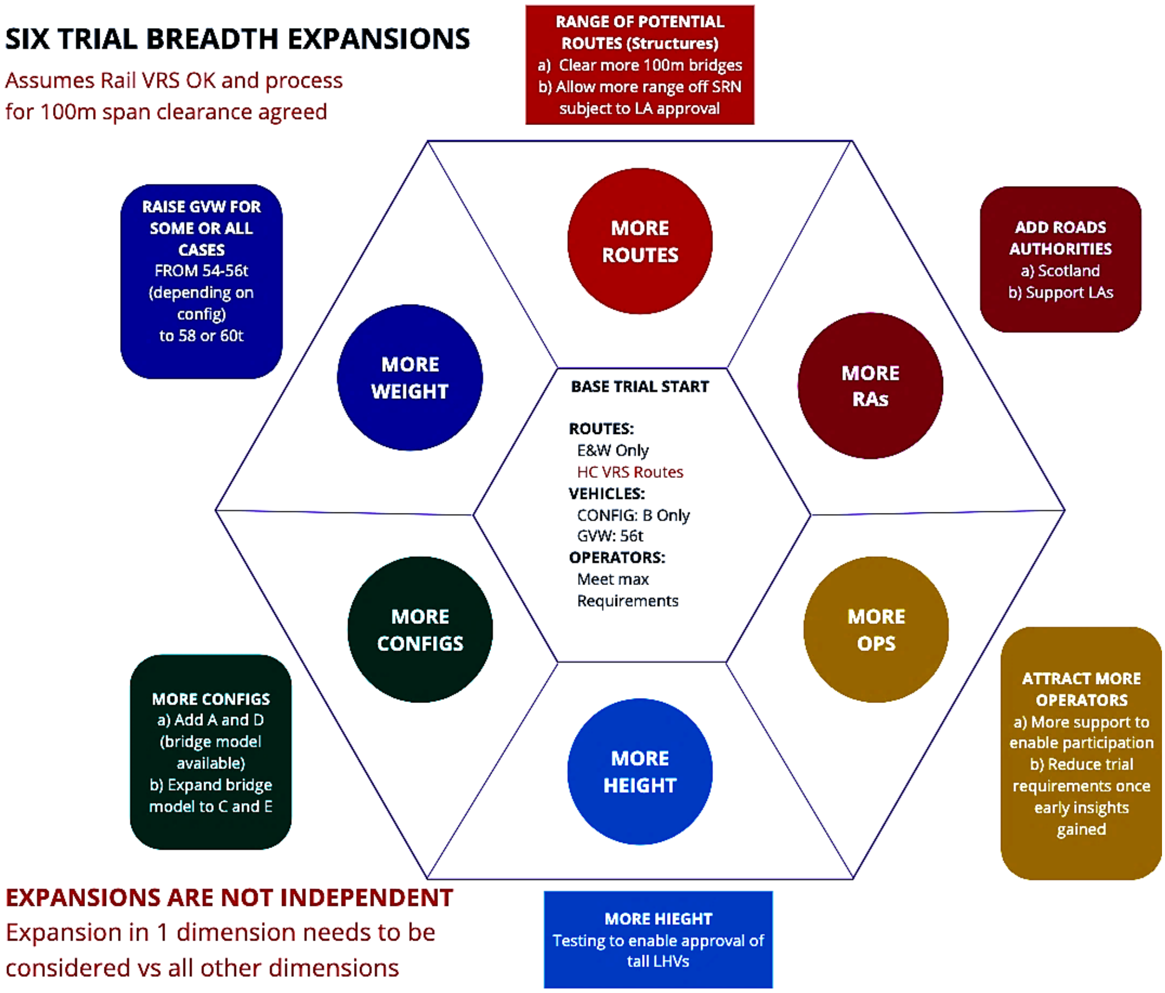
Introducing new trial conditions to permit any one of these expansions is likely require an update to the Draft Safety Case (which will have to be approved by the relevant Roads Authority). As such, it involves using the established relationship and the project level safety control and review group to reiterate selected elements of the feasibility work for a new vehicle variant to establish confidence in safety levels or new risk mitigation controls. However, it also means that new population segments are created across the Monitoring and Evauation (M&E) dataset. For example, introducing a higher GVW category might mean not only new operators and vehicles coming on to the trial, but existing LHVs starting to operate at the higher weight. This will increase the complexity of the M&E.

4.5.2 Consideration of likely Trial Expansions

Based on industry discussions to-date and general consideration of how the trial scope could feasibly change, a range of generic expansions have already been identified. These expansions would have co-dependencies between them, e.g. an increase in the permitted GVW could only come as a result of a reassessment of parts of the Draft Safety Case, which could then open up new routes at certain GVW levels.

Figure 2 shows six expansions to the breadth of what a trial might encompass that could be considered as later developments if a trial were started with the base scenario only.

Figure 2: Six trial breadth expansions considered.



The possible expansions are explored below, but the actual path any expansions would follow may not be fully predictable at this stage.

More weight

At the time of writing, the draft safety case work on Bridge Vertical Loading is setting maximum GVW limits for Configs A, B and D at 54-56t depending on the configuration.

The limiting factors may, it seems, not be actual structural capacity (in many cases) but the ability to prove the structure is adequate **for multiple LHV occupancy** without individual structural analysis, which is very costly. For the bridges ‘cleared’ to date by this analysis, this has been achieved by finding the maximum GVW at which an LHV induces a load in the bridge that is no more onerous on the structure than bridge design and assessment codes set as the minimum standard for bridges. The current proposal for a trial is that any bridges requiring major engineering work would not be considered for trial routes, as this would be expensive, and work might not even be completed in the timeframe of any trial.

It may be that with additional LHV loading pattern data (from the early trial), some increase in maximum GVW might be sanctioned, OR at least some additional bridges approved for use on the trial, at the current GVW limits. Any expansion in this area would require a safety case update and would add a significant discontinuity in the trial monitoring and evaluation data, as a change to the route acceptance criteria was introduced.

Increasing max GVW would be one of two major determinants of demand for LHVs.

More Height

We already know from the Stakeholder Survey and the example Use Cases that around half of the operators interested in LHVs are currently operating dual-deck standard or longer semi-trailers moving low-medium density goods. In most cases these operators would not move to LHVs unless tall / dual-deck designs were permitted. A single deck LHV moves 40 pallets vs a dual deck LST moving 60 pallets with a much lower regulatory and cost burden. As such a height limit will limit the benefits from a trial in proportion to the reduced take up, reducing but not eliminating the benefits.

The unlimited vehicle height (in reality 4.9m) in GB introduces an alternative to LHVs not present in any major international LHV trial so there is no real-world data on stability of such vehicles whether for bulk loads or dual-deck pallet loads.

Permitting tall / dual-deck LHVs would require simulation and possible test track work in a pre-trial preparation phase or in parallel with the early trial in order to establish objective comparisons with baseline vehicles (HGVs, LSTs and LHVs at limited height). However, if that work proved that, as at 4m height, the stability risks associated with an additional articulation point could be successfully managed with appropriate designs and safety systems (e.g. ESC), then it may become possible to permit tall LHVs relatively quickly after completion of that work.

Permitting tall / dual-deck LHVs would be the other major determinant of demand for LHVs.

More Routes

Expanding the range of routes that are approved on the trial could occur in a number of ways:

1. The diversity of routes applied for by operators is likely to expand over time, as more LHVs enter service and a wider range of operators consider their use.
2. The trial route approval process may start with very conservative route risk thresholds, which might be relaxed as more experience is gained and confidence in

the route management and compliance process increases. This in turn could amplify (1).

3. The max GVW limits could be adjusted upwards or the Height limits / dual-deck approval could be given, which would bring interest from new operators for whom the new weight makes LHVs economically viable.

More Road Authorities

The main focus in Stage 2a of the feasibility study has been on National Highways (NH) as the Road Authority (RA) for the trunk network in England and Wales, because unless they approve a trial on their network, a trial would be impossible.

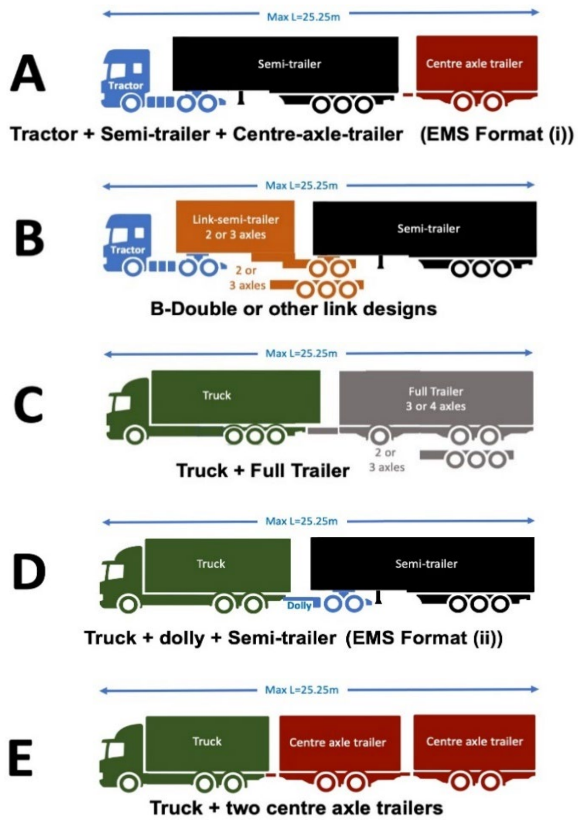
Approval from Transport Scotland (TS) would be required to open up routes on their roads. Contact with TS in Stage 1 of the study suggested we should do the preliminary work with NH and then come back to them as their standards on, for example, bridges are the same as for NH. They did observe that due to the lack of motorways north of Perth (where the M90 ends) any LHV use might be shipping between England and the M8 corridor, which primarily benefits operators based in England.

Engagement with Local Authorities will be on a route-by-route basis and contact with the LGA and ESDAL teams suggest it will likely be via the LA Abnormal Loads Officer (ALO) and the local police force.

More Vehicle Configurations

Of the configurations being considered (Figure 3), the focus in Stage 2a has been on configurations A, B and D, as these were expected to cover the range of bridge loading cases.

Figure 3: Core LHV configurations at 25.25m & <=60 tonnes. Source: Adapted from (Aarts, et al., 2010)



From the stakeholder survey, we know that Config C may also be attractive to many operators and so there may be requests for its inclusion. Config E was the only one that had notably less interest, despite its manoeuvrability, it is the least stable. Adding either configuration would require assessment and an update to the Safety Case.

A number of operators have also asked whether an LHV trial could also be open to heavier configurations that are longer than standard HGVs, but not as long as an LHV. Several use cases have been submitted at various lengths and formats.

This is not in scope of the current study but as explained earlier could be considered separately in the future. This could also have some synergy with other weight increase challenges, such as higher GVWs for 32t Rigid and 44t Articulated vehicles.

In addition to this, the elongated cab concept was intended to improve aerodynamics, energy consumption, emissions and safety by allowing additional length to permit curved front ends without compromising load space. If 25.25m were set as an independent length limit applicable to all combinations, then with standard vehicle and trailer modules, the elongated cab concept could not be used in LHV combinations. If the permissions for LHVs were created such that the Construction & Use Regulations permitting the elongated cab concept could still be applied, then it is still the case that it could not be used with LHVs with standard unsteered trailers because the combination would not meet manoeuvrability criteria. However, where LHV combinations included steered axles that enabled compliance with turning limits, then in practice the maximum length could be slightly greater than 25.25m where tractor units approved as 'elongated cabs' were used. The same issue will also be relevant to LST combinations.

More Operators

The final expansion would be any adjustment to the trial conditions that would open it up to a wider range of operators. This could include:

- Providing centralized support or automation to assist with easier route applications (as is now the case in the Netherlands).
- Lowering the telematics requirement threshold.
- Lowering any requirements set on business 'status' in the initial trial (such as financial standing, size or perhaps current status with OTC).

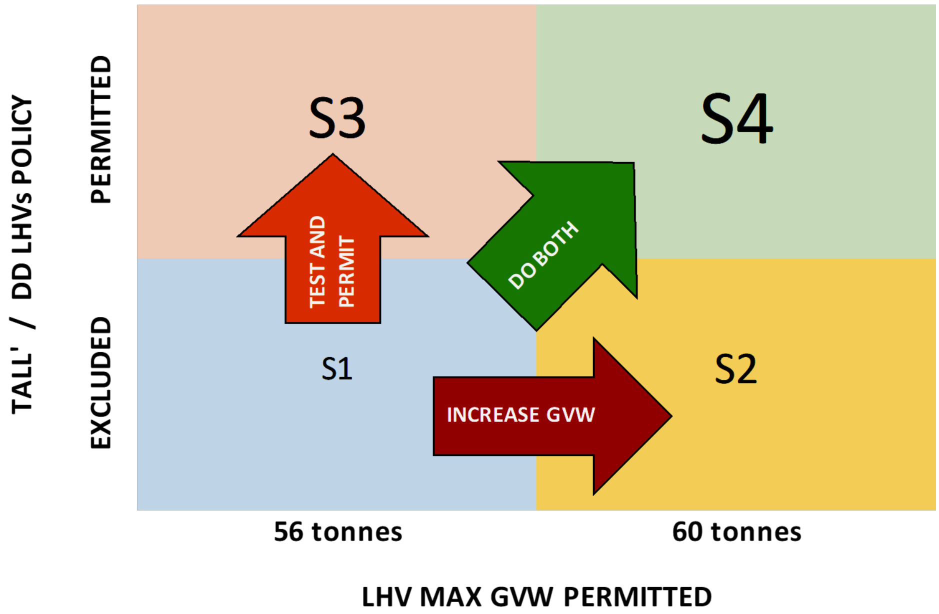
4.5.3 Expansion Priorities

As part of our feasibility work, the team explored which expansions might have the greatest effect on overall potential demand for LHVs during a trial.

More Roads Authorities: While expansion to Scotland will be important, it is not thought to be likely to be as much of an issue as the two major issues noted by operators as critical to their decision to adopt LHVs, or not – that is, Weight and height. This then suggests there are four expansion scenarios that would be of most interest to the industry, as shown in Figure 4

In the Stage 2a work, the criteria lists earlier in section 4.4 (the prudent 'low demand' scenario S1 in the figure) is used as the basis of the Draft Safety Case for National Highways. The ranges of demand cited earlier are based on sensitivity cases at [-50%], [-25%] and {+25%] of the Scenario 1 base figure.

Figure 4: Trial demand scenarios enabled by key expansions.



WEIGHT: A segment of the industry is primarily interested in LHVs for the increased GVW and will be expecting the notional EU GVW of 60t (although this is not applied in all countries). At the time of writing, NH may only permit 54-56t (depending on Config A, B or D) with the current bridge assessments.

HEIGHT: Many operators already use dual-deck or tall bulk loaded LSTs and will be unlikely to move to LHVs at a lower height.

While either change would require an amendment to the safety case, of the two, the HEIGHT may be easier to resolve (by testing and simulation, perhaps even during Stage 2b, before the trial starts) since increasing the weight requires significantly different bridge loading assumptions across the entire network.

4.6 Monitoring and evaluation

If DfT decide to launch a trial, the purpose would be to evaluate whether LHVs might be permitted on GB roads in the long term and if so, under what sort of regulation. We also noted that a set of top level Evaluation Questions (EQs) that were agreed with DfT for the purposes of this stage of the the work. Alongside the work to assess the feasibility of **running a trial**, we have also looked at the feasibility of **successfully evaluating that trial** against these 10 questions. This has in turn led to a conceptual design for monitoring the trial – including exploration of the monitoring and data management requirements – and likely evaluation methods that would need to be applied

EQ1 What do operators use LHVs for?

EQ2 What are the (real world) savings realised in LHV journeys?

EQ3 What are the resulting (real world) reductions in emissions?

EQ4 Will LHVs be involved in more road casualties, or fewer?

EQ5 Will LHVs cause more or less damage to road infrastructure or to other assets?

EQ6 What special operational requirements will be appropriate for LHVs?

EQ7 What proportion of the existing national fleet of HGVs and trailers might be replaced by these new vehicles, were numbers not restricted (i.e. post-trial)?

EQ8 What wider system elements might influence, or be affected by trial (and any wider adoption post-trial) of LHVs?

EQ9 What are the real-world economics of LHV operations including the costs and benefits to operators and other stakeholders?

EQ10 What is the public attitude to LHVs and what public engagement would be necessary alongside any introduction of LHVs?

4.6.1 Three key assumptions

We used both Theory of Change (ToC) and some System Mapping approaches to explore the range of issues involved in evaluating a live commercial trial. Some key requirements of the design required to make an LHV trial feasible, emerged:

- **Some trial and monitoring requirements are needed to support the safety case** These requirements become non-negotiable and cannot be changed without revising the safety case. These then define some monitoring requirements and so offer particular approaches to evaluation data gathering.
- **Some trial assumptions set the scene for the data gathering design** These assumptions are both led by and lead to some of the evaluation design thinking, including access to counterfactual data.

4.6.1.1 M&E requirements linked to the draft safety case

The primary concerns for Roads Authorities are the increase in weight and its distribution across structures and safety related incidents. The trial design must demonstrate robust processes for regulation of routes and the vehicle weights, including the control of levels of multiple-LHV occupancy on any bridge and all safety related incidents. The M&E system plays a major part in these elements of the trial design, and needs to include monitoring of the regulation activities and also their effectiveness, by capturing data on events such as:

- Vehicles exceeding their permitted GVW.
- Actual load weights.
- Deviations from routes (and the reasons for doing so).
- Actual multi-LHV bridge occupancy events.

There are then a number of secondary factors where monitoring - and the evaluation of compliance – must support the safety case, such as driver behaviours (harsh braking, cornering), driving 'lines' through corners, vehicle spacing (for managing bridge loading).

4.6.1.2 M&E assumptions driving the data gathering design

Three assumptions have been agreed with DfT based on the emerging trial design issues and the requirements of the draft safety case. While these have emerged from challenges in the trial design, they actually reduce the burden on operators for manual data collection and simplify many of the M&E requirements. The assumptions are shown Table 6.

Table 6: Three key M&E Assumptions

	Assumption	Rationale
A1	**Routes have stable 'work' characteristics** which do not need to be gathered at trip level.	…based on the premise that the general experience in other EU countries has been of LHVs being operated on major high frequency trunking operations, rather than diverse general haulage.
A2	**Telematics is already required for some data** and so can be leveraged to reduce manual data collection burden on operators.	… based on both the expectation that tight route compliance monitoring will be required by DfT (at least at first) and the roads authorities' safety cases, for any LHV trial and also the fact that some studies of driver behaviour and harsh vehicle motion would be needed to evaluate the role of driver behaviour in safety performance.
A3	The same information can be required for the operator's matching same-fleet-std-trailers (SF-ST) data required for counterfactual analysis.	… based on the understanding that the general background population of HGV data is not a very good 'match' as a counterfactual to LHV operations due to the wide variety of routes and cargo mixes. The LHVs are expected to be introduced gradually into suitable existing operations, which then offer the best source of counterfactual data.

4.6.2 Data monitoring and evaluation Requirements

We have developed a very detailed list of M&E requirements (similar to that described in 3.7for the trial design itself), with details of how each monitoring requirement links either to a commitment in the draft safety case or to an evaluation approach needed to inform the answer to one of more of the high level EQs.

The individual trial monitoring requirements has been divided into levels of data granularity.

Whole Trial: The broadest level is data at a whole trial level which defines the boundaries of what is being evaluated – an example would be the limits of permitted LHV configurations and the maximum GVW permitted for each.

Per Operator, such as the nature of their business (at application to the trial), marginal CapEX and OpEX costs (later in the trial) and future demand for LHVs.

Per Vehicle data which would come from operators as well as from VCA at the point of vehicle approvals (data from Model Reports and VSOs).

Per Route data would include not only the GIS path, but also route characteristics such as leg type, cargo type, mode of appearance and time of day/ days of the week which are assumed to be broadly static (as discussed earlier in 4.6.1.2).

Per Event data, such as trip start/end time location and weight, collision or harsh braking/cornering event detected – all of which can commonly be defined in the reporting from a modern telematics system.

Trip detail data, which may only be needed for short time periods where analysis of trip level (minute by minute) telematics data is needed as part of a Special Topic Analysis (STA) designed to provide evaluation of a specific issue (such as driver behaviours, actual pathway analysis or real world fuel use comparisons). This 'STA' approach was used in the recently completed GB trial of Longer Semi-Trailers (LSTs), to enable some very specific evaluation analysis, without imposing the burden of capturing this level of data constantly for the entire trial.

These requirements have then been used in drafting the trial data management requirements – including telematics data – discussed in section 4.7.

The full requirements list is too detailed to include here, so a summary is shown in Table 7.

Table 7: Data sources informing high level EQs

	High Level EQs	Monitoring data sources for evaluation
1	What do operators use LHVs for?	Questions in operator trial application Details from individual route applications
2	What are the (real world) savings realised in LHV journeys?	Cost data from operators via required survey Trip/km savings derived from aggregated trip data and comparison to SF-ST (Same Fleet – Standard Trailers) and modelled counterfactual
3	What are the resulting (real world) reductions in emissions?	Derived from modelling LHV movements (distance, weight, average speeds) vs SF-ST
4	Will LHVs be involved in more road casualties, or fewer?	Injury incident reports and telematics collision event detection, vs equivalents for SF-ST and national data for the same routes PLUS comparison of proxies (e.g. harsh braking) PLUS qualitative investigations
5	Will LHVs cause more or less damage to road infrastructure or to other assets?	Derived from collision event information and (for pavements and other assets, actual LHV weight and average speed data)

	High Level EQs	Monitoring data sources for evaluation
6	What special operational requirements will be appropriate for LHVs?	Trial arrangements as baseline, with complexity-aware evaluation to review underlying effects
7	What proportion of the existing national fleet of HGVs and trailers might be replaced by these new vehicles, were numbers not restricted (i.e. post-trial)?	Trial data on LHV use and loading can be used to for demand modelling
8	What wider system elements might influence, or be affected by trial (and any wider adoption post-trial) of LHVs?	Special topic analysis of potential intermodal effects. System mapping and engagement with other road freight decarbonisation initiatives
9	What are the real-world economics of LHV operations including the costs and benefits to operators and other stakeholders?	Derived from input cost data and outcome trip and fuel-use/emissions data
10	What is the public attitude to LHVs and what public engagement would be necessary alongside any introduction of LHVs?	Special Topic Analysis using professional public attitude services, considering public perceptions and actual experience of sharing roads with LHVs

4.6.3 Sparse data (Injury and other data)

A key question for any trial will be whether the new vehicles result in a greater risk of injury incidents or more severe incident outcomes.

There are two parts to evaluating injury collision risk:

The “Per km incident rate” question,

“Do LHVs have more/fewer incidents per kilometre than the existing HGVs they replace, when operating on the same routes, carrying the same types of cargo?”

This question is about the ‘like for like’ comparison of the vehicle to the one it replaces, on a given journey.

The “Per unit of cargo moved” question,

Does moving a given quantity of cargo on LHVs results in more/fewer incidents than moving the same cargo on standard vehicles?

The simple mathematics of the increased load space, mean that 2 fully loaded LHVs can move the same cargo as 3 existing 44t vehicles. So, at the same "Per km incident rate", the "Per unit of cargo moved" rate will be 33% lower – the net gain is clear. However, the question of whether LHVs are involved in incidents at a higher or lower rate per km is still of interest but may be challenging to evaluate due to a lack of incident data. As an alternative, some proxy data using telematics measurement of harsh braking might be considered to look for 'near miss' cases that could be studied.

The international experience summarised in the Literature Review for this study shows that in other LHV trials, injury incidents are rare:

- In the Netherlands, between 2001 and 2007, there have been five accidents involving LHVs and no serious accidents have been reported (Feddes, 2019).
- In Germany, accidents numbers involving LHVs were reported to be low. Of six case-studies, none of them reported any major accidents during the trial. (Rodrigues, Payak).
- A 2020 study highlighted the lack of consistent evidence regarding the road safety impact and conducted a comparative analysis of existing data sets of countries (Castillo-Manzano 2020).

Given that EU based LHV trials started in the early 2000s, before even the studies above where conducted, they mostly approached safety evaluation using qualitative, rather than statistical approaches as no individual trial would experience sufficient injury events to support a statistical comparison to the equivalent standard vehicles injury incident rate.

Analysis of a hypothetical 7 year trial (54-56t GVW, 4.2m height), with a central estimate of demand (from the ranges discussed in earlier sections) show that even if the observed trial incident rate is 20% less than the background rate (for standard vehicles) the uncertainty in the observed rate is still too great to be confident at the 95% confidence level that the true LHV incident rate is less than the background rate. The observed difference could just be natural variance in the data. To reach a statistically robust conclusion, either the trial would need to be a year or two longer, or have more vehicles involved (demand in the upper range of the current uncertainty range) OR the trial would need to observe an LHV incident rate that was 40% below that for standard vehicles, which would be a greater improvement that that seen in any international trial so far reported.

Given the limitations regarding the analysis of traffic incidents, to answer the safety question, the evaluation of the safety impact could draw on a wider range of data, as earlier EU LHV trials have done. Three options should be considered:

- **Monitoring proxies for safety outcomes:** Instead of relying solely on collision rates and number of fatalities, commonly considered pre-cursors to accidents would provide a greater quantity of data. As a first step, this would require the identification of indicators for near-miss accidents. One variable often presumed to be related to accidents are Harsh Braking Incidents (and there is some evidence for this). Other potential indicators are slow acceleration or over-speeding (especially in cornering) or any high lateral acceleration (for example when changing lanes or avoiding a hazard).

- **Capturing deeper qualitative data on LHV accidents:** In-depth data about the accident sequence and behaviour of LHVs where incidents do occur, perhaps including cab video and telematics motion data, would allow us to assess if any LHV characteristics contributed to the occurrence of the accident in the first place, and the severity of it (e.g., fatalities).   The emerging Draft Safety Case (deliverable A2) proposes that in the event of a fatal or serious incident involving an LHV on the trial, a formal accident investigation should be carried out, going beyond what is covered in the police STATS19 report or insurance study.
- **Studying proxies and qualitative data for SF-ST (Same Fleet-Standard Trailer) accidents:** The above can be combined with inspecting comparable accidents where LHVs were not involved. Analysis of sequence and severity of SF-ST accidents from the operators running the LHVs and on the same or similar routes, including and video/telematics data, would allow us to explore whether the accident sequence (how it happened) and outcome of the accident would have been different had the vehicle involved been an LHV.

4.6.4 Complexity aware evaluation approaches

Complicated vs Complex: A space rocket is **complicated**, but the engineering involved can be understood and broadly its behaviour modelled and predicted. Any system involving independent human choices a **complex** system with many dependent factors and crucially, emergent properties over time that change the baseline conditions and make it hard to predict behaviour or to attribute outcomes to particular inputs.

We were aware that the trial being considered, and its evaluation, were likely to involve not only complicated factors but also real complexity. The emerging trial design involves:

Live, commercially driven operations, with a large group of self-selecting operators, rather than (as in some trials) a small group of tightly controlled operations under a narrowly defined set of conditions, designed to minimise the number confounding factors.

Multiple vehicle configurations (illustrated here A-E) which have difference characteristics in terms of manoeuvrability and stability, attractiveness to different commercial uses and implications in terms of marginal capital cost (extra elements) for the operator.

Diverse routes, in that in a commercial trial, routes are proposed on the basis of operator demand, rather than being pre-selected for their particular characteristics, although the expectation is that routes would then be filtered by a rigorous approvals process and route monitoring of route compliance, as well as collisions and other indicators.

A changing baseline as the trial scope may expand over time in some or all of 6 dimensions discussed in section 4.5.2, in a sequence not known at the start of the trial.

Interactions with the Trial Safety Case where any adjustment to the trial or evaluation design could require an update to the safety case, which in itself, may then result in new conditions, again changing the evaluation baseline.

Outcomes likely to be strongly influenced by human and socio-economic factors such as operator investment and operational decision-making, driver behaviours, wider stakeholder perceptions etc. Responses and behaviours will differ at different times due to the changing background context (e.g. market factors, suitability of other transport options), changing trial requirements, and emerging experiences with LHVs over time.

The trial would be an intervention in a "complex adaptive system" which is a specialist area explored in the 2020 update to the Magenta Book ((UK), 2020) and any evaluation will need to use a combination of different evaluation approaches. This is likely to include:

- Statistical association, QED and system mapping, with the potential to expand to generative causation and configurational approaches such as QCA.
- Mixed-methods, drawing on qualitative and quantitative data.
- Agile commissioning and iterative approach.

4.7 Trial data management

A robust data management system will be required both to support the arguments made in the safety case around regulation of LHV movements and to ensure that the data required for the evaluation is captured in a useable format.

We envisage a three-part data system reflecting the different nature of the data being held, the access requirements, the ease of integration with analysis tools and possibly, the skillset required to design, build and use each of the parts.

- A Trial Management System (TMS).
- A Route Management System (RMS).
- A Trial (Monitoring And) Evaluation Data (EDS).

4.7.1 Trial Management System (TMS)

The TMS is essentially a management information system and ideally would be accessible by a range of external users able to view data and activities at an appropriate level, with full secure This system is about operating and managing the trial efficiently and the key challenge is that it has to manage and report on:

- Applications and approvals.
- Asset data (direct input by VCA).
- Reporting / Dashboards for multiple stakeholders.

To do this, it must also contain summarised data from the other two systems, such as summaries of the routes approved for an operator (from the RMS) and the scale of use of those routes (from the EDS), with details of any events of interest, such as collisions.

Over a 7 year trial, the TMS might need to hold 2-7 million data records depending on the demand scenario (S1-S4).

4.7.2 Route Management System (RMS)

The RMS manages the route information and does not need to contain as much trial data as the other two systems. However, it would have the most challenging functional requirement if it is to be the evidence base and system for taking in route applications from operators and performing necessary route risk assessment.

In the pilot, and very early trial stages, this could be done ‘by hand’ using a collection of desktop tools to further define the actual process required. As the trial grows, an efficient system will be required that enables effective route applications, approvals and management at scale. Not least of the challenges is the need to have online routing access that is linked to the national and local road network data. access controls.

It is possible that much of the functionality required for the RMS might already be available in the new version of an existing system used to manage routes for abnormal loads (ESDAL v4 due in 2024), with only a smaller, bespoke, segment of the RMS needing to be built to support the trial.

Over a 7 year trial, the TMS might need to hold 100-500 thousand data records depending on the level of demand.

4.7.3 Evaluation Data System (EDS)

The EDS is the primary source data for both compliance reporting and evaluation analysis and in the M&E design envisaged here, would largely comprise telematic data sent or pulled directly from the telematics providers (using APIs) at the EVENT level. Analysis for compliance and evaluation would need to be able to draw on this data, along with operator, route and vehicle data from the other two systems.

4.7.4 Counterfactual Data

The preceding discussion and estimates of data scale – in particular for the EDS - relate only to the trial primary information from the LHVs. The trial will also need what is called ‘Counterfactual Data’, to which the LHV trial data will be compared.

For each item in the Monitoring and Evaluation requirements list, options for counterfactual data are also discussed. While some comparison can be made to national statistics for large HGVs, the optimal source for counterfactual data is 'Same Fleet – Standard Trailers' (SF-ST) - for vehicles from the same company, doing the same work and routes, perhaps even using the same pool of drivers. Using SF-ST data:

- Removes almost all of the confounding variables present in national data (factors where the LHV operations differ from 'average' HGV operations).

- Does not add much extra burden, since if the same telematics systems and provider are in place, then accessing the data should be possible using the same processes as for the LHVs.
- Opens up the possibility of LHV vs SF-ST comparisons of both simple outcomes (for example, incidents) and more complex analysis, such as differences in vehicle path choices and other driver behaviours.

Assessing the scale of counterfactual data that will need to be held is not quite as simple as 'doubling' the EDS data scaling figures presented earlier, as this counterfactual data may not be gathered in the same pattern as the main trial information. It could be a mixture of:

- Pre-LHV operational telematics data (a batch of 3 months prior data could be a trial requirement).
- On trial summary data – such as high -eval event count data.
- On-trial 'deep dive' analysis – collecting the detailed SF-ST fleet data (such as accelerations etc) only for a defined period during the trial for each operator.

Further analysis of the scale of counterfactual data will be needed.

4.8 An integrated data management framework

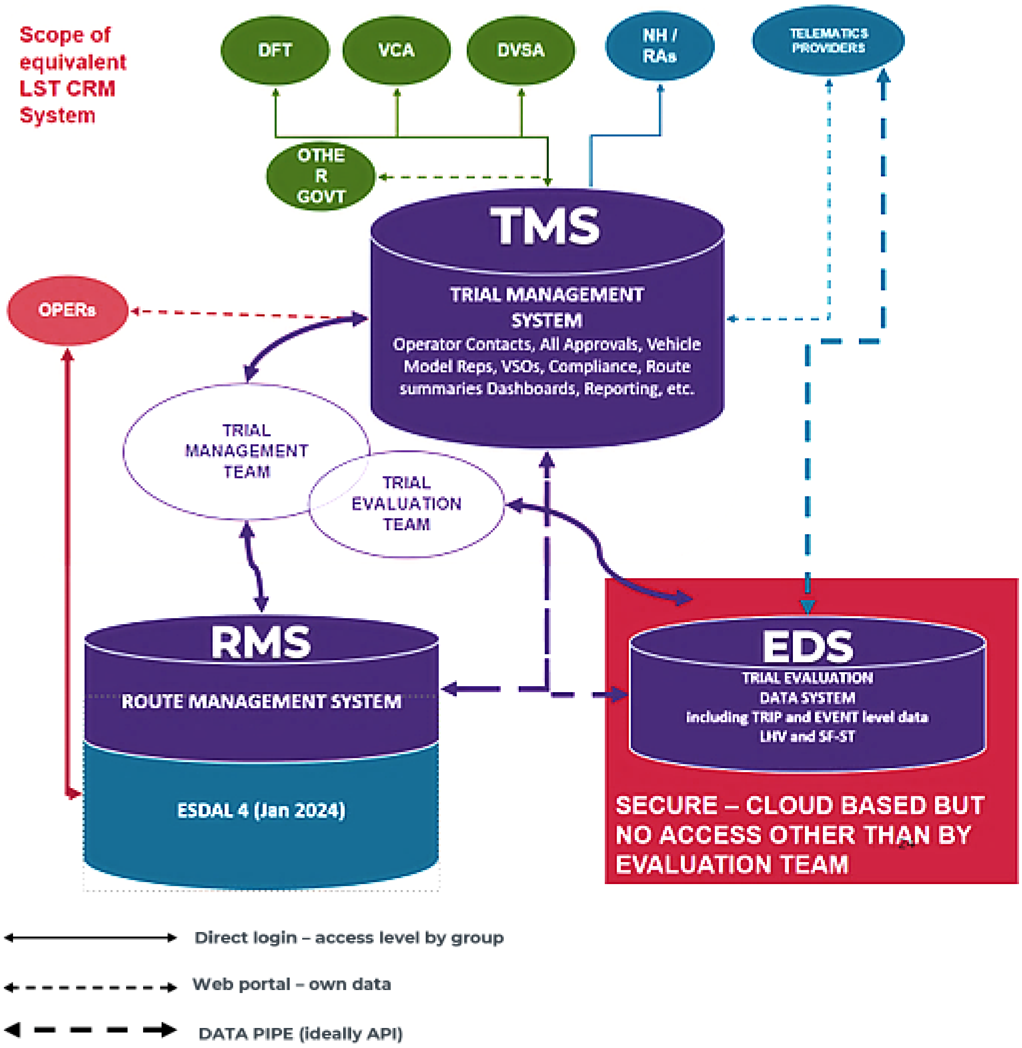
Ideally, a single overarching design for a trial data framework would be created as part of any pre-trial development work, rather than allowing the three elements to be designed independently, which would be likely to cause problems with integration and duplication of information across the systems later, making analysis more challenging.

Figure 5 shows a conceptual design of an integrated data framework capable of meeting the requirements for a full scale commercial trial. The same system could be further developed to serve a long term LHV regulatory process or could be used as the prototype for such a system.

The trial management and trial evaluation teams (whether separate or part of one group) would need access to all systems. Other stakeholders would have controlled access to appropriate data.

Whilst this may appear complicated, it is actually similar to what was put in place by the end for the recently completed GB trial of LSTs (although in that case, a single integrated design emerged over the trial period, rather than being planned at the start).

Figure 5: Trial Data Management Framework Design Concept



5.

Policy Options

5 Policy Options

The project team has considered carefully what the findings mean for the policy options open to the DfT and their advantages and disadvantages.

5.1 Options for Trial Design

The options below have been identified as possible approaches, but are not exhaustive and other permutations or adaptations of these options may be feasible:

A. Do Nothing: permission for a trial would be denied.

B. Step by Step Expanding Trial: Permit a trial based on the approach of a 'path of least complexity' to create a limited trial with minimum costs and delay. In parallel, work with industry and highway authorities to undertake the necessary research and develop the necessary processes to expand the scope of the trial. Several sub-options exist:

   i Vehicle configuration: B-double only; config A, B, or D only.

   ii GVW: allow maxima suitable for UK infrastructure, or as lowest common denominator for all permitted configurations.

   iii Allow reduced manoeuvrability, start with a low cap on number of routes/vehicles.

   iv Require compliance with existing manoeuvrability, start with a cap on routes/numbers but at a higher level than ii.

C. Full EMS trial: Permit a trial of any configuration meeting the criteria, without a cap on number of routes and only a high cap on number of vehicles (c3,000). Base route approval processes on worst case. One sub-option to be considered is:

   i GVW: allow maxima suitable for UK infrastructure, or as lowest common denominator for all permitted configs.

Option C recognises that LHVs are safely and economically deployed in many countries and several industry stakeholders would advocate simply doing the same with minimal additional controls. Subject to the reduction of GVW to 54-56 tonnes to ensure bridge loads are not exceeded, it is possible this could be effective in the UK too. However, there is a risk that in practice it may not actually achieve benefits faster than option B because interaction with roads authorities to-date suggests that there are a lot of actions they would consider extremely important to complete before such a wide-ranging trial commenced, which could delay the start of the trial substantially.

Option B essentially acknowledges the scale of those actions and aims to tackle them step by step. Its initial benefit will be smaller, but it will enable well controlled progression to more benefit later, with a lower risk of incident or lack of preparation undermining progress. Essentially this would represent a commitment to move the UK to parity with many other European countries in this field over a prolonged period of perhaps around 10-

15 years. Within this, there are choices about whether to start with heavy restriction on vehicles, allowing wider participation and more routes, or heavier restrictions on participation and routes.

5.2 Options for Trial Conditions and Monitoring

For either of Option B or Option C above, the DfT will want to be able to compare a number of options for how tightly the trial is controlled and the level of monitoring and evaluation they require. The choices here are common to all live trials where a higher level of control and monitoring may provide greater assurance of safety and compliance from operators and also offer richer data sources for trial evaluation and later policy decisions. However, a very tightly controlled trial with very detailed monitoring requirements:

- places a greater burden on operators and government stakeholders – which in turn can suppress participation, resulting in a less diverse set of data sources.
- reduces the range of policy options to which the trial results can be applied.

These levels of Control would need to be considered in any Pre-Trial Impact Assessment, which might need to cover four options:

I. Do Nothing (No trial).

II. Low Control and Monitoring
A minimum required to deliver a trial which would pass a roads authority safety case, poses no net increase in risk, maximises trial participation and delivers a minimum acceptable evidence base for evaluation, but may lack some 'margin' in terms of assurance, compliance monitoring and depth of evaluation.

III. Medium Control and Monitoring
A refined version of the current case that has been explored here and used as the basis for the assessment of impacts. This would be the trial design team's 'best judgement' set requirement that balances the trade-offs between maximising participation whilst ensuring safety, compliance and data outputs to support exploration of all evaluation questions at a reasonable depth,

IV. High Control and Monitoring
A design the focuses on maximising safety assurance, compliance monitoring and production of data capable of in depth analysis of all evaluation questions currently agreed or which may emerge during the trial.

6.

Overlap with other freight decarbonisation initiatives

6 Overlap with other freight decarbonisation initiatives.

Up to this point, the feasibility of an LHV trial has been considered largely in isolation and has been assumed to be open to all suitable vehicles regardless of powertrain. However, at the same time, the freight industry will be going through one of its biggest ever technical changes with the planned phase out of diesel trucks and the introduction of alternative power trains that produce zero emissions at the tailpipe. In reality, if it goes ahead, an LHV trial will need to co-exist with a range of other policies and technical developments.

It is the case, that the potential to use zero tailpipe emission vehicles as part of LHV combinations, may change the case for using them. The full range of stakeholder views expressed during the project can be represented by the statements below:

- BEV LHVs – two opposing views:
    - LHVs could slow down electrification of the fleet because they will need more battery capacity so will take longer to electrify, OR
    - Emerging BEV tractor units would have no problem pulling an LHV combination for goods not requiring the maximum GVW. LHVs would remove one of the barriers to adoption of ZEVs, which is the increased unladen weight and/or limited space reducing payload compared to a traditional diesel HGV.
- LHVs will accelerate the transition to net zero because they are more energy efficient so fewer solar panels or wind turbines will be needed to meet the total electricity demand of road freight transport.
- Electrification will change the competitive relationship between road and rail freight because the difference in emissions per tonne km will disappear, though the difference in energy efficiency will not.

The weights and dimensions barrier to the adoption of zero emission technologies occurs because ZEVs tend to weigh more and/or take up more space. With a fixed total weight, length and height, this reduces payload and requires more vehicle km for the same freight task, undermining the benefit. Many industry stakeholders advocate straight increases in axle weight and GVW to compensate for the marginal additional mass. A proposal from the European Commission goes further and increases GVW for electric vehicles without a tie to the actual weight of the ZEV technology. This is intended to incentivise technical development to reduce the weight and gain payload as a positive advantage for BEV. However, based on the findings of this study, this could be a significant concern for bridge loading, for structural road wear and VRS. The European Impact Assessment for their proposal does consider a high cost on infrastructure maintenance and bridge investment but does not consider the carbon consequences of that same effort. The way to alleviate these concerns is to spread the load out over greater lengths of structures and more axles, that is, to make standard HGVs more like LHVs.

The use of e-Trailers has been proposed as a partial solution to this problem. This allows the weight and space required for batteries or hydrogen storage to be spread between tractor and trailer. The downside is that there are many more trailers than tractors in the logistics system, so the total quantity of batteries (including precious metals that are difficult and dirty to mine etc) required to support road freight would be much greater. However, in most LHV combinations there is a dolly or 'link' trailer that would already be considered specialist equipment. If this was battery powered, it could prevent the need for still further batteries or hydrogen storage on the tractor unit.

In addition to this, traditional weights and dimensions regulations are becoming extremely complex with a wide range of permitted deviations for specialist configurations and niches, while still acting as a barrier to innovation. As such, there is an opportunity for smart integration of a wider range of these issues into a trial framework and assessment process designed for LHVs.

The ultimate future expression of this approach could be a scheme that completely removed weight and dimension limits provided that vehicles met a series of standards governing important performance characteristics (such as bridge loading). All of those vehicle and load types and decarbonisation issues could potentially be incorporated in a single scheme that considered the following elements of performance:

- Energy efficiency and tailpipe emissions.
- Nature of the load (divisible or indivisible).
- Overall height.
- Acceleration and traction performance.
- Low speed manoeuvrability and directional stability.
- High speed stability.
- Infrastructure loading.

For each of these performance categories a score (e.g. out of 5) could be assigned to indicate the progression from best to worst performance. Road authorities could be obliged to categorise their road network according to the same performance levels. Telematics monitoring by an independent 3rd party could be used to ensure that the right level of vehicle performance and compliance is matched only with the roads that are suitable for those levels. Several countries already operate schemes along these lines under the heading of 'performance based standards' and 'Intelligent Access' but they are best known as Australian policies.

Zero emissions vehicles could be incentivised with higher capacity or access to more roads but without permitting them on unsuitable structures. It would encourage the market to develop technology to best meet the, often conflicting, constraints of productivity, safety, environment and the protection of infrastructure. The network of roads to which vehicles could gain access would not need to change in one quick step (e.g. an upgrade of bridges to allow heavier battery vehicles) but could evolve in line with operational need.

If implemented as a replacement for existing weights and dimensions regulations, this approach would clearly be a very large departure from the current practice and would be expected to take significant time and effort to develop. However, the principles of this process may naturally follow performance based elements and, if considering the whole scope of potential challenges in weights and dimensions, may permit an evolution of a UK specific version of this concept over time.

7.

Conclusions

7 Conclusions

A GB LHV trial appears to be technically feasible if the initial GVW is limited to 54-56t GVW and height to 4.2m but setting up and supporting the trial has some significant challenges.

If such a trial were to be implemented, the scope limitations would mean the benefits would be substantially smaller than with an implementation at 60 tonnes with unrestricted height. Even with this restricted scope, significant immediate benefits are achievable. However, such a trial would be substantially more complex than the longer semi-trailer (LST) trial in terms of initial creation, trial approvals and subsequent management. Some uncertainties remain as to exactly what each road authority will require to approve a safety case and, as a minimum independent assurance of the work to-date is required. Reaching an agreed position is likely to take additional investment and, assuming that is resolved, significant effort would then be required to approve individual routes, vehicles and operators in compliance with the safety case. Ensuring it met all the objectives for feasibility, safety, infrastructure, monitoring and evaluation would require a commitment to sustained investment by government and private sector for at least 7 years.

European experience suggests take up is capped will below the maximum ‘potential’ (base solely on analysis of load weights) by other factors, which will include the burden imposed under the rules and conditions of any trial and the ‘fit’ of LHVs into wider operations.

Maximum weights and dimensions are a potential factor limiting uptake of early ZEVs in some markets. Electric drivetrains are comfortably powerful enough to tow an LHV and it may be that a trial of LHVs could help mitigate some of the early uptake issues with ZEV.

A ‘rapid start’ trial could be possible and would avoid the risk of progress being delayed for a long period while assessment and a safety case is made to cover every possible LHV permutation of design and GVW. This approach would mean the trial would start with very tight constraints due to roads authority requirements, and could then expand over time, subject to additional funding for analysis and testing, along with added process complexity.

The potential benefits of using LHVs substantial and are proportionate to the level of take up, with value being delivered both the business and society. However, the benefits accrue only to the sub-set of businesses who were able and willing to take on the new vehicles (and associated trial conditions), whilst the taxpayer would bear a disproportionate portion of the costs, unless some cost-benefit balancing mechanism were introduced.

The study concludes that a GB trial of LHVs is technically feasible but requires significant up-front investment by government with some uncertainties remaining. In the short term at least, such a trial would need to start with limited options for LHV configurations, weight (54-56t) and height (4.2m). These constraints would significantly reduce, but not eliminate, the substantial immediate benefits that could be realised. To gain the greater decarbonisation and economic benefits that would be available if additional weight, height and route access could be shown to be viable, would require additional work. DfT, roads authorities, and the industry would need to regard this a 10-15 year journey of expanding LHV use cases.

8.

Glossary

8 Glossary

Acronym	Title	Description
ABS	Anti-lock braking system	A system that detects when a wheel is about to lock and modulates the brake pressure to prevent it.
ADAS	Advanced Driver Assist System	A general name given to systems intended to help drivers with discrete aspects of the driving task, typically information systems, warnings and collision avoidance technologies
AEB	Advanced Emergency Braking	Also known as Automated or sometimes Autonomous emergency braking. External sensors detect the risk of an imminent collision and, if the driver has not responded appropriately, the system will apply heavy braking to avoid the collision or reduce the impact speed.
AIL	Abnormal Indivisible Loads	An Abnormal Indivisible Load is any load that cannot be broken down into smaller loads for transport without undue expense or risk of damage.
BEV	Battery Electric Vehicles	A type of electric vehicle (EV) that exclusively uses chemical energy stored in rechargeable battery packs, with no secondary source of propulsion
CEDR	Conference of European Directors of Roads	A non-profit organisation established as a platform for the Directors of National Road Authorities.
CMS	Camera Monitor System	A system that provides the driver with a view around the vehicle via an external camera and images viewed on a monitor inside the cab. When complying with applicable regulations, these can be used to replace mirrors.
DfT	Department for Transport	The Department for Transport is the government department responsible for the English transport network.
EBS	Electronic Braking System	EBS and its components reduce the build-up times and response in brake cylinders.
EMS	European Modular System	A concept of allowing combinations of existing loading units (modules) in longer vehicle combinations to be used on predefined parts of the road network.
EC	European Commission	The EU governments administrative branch (similar to the UK civil service).
ESC	Electronic Stability Control	A system that detects if a vehicle is not following the directional path intended (as calculated from steering wheel angle and speed) or is rolling over and applies braking at selected wheels in order to prevent or correct the instability.
EU	European Union	The political association of 27 Member States.
GB	Great Britain	England, Wales and Scotland.

GVW	Gross Vehicle Weight	The total weight of large trucks, hauling trailers and other large vehicles.
HCT	High Capacity Transport	Bigger than conventional road freight vehicles, able to transport a larger weight or/and volume of cargo in one trip than a normal vehicle would.
HFCEV	Hydrogen Fuel Cell Electric Vehicles	Hydrogen Fuel Cell Vehicles Hydrogen Fuel Cell Vehicles (FCVs) are similar to electric vehicles (EVs) in that they use an electric motor instead of an internal combustion engine to power the wheels. However, while EVs run on batteries that must be plugged in to recharge, FCVs generate their electricity onboard.
HGV	Heavy Goods Vehicle	A goods vehicle in excess of 3.5 tonnes GVW but in the context of this report used to denote a standard legal vehicle of up to 16.5m length for an artic or 18.75m for a drawbar.
IAP	Intelligent Access Programme	A telematics based monitoring system used to monitor compliance with route restrictions and other conditions attached to permits to operate vehicles.
ICE	Internal Combustion Engine	The internal combustion engine is a heat engine in which combustion occurs in a confined space called a combustion chamber.
IVU	In-vehicle Unit	An item of technology fixed into a vehicle.
LHV	Longer Heavier Vehicle	A vehicle combination that is both longer and heavier than the standard current authorised weights and dimensions (e.g. 44 tonnes and 18.75m).
LKA	Lane Keep Assist	A system that monitors the position of the vehicle relative to lane markings and/or road edges and applies small steering inputs to encourage the driver back into the correct lane if the boundaries are crossed without the direction indicators being activated.
LST	Longer Semi-trailer	A semi-trailer that is longer than the standard EU length of 13.6m.
PBS	Performance Based Standards	Rather than assessing a vehicle based on prescriptive length and weight limits, PBS focuses on how well a vehicle behaves on the road, through a set of safety and infrastructure protection standards.
RIM	Road Infrastructure Management	An application that provides a way of collecting road use data from vehicles to inform and optimise the management of road networks.
SOA	State of the Art	The best and most recent technology or standard currently available
SRN	Strategic Road Network	The road network managed by National Highways, including Motorways and some major A-roads.
STGO	Special Types General Order	The Special Types order allows special types of vehicles some concessions from the standard Construction & Use regulations.
TCA	Transport Certification Australia	TCA has oversight on the role of service providers to deliver telematics applications through the National Telematics Framework in Australia.

TEU	Twenty Foot Equivalent Units	A TEU or Twenty-foot Equivalent Unit is an exact unit of measurement used to determine cargo capacity for container ships and terminals.
TMA	Telematics Monitoring Application	A platform provided by the TCA in Australia to interface with companies' telematics systems.
TRID	Transport research international documentation	An integrated database that combines the records from TRB's Transportation Research Information Services (TRIS) Database and the OECD's Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database.
UK	United Kingdom	The United Kingdom of Great Britain and Northern Ireland.
ZEV	Zero Emissions Vehicle	A vehicle that does not emit exhaust gas or other pollutants from the onboard source of power.

9.

References

9 References

(UK), H. T. (2020, April 1). *Magenta Book: Supplementary Guide: Handling Complexity in Policy Evaluation.* Retrieved November 22, 2023, from https://assets.publishing.service.gov.uk/media/5e96c98ed3bf7f412d7f7bb0/Magenta_Book_supplementary_guide._Handling_Complexity_in_policy_evaluation.pdf

Aarts, L., Honer, M., Davydenko, I., Quak, H., de Bes - van Staalduinen, J., & Verweij, K. (2010). *Longer and heavier vehicles in the Netherlands: Facts, figures and experiences in the period 1995-2010.* Netherlands: Rijkswaterstaat Ministry of Transport, Public Works and Water Management.

Balint, A., Fagerlind, H., Martinsson, J., & Homqvist, K. (2014). *Accident analysis for traffic safety aspects of High Capacity Transports.* Chalmers University of Technology, Department of Vehicle Safety.

Brand, P., Hahne, A. S., & Smallwood, J. (2023). *LHV Trial Feasibility Study: Haulage Operator Attitude Survey Report.* London: Department for Transport.

de Saxe, C., Kural, K., Schmidt, F., Van Geem, C., Kharazzi, S., Berman, R., . . . Woodrooffe, J. (2019). *Definition and validation of a smart infrastructure access policy utilising performance based standards.* Brussels: Conference of European Directors of Roads (CEDR) contractor report 2019-03.

European Commission. (2023). *Commission Staff Working Document: Report on the implementation of the amendments to Directive 96/53/EC introduced by Directive (EU) 719/2015.* Brussels: The European Commission.

Irzik, M., Kranz, T., Buhne, J.-A., Glaeser, K., Limbeck, S., Gail, J., . . . Kaschner, R. (2016). *Field trial with longer trucks: Final Report.* Bergisch Gladbach: German Federal Highway Research Institute (bast).

Knight, I., Brand, P., & Smallwood, J. (2022). *LHV Trial Feasibility Study: Literature Review.* Leeds: WSP report.

Knight, I., Newton, W., McKinnon, A., Palmer, A., Barlow, T., McCrae, I., . . . Taylor, N. (2008). *Longer and/or longer and heavier goods vehicles (LHVs) - a study of the likely effects if permitted in the UK.* Crowthorne: TRL Published Project Report PPR 285.

Knight, I., Smallwood, J., Brand, P., & Dickson, M. (2022). *LHV Feasibility Study: Final Report.* WSP report xxx.

NTC. (2018). *Reforming the performance-based standards scheme: Policy paper.* Australia: National Transport Commission.

Vierth, I., Berell, H., McDaniel, J., Haraldsson, M., Hammarstrom, U., Yahya, M.-R., . . . Bjorketun, U. (2008). *The effects of long and heavy trucks on the transport system: report on a government assignment.* VTI Rapport 605A.

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