DfT FAME:
Feasibility Report

FINAL REPORT

MDS Transmodal

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1. INTRODUCTION

1.1. Objective

The Department for Transport (DfT) has commissioned MDS Transmodal (MDST) to produce a detailed analytical system design for a Freight Analysis and Modelling Environment (FAME) in order to enhance the Department's analytical capability to support investment decisions, policy development, emergency responses and strategic directions.

This Feasibility Report sets out the results of the following:

- The state of the art in freight transport modelling, which the FAME should seek to at least match;
- A description of the freight transport 'system' which the FAME should be seeking to simulate;
- A framework for the FAME, summarising its objectives and the key components required to meet the needs of users within the DfT;
- Recommendations for the scope and design of the FAME, taking account of the likely feasibility of various approaches based on the consultancy team's experience in freight transport economics and modelling; and
- Conclusions on overall feasibility of developing FAME, including a risk register.

1.2 Methodology

State of the art in freight modelling

A short literature review was carried out of papers on freight transport modelling produced in the English language over the last 20 years, considering MDST's own experience and three specific other studies that are relevant to the DfT and National Highways[1]. This allowed a high-level assessment of the state of the art to be developed, taking into account both the traditional four-stage transport model and agent-based modelling approaches and highlighted potential alternative approaches to the model development, along with their advantages and disadvantages based on evidence from the literature review.

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[1] Review of Freight Modelling, 2002 (led by WSP), Base Year Freight Matrices, 2010 (WSP) and Freight Demand Scoping Study for Highways England, 2018 (ARUP & AECOM).

The freight transport market

A review of the freight transport market was completed by providing a summary, and update where necessary, of the most relevant sections of MDST's report on *Understanding the UK Freight Transport System* (MDS Transmodal, for the Government Office for Science, 2017-18), with the objective of highlighting, in particular, the market mechanisms that need to be simulated by FAME. This has focused on market mechanisms and the political economy of freight transport that would need to be simulated by a model.

Assessing the feasibility of the FAME

The FAME framework was developed by discussing the likely requirements of different users with the DfT, following a review of the Terms of Reference for the project.

The feasibility of the FAME in terms of its scope and functionality was assessed based on the collective experience of the consultancy team over a period of up to 40 years in the fields of freight transport modelling and freight transport economics. This experience has included developing national freight transport demand models for Great Britain, Ireland, the Kingdom of Saudi Arabia and Malawi, as well as large-scale world regional freight transport demand models for the European continental mainland and the Horn of Africa and global models of trade and container shipping deployment.

2 REVIEW OF THE STATE OF THE ART IN FREIGHT TRANSPORT MODELLING

2.1 Introduction

The examples of freight modelling available within the literature can be broken down into the following three categories:

1. Policy and intervention models: models that describe specific applications as they relate to particular policy or infrastructure initiatives such as the switching of cargo from road to rail or coastal shipping;
2. Company specific models: designed to permit specific cargo owners or distributors to optimise their own freight solutions (typically associated with warehouse locations etc.);
3. National and regional models: designed to assist in national or regional modelling and mainly for the public sector (road and rail network development, policy initiatives such as road pricing etc.).

In this case the primary interest is in the third case, but some mention of the first two categories is worthwhile.

2.2 Policy and intervention case studies

There is an extensive literature concerning the first category, largely because it is within the scope of student or research projects and can be addressed with limited data sets to deal with specific questions. The objective is often to test whether a specific policy initiative could be effective and will deal with a sub-set of total freight movements. This could include, for example, freight between two coastal regions, for a specific commodity and the case for switching to rail or a given infrastructure project. For example, a model has been recently developed for Rail Baltica (taking into account competition with other modes) as a subset of the TRIMODE pan-European model (see below) and for the Gulf Cooperation Council (GCC) on rail freight (based in part on the national models of participating countries). Both specific railway lines are currently under development.

2.3 Company specific case studies

These are mainly covered by commercial software suppliers. A well-known example is the CAST model, which was developed by Barloworld[2]. - There are many companies that will, from time to time, seek to review their distribution strategy and this can often involve tendering between third party logistics companies. Such companies find it convenient to standardise the way in which they test propositions

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[2] Following a takeover of much of Barloworld's business by Llamasoft, the software is now called Llamasoft Supply Chain Guru X. Further information on this software is available at the following link: https://help.llama.ai/release/native/modeling/modeling-topics/Home.htm

(such as the size, location and number of warehouses to be employed). The main technical pressure is on transport costs; the demand data is generally supplied by the client. However, there will also be applications in areas of international network development (sea and air) where shipping lines or the ports serving those lines wish to be able model different network solutions based on transport cost models to test changes in route solutions etc.

2.4 National and regional models outside the UK

The market for these models is mainly in the public sector because it is the public sector that is responsible for most road and rail networks. However, there may be private sector entities who would wish to lobby government for the development of specific network interventions. There are also cases of modelling the goods moved for a particular industry or sector (e.g. SYNTRADE for the German food industry), but such models will have 'boundary' problems and cannot easily define control totals based on overall freight movements. Other models have been developed to model competition in the ports sector (e.g. pan European container traffic), such as MDST's European Container Port Demand Model which was developed for the North Adriatic Ports Association in 2010-11.

The National Cooperative Highway Research Program (NCHRP) in the United States (2008) proposed a classification system for the degree of depth freight models adopt, which will be largely dependent upon the data that is available and the sophistication and flexibility of the scenario building required. These were:

A. Direct facility flow factoring method (which implies traffic counts);
B. O-D factoring method (requiring a survey of vehicle origin-destinations for one mode);
C. Truck Model (some relationship between exogenous variables and trucks generated);
D. Four-step Commodity Model (relationship between commodities, tonnages and including modal split);
E. Economic Activity Model (the further addition of economic drivers to estimate freight volumes generated).

As we shall see, national and international models tend to fall between levels D and E.

Such models will generally need to cover readily defined geographical areas that are larger than the normal geography defined for passenger transport models. This is because freight traffic (particularly heavy freight) tends to have a much longer mean length of haul than passenger traffic and so cannot be easily or usefully modelled at the metropolitan level. It is also important that entry points to the defined area are relatively few and also well defined, which means that an island such as Great Britain is ideal as a defined model area.

For countries located in the continental mainland there is, therefore, an argument for modelling at the European scale to reduce the importance of land boundaries, which explains the development of two models over the last 20 years called TRANSTOOLS and TRIMODE.

TRANSTOOLS was developed some 15 years ago and was designed to model across the European space for passengers and freight. It was largely designed to forecast traffic volumes by network link.

TRIMODE[3] was developed over the period 2015 and 2020 and was more ambitious. It sought to also link the demand for freight with the underlying economy (therefore feeding directly from production/consumption drivers) and thereby link future demand with economic growth, policy initiatives that envisaged a shift away from oil and consequential implications for transport network capacity. This project has been completed but, as far as we are aware, it has not been applied with results being provided in the public domain.

Two other EU level models have been identified but do not appear to have been pursued, being ‘LOGIS’ and ‘Worldnet’.

Beneath this level, a number of national level models have been developed. These include, as well as the Great Britain Freight Model (GBFM) for the UK, models that have been developed for Italy, the Netherlands, France, Germany, Norway, Sweden, Belgium, North America, New Zealand, Qatar and Saudi Arabia.

All appear to be structured in a similar way, using the classic 4 step transport modelling approach of generation, distribution, modal split and assignment.

The Italian model has 267 internal zones, 5 commodity groups, includes all 4 steps and road, rail and combined transport modes (road-rail intermodal)[4].

Two Dutch models have been identified. These are:

- SMILE+, which has 40 internal and 60 external zones, 50 logistical ‘families’, includes all 4 steps and road, rail, inland waterway, sea, air and pipeline modes[5].
- Basgoed, which has 40 internal and 30 external zones, 10 commodity groups (NSTR1), includes all 4 steps and road, rail and inland waterway modes[6].

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[3] MDST was involved in providing advice on freight transport markets and data, but the actual freight modelling was completed by TRT with much of the work sub-contracted to Ian Williams.

[4] It is reviewed by Marzano and Popola in a paper at the European Transport Conference 2004, Strasbourg

[5] See Tavasszy et al., International Transactions in Operational Research, 1998, pages 447-459

[6] See Tavasszy, CTS seminar on European and National Freight Models, Stockholm, 2011

The French model (MODEV) has 277 internal and 19 external zones, 10 commodity groups (NSTR1), all 4 steps (including a logistics sub-mode) and road, rail, combined transport and inland waterway modes[7].

The German model (BVWP) has 439 internal and 112 external zones, 10 commodity groups (NSTR1), all 4 steps and road, rail, inland waterway and sea modes[8].

The Norwegian model has 475 internal and 61 external zones, 32 commodity groups (NSTR2), all 4 steps and road, rail, sea and air modes[9].

The Swedish (Samgods) model has 290 internal and 174 external zones, 35 commodity groups (NSTR2), all 4 steps and road, rail, sea and air modes[10].

The Belgian model (NODUS) has 600 internal and 250 external zones, only mode split and assignment steps and road, rail and inland waterway modes. A separate model for Flanders (ADA) has 309 internal and 22 external zones, all 4 steps and road, rail, inland waterway, sea and air modes[11].

Several freight models have been identified in North America, generally at the state or Canadian province level. An example is that from Southern California (HDT) which is a traditional four step model, including ports.

The New Zealand (FMM) model deals only with international freight but does take into account total operating costs (i.e. to determine user benefits).

The current Qatar model has been developed by MDST in collaboration with PTV and is a four step model replacing an earlier three step model that did not include the maritime mode.

The Saudi Arabian model (National Strategic Transport Model, developed by MDST in collaboration with PTV) has 658 internal and 32 external zones, includes all 4 steps, road and rail modes and forecasts port traffics.

The key point in this analysis is that all these models are based on the 4-step model methodology and none of them use agent-based modelling.

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[7] See MVA and Kessel + Partner, Paris/Freiburg, 2006

[8] See Intraplan and BVU, Munchen/Freiburg, 2007

[9] See Kleven, CTS-seminar on European and national freight demand models, 2011

[10] See Vierth, CTS-seminar on European and national freight demand models, 2011

[11] See de Jong et al, European transport conference, Glasgow, 2010.

2.5 Access to data

In each of the above cases, it is clear that use has been made of existing (generally nationally collected) data. All European countries collect data along similar principles to the UK Continuing Survey of Road Goods Transport (CSRGT), traffic volumes are available by road and rail at a detailed network level and port data is available on a standardised basis. The collection of freight transport data is driven by EU data collection policies and extensive economic data is also available but at a value (not tonnage) level.

Private sector sources of data through the automated recording of vehicle movements (e.g. Trafficmaster and INRIX) have become available but this has the weakness of not being able to identify the goods carried within a road vehicle and so logical relationships between goods moved and demand for vehicle movements cannot be established. Also, unless a large proportion of vehicles are captured in the data, there is the danger of the sample not being representative of the whole population. There are, nevertheless, opportunities to cross reference data sources which have yet to be fully explored. For example, CSRGT data could be grossed up by traffic counts and origin-destination pairs, addressing a problem which has been identified in studies since 2002 of the inconsistency between CSRGT and network count outputs.

Port data is publicly available at a very detailed commodity by overseas-country level through HMRC and is in the public domain. Post Brexit, this level of port data is now also publicly available for trade between the UK and the EU countries from HMRC; prior to Brexit, trade data did not specify the UK port used for EU trade.

However, there has been a continuing debate concerning the modelling of ‘logistics’ and supply chains in such a way that traffic can be traced ‘through’ distribution centres (DCs). As far as we are aware, no practical solutions have been identified beyond the level of an individual organisation, or how any examples could be grossed up to avoid distortion. While data tracing is relatively straightforward at the individual firm level (using software such as CAST) this is very challenging at a national level and involves access to private sector data that is generally not available or not shared. It may be more sensible to regard all land uses at the origin and destination of each journey as ‘adding value’ such that they are considered independent journeys, to avoid this problem, particularly as almost every distribution centre does add value if only by re-sorting/re-labelling goods. In that way, except where the cargo unit itself is transferred unopened (as with a container or a trailer at a port or rail terminal) individual legs can be modelled separately.

A feature of the literature examined was that in more recent years more attention appears to have been paid to ‘big data’ and rather less to the development of ‘four-step’ models. This may be because the ‘four step’ model requires extensive data sources to produce a reliable output and is best suited to models designed to examine policies and interventions that relate to a defined geographical area. By contrast, ‘big data’ approaches (with data generated by digital technologies) can be undertaken using more readily available data (albeit often sold at a high price) and can therefore be more rapidly deployed. It may also be that in many countries, the four step approach has already been established and the case for further research papers will have passed and that a market has developed for 'quick answers' from big data providers concerning a single mode or local geography (e.g. a road based issue concerning a specific length of road, a port or a local community).

We found no model applications using digital technology (e.g. mobile phone data) which could deal with multiple modes and, indeed, applications of 'big data' were almost all road based. Several weaknesses did emerge, such as the risk of samples being unrepresentative, protecting data privacy (legal issues) and the fact that the commodity and cargo tonnage carried was not available. It would therefore be difficult to develop a model built entirely on data derived using digital technology that could inform on the impact of policies involving modal change.

Digital technology derived data for HGVs did, however, have the potential advantage of being able to track the 'behaviour' of different types of truck very precisely to establish, for example, dwell times, loading and discharging times and the number of deliveries vehicles made by land use. An emerging feature of models has been the 'tour' based approach, tracking the behaviour of freight vehicles to determine dwell times at different locations. However, cross referencing to land uses then requires that very precise location data is available.

This digital technology derived data for HGVs can be a good source for point-to-point journey times and routes taken.

'Big data' may provide some further insight into the way that road haulage operators manage their fleet, but does not appear to provide a substitute for the more conventional 'four-step' approach.

2.6 Experience in Great Britain

The Great Britain Freight Model (GBFM)

The principal freight model operated within Great Britain has been the Great Britain Freight Model (GBFM), now in its version 6.2 format. This has been described in detail by third parties and particularly in the *Freight Demand Scoping Study* by ARUP and AECOM in 2018 for Highways England (now National Highways). The model is owned and mainly operated by MDST, although the DfT has had a license to use GBFM v5 since 2006 and TfN has a license to operate v6.2 up to March 2024.

GBFM version 5 was based on collaboration between the DfT and MDST and had about 2,600 zones, whereas version 6.2 has 7,078 internal and 135 external zones. The development of GBFM followed the *Review of Freight Modelling* commissioned by the DfT in 2002. It is a standard four step transport model employing a wide range of data sources. It is calibrated to replicate modal shares and it assigns flows along the road and rail networks and through ports. The model extends onto the Continent and to Ireland and includes short sea unit load shipping links so that competition between ports in this market is taken into account.

The DfT was provided with a free license to use v5 of the software (which remains in place) and training to use it; DfT ITEA (predecessor of TASM) also had a call-off contract with MDST via WSP up to 2010 so that it could receive technical support both on modelling using GBFM and with knowledge of the freight transport market. DfT TASM has continued to use the model for the purposes of producing traffic forecasts between 2010 and 2021.

In late 2021 DfT TASM commissioned MDST to update GBFM v5 so that it could be used to develop the most recent traffic forecasts that have been published by the Department.

Since 2010 MDST has continued to use the model for a wide range of clients, including the Cabinet Office, Transport for the North, Midlands Connect, Network Rail, Highways England, the National Infrastructure Commission and private sector infrastructure providers such as ports and large-scale warehouse developers. It was also used by DfT policy-makers to examine policy options for waterborne freight transport in 2018. On four separate occasions GBFM v6.2 was used to assess the impact of various HS2 configurations on rail freight and to examine the potential impacts on freight of East-West Rail on behalf of DfT; these projects involved the use of a rail capacity module for GBFM which MDST has developed, which allows the impact of network capacity constraints to be assessed.

MDST has carried out five separate rail freight forecasting exercises for Network Rail since 2013, in which the results have been subject to validation by the freight transport industry.

In 2021-23 MDST has used GBFM v6.2 to examine the strategic supply and demand, including developing techniques to constrain capacity of RORO services and RORO ports.

MDST has used GBFM for a large number of strategic highways projects, where multi-disciplinary consultancies need specialist freight transport modelling input; freight outputs are then used as inputs alongside passenger traffic to highways models (often using SATURN). Examples of projects on which MDST has worked include the Lower Thames Crossing, the A14/M1 Junction, the A66/A69 Northern Pennines corridor, the Trans-Pennine Tunnel, the M60 North West Quadrant, the Oxford-Cambridge Expressway and Operation Brock in Kent. DfT would have received many of the business cases for these highways links, based in part on outputs from GBFM.

With the exception of DfT TASM and TfN since 2020, none of these clients has requested a license to use GBFM, which we believe is due to them not usually needing a long-term modelling capability and realising that the use of the model requires a combination of both transport modelling expertise and an in-depth understanding of how the freight market works, particularly as there is often also scrutiny of results from the private sector freight transport industry.

Other models developed in the UK

The DfT commissioned a separate project called Base Year Freight Matrices (BYFM) from WSP that reported in 2010. This had 408 internal and 52 external zones, plus 149 ‘point’ zones (ports, airports and distribution centre clusters) and 31 commodity groups. This model relied on GBFM to provide a base year pattern of traffic against which to calibrate an origin-destination matrix, essentially seeking to replicate the concept of a conventional input-output econometric process through conversion to tonnage (a ‘production-consumption approach’), relating economic activity based on Standard Industrial Classifications with commodities recorded within the Continuing Survey of Road Goods Transport. The BYFM report described the various weaknesses of the data inputs very fairly and succeeds in achieving reasonable matches between its base year results and 4 screen-line flows. It was not calibrated against modal or port market shares. BYFM took rateable value (not m^2) of all warehouses as an explanatory variable.

An earlier model (EUNET) modelled freight across Northern England some 20 years ago.

A more recent development has been a “National Freight Model” which was developed by City Science in 2021-22. As far as we are aware no technical documentation for the model has been made public, presumably for reasons of commercial confidentiality, and therefore the actual functionality of the model is uncertain. Having said that, the project seems to have involved developing a baseline origin-destination matrix, with highways assignments, for road freight transport and using CSRGT for the purposes of validation; the HGVs are split between different sizes of HGV as in GBFM v5 and sought to follow cargo through different stages in the supply chain (as in the BYFM and TRIMODE). The IPR is understood to belong to City Science and, as far as we are aware, the only active use of the model is for Thurrock Council, which is developing a new transport model.

2.7 The four nations of the UK

FAME has the objective of incorporating all four nations of the UK on, as far as possible, an equal basis. Great Britain (GB) is a naturally bounded island and therefore works well as the main area of interest for a model, where the transport will be principally by road and rail and mainly conducted with vehicles registered in GB. Connections to Continental Europe, the island of Ireland (both Northern Ireland (NI) and the Republic), and the rest of the world enable freight to arrive and depart through ports and the Channel Tunnel.

There are several data sources that are available at the GB level and the UK level (DfT CSRGT and Port Freight Statistics), which makes it simpler to populate a model with data for Great Britain and Northern Ireland.

Another issue is the geographic zoning of any FAME model as the approach taken in the National Transport Model (NTM) was (for England) based on the MSOA zoning system and therefore on where people live. While this type of zoning system should also work well for many other areas of the UK such as the Central Belt of Scotland and South Wales, it will lead to larger geographic zones in less-populated areas such the Highlands of Scotland and Mid Wales; this may be an issue for the modelling of the transport of products of industries such as agriculture, forestry, fishing, aquaculture and whisky.

2.8 Initial observations on the state of the art

General observations

The above review, linked to lessons learned by MDST in developing GBFM and related applications (e.g. rail assignment and appraisal), suggest the following:

- There is an obvious attraction to taking a production – consumption approach in the development of freight models because this allows linkage to the 'real' economy. However, because the more reliable tonnage data (from a transport perspective) is from the survey and census data available for road (CSRGT), rail and ports (DfT and HMRC), there is merit in taking this freight transport data as a given and then interpreting these flows in production and consumption terms in such a way that forecasts can be based on relative changes in economic indicators and not taking those economic statistics as the 'starting point'. This is the approach adopted within GBFM v6.2. In this way production – consumption tables could be readily derived from the freight data. This was a lesson learned by MDST in the TRIMODE study. The relationship between production data measured in value terms and origin data in tonnage terms is not reliable and will vary hugely even within a single SIC. For example, the weight to value relationship between (say) tyres and head light bulbs would not be expected to be similar, but both are motor vehicle components.

Modelling exercises can benefit from taking land use into account. The most important such explanatory parameter will be the distribution of large distribution centres, which (as an origin or destination) probably account for half of all freight moved in Britain. It is important to use m^2 and not rateable value as the explanatory variable and to take much greater account of the larger buildings classified as warehousing because a large proportion of buildings classified in the VOA (Value Office Agency) database as warehousing are small units that handle a small minority of heavy freight and can have higher rateable values because of their locations. By taking land-use and changes in production and consumption (population) forecasts into account a freight transport model can produce forecasts that are internally consistent with economic, demographic and spatial projections.

- There should be consistency within FAME between the freight transport costs used for modelling and forecasting and for transport appraisal.
- Appraisal needs also to consider air quality and other parameters. All that is currently available (and used in GBFM) is based on the values that underpin the grant levels provided by the DfT under MSRS. Forecasting without realistic appraisal values is not useful.
- There may be scope for integrating data now available through mobile phone and automatic traffic count data into the databases already used in modelling techniques through allowing the tracing of routes and the development of performance indicators (time lost through vehicles not operating at free flow speeds; trains operating without delays caused through pathing delays etc.).
- Freight transport modelling requires a suitable model, modelling skills and judgment as applied to a freight model and an understanding of how freight transport markets and their underlying commercial mechanisms work.

Agent-based modelling

There was one experiment we are aware of in the UK using agent based modelling (ABI3L), which MDST was heavily involved in (with Cranfield University). However, this was not a success because even where base year flows could be replicated it was very difficult to interpret results in terms that could be associated with policy levers and therefore consultees could not see how to make use of the outputs. The 'actors' were taken as individual origin-destination movements.

There might be a case for modelling at the company level (and therefore taking an agent-based approach), given that in reality it is decisions at that level that dictate where private sector infrastructure is developed and rail and maritime services are established, which then dictate how other actors react i.e. individual consignments can only be forwarded if the private sector infrastructure and services have already been established. In principle new services develop in response to already established services (e.g. a feeder shipping line carrying for a deep-sea line).

In practice, however, the fact that no two significant companies will be identical and (road haulage apart) the freight industry tends towards oligopoly means that to realistically model on this basis would involve identifying the infrastructure and service characteristics of each company, bearing in mind the high levels of vertical integration now being engaged in (e.g. shipping lines trading as door-to-door logistics companies).

It may also be possible to generalise, and for example set up several "agents" representing rail freight operating companies that can decide which rail terminal pairs to operate intermodal rail services between, given a particular policy environment. Such models have an element of randomness such that repeated model runs of the same scenario can produce different results. Interpretation of results therefore requires several runs to give a flavour of likely outcomes.

Overall, however, the practice of developing national freight models, particularly within Europe, appears well established and dates broadly from when national and international freight data sources became more widely available (via Eurostat standardization). Almost all adopt the 4 step approach[12]. The review of the evidence suggests there is a broad consensus on adopting the 4 step approach because it allows specific levers to be applied in scenario building that can be readily understood, albeit that interactions between different 'freight players' cannot be easily reflected. A particular challenge is that of non-road haulage service provision where the ability to consolidate sufficient traffic to fill (and pay for) a train or ship in a market context is inevitably an iterative process, unlike

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[12] Further information on the overall subject of freight transport modelling, and extensive lists of sources, are available from the following sources: Tavasszy and de Jong, Modelling Freight Transport, 2014; De Jong et al, Recent developments in national and international freight transport models within Europe, June 2012; Doustmohammadi et al, Comparison of Freight Demand Forecasting Models, International Journal of Traffic and Transportation Engineering, Vol. 5 No. 1, 2016, pp. 19-26; Shoman et al, A Review of Big Data in Road Freight Transport Modeling: Gaps and Potentials, Data Science for Transportation, February 2023

most passenger transport modelling exercises where, for example, a public sector bus network would be introduced as an exogenous input to a scenario, regardless of whether it can ‘pay its way’ from the farebox.

3 REVIEW OF THE FREIGHT TRANSPORT MARKET

3.1 Introduction

The freight transport market in the UK can be defined for the purposes of this report as encompassing:

- Users of freight transport services (principally shippers and receivers of cargo);
- Freight transport and logistics service providers; and
- The infrastructure networks which the freight transport services use.

This implies that FAME needs to account for all three elements of the market, which would encompass the demand for freight transport services, the provision of freight transport services and use of transport networks.

Freight transport is needed because goods available at one geographical location are required at another location for processing, sorting or consumption. Freight transport is therefore an example of what economists call a derived demand as the transport is not required in itself, but only as a means to satisfy another demand.

As a derived demand, the demand for freight transport does not come directly from consumer needs or wants but from private sector companies such as retailers, manufacturers and processors. However such organisations are ultimately responding to consumer demand for goods and the level of demand for goods will be influenced by various factors, including the size of the population, the performance of the wider economy and changes in tastes and fashions over time.

Freight transport and logistics services are delivered almost exclusively by private sector companies which invest heavily in fixed infrastructure, such as port facilities, rail terminals, distribution centres, and mobile equipment such as trucks, vans, fork lift trucks, ships and railway locomotives and wagons.

The private sector freight transport services need, however, to use publicly owned infrastructure such as road and rail networks.

3.2 The political economy of freight

As well as using publicly owned and funded transport infrastructure, freight transport service providers are also subject to the taxation and regulatory regimes that the public sector puts in place. Changes in taxation and regulation may lead to more efficient outcomes for the wider economy and society as a whole, but will also affect the value of private sector investments that have been predicated on the existing fiscal and regulatory position. It follows that Government needs to understand the current landscape for freight transport as future interventions are likely to require a combination of public investment in road and rail network infrastructure, changes in the regulatory framework and the taxation regime and the application of appropriate planning policies. These changes should be designed, wherever possible, to increase the efficiency of the freight and logistics sector by reducing its costs; this is particularly important as freight transport should be seen as a cost of production and as having an impact on the productivity of firms and the UK economy as a whole.

Freight transport movements also have impacts on the environment and on the quality of life and health of citizens and so an appropriate balance needs to be found between, on the one hand, economic objectives and, on the other hand, quality of life and environmental objectives. These wider impacts on society which are not fully incorporated into the process paid by shippers and receivers in the market place are known as externalities or non-user costs.

The freight transport industry is highly competitive, facilitated by the relative ease of entry into the road haulage market, which is the dominant mode of freight transport. This means that most individual providers of freight transport services have low margins and generally seek to minimise their costs (their user costs) in order to remain competitive in the marketplace and commercially viable.

As the freight transport industry is highly competitive, any interventions by the public sector will lead to a response from the private sector operators and any resulting changes in costs will be passed on, in the medium to long-term, to the industry's customers and, ultimately, to the wider economy.

In conclusion, therefore, the role of FAME should be to simulate the functioning of the largely cost-driven freight transport market, while taking account of the availability of publicly owned infrastructure and the existence of tax and regulation which influences the behaviour of the market players. FAME also needs to be able to accommodate future scenarios that change the quantum of freight transport demand (based on forecasting) and allow for a market-based response to changes in public sector policy to achieve wider public objectives (to test the impact of public sector interventions).

3.3 Definitions of freight transport

As explained above, **freight transport** is the carriage of goods between an origin and a destination for commercial reasons because goods available at one geographical location are required at another location for processing, sorting or consumption.

Logistics is a broader concept that involves designing and managing supply chains for individual organisations. It seeks to efficiently manage the purchasing, manufacturing and storage functions and the transport as an integrated system.

FAME is likely to be mainly focused on simulating freight transport at a strategic level rather than logistics, but attention is also needed on distribution centres because of their importance as nodes in the wider freight network, in adding value to the goods stored and in creating employment.

Freight transport can generally be categorised by its:

- Origin or destination, with a particularly important distinction being between domestic freight transport (i.e. within the UK) and international freight transport between the UK and other countries, whether the European Union or with non-EU countries;
- Mode of appearance (principally bulk or non-bulk for land-based transport);
- Mode of transport (road, rail, inland waterway, coastal shipping, air, pipeline etc.)

Domestic freight transport is defined as the carriage of goods with both the first origin and final destination within the United Kingdom, while **international freight transport** is the carriage of goods with either an origin or destination outside the United Kingdom. As Great Britain is an island, all international freight has to be handled through a port, airport or through the Channel Tunnel, while for Northern Ireland international freight transport can also involve movements across the land border with Ireland.

Bulk freight transport is where large volumes of a homogenous cargo are carried in specialised transport equipment between specialised terminals. Examples include the transport of aggregates from a quarry to an urban rail terminal and the transport of petroleum products by sea in oil tankers from an oil refinery based on an estuary to a coastal tank farm.

Non-bulk freight transport is made up of two main categories of cargo:

- Unitload transport: where cargoes are carried in standard “box” units, mainly road trailers and containers. Examples are where a truck makes a delivery of food and beverages from a distribution centre to a supermarket or where a container containing consumer goods from China is transported on a rail service from a container port to an intermodal rail freight terminal, where it is then loaded onto the back of a truck for delivery to a distribution centre.
- Semi-bulk transport: where high volume industrial products are ‘packaged’ to ease handling without being in pure bulk form or being transported in a unit. Examples include steel coils, paper rolls or packaged timber.

FAME therefore needs to have a geographic zoning system, which allows for both internal zones (within the UK) and external zones (beyond the UK). It will also need to be able to simulate movements of bulk and non-bulk goods and by different modes of transport as this defines their economic costs (a cost to the wider economy), their externalities and the demand for network infrastructure.

3.4 Measuring freight transport

Freight transport is usually measured in terms of freight tonnes lifted or freight tonnes moved. Freight tonnes moved can be expressed in tonne kilometres (tkm) or, for road freight, vehicle kilometres (vkm). Tonne kilometres is generally regarded as the most relevant measure for defining modal share as it provides a measure of the amount of freight transport required.

The combination of tonne kilometres and tonnes lifted allows the length of haul to be derived, as follows:

Tonne Kilometres (tkm) = Tonnes Lifted x Length of Haul in Kilometres

Tonne Kilometres / Tonnes Lifted = Average Length of Haul in Kilometres

Average length of haul (and the variation around the mean) is important in the context of policy development (and therefore FAME) because longer hauls are more likely to be commercially viable for rail freight, which has, in general terms, a lower variable cost per tonne kilometre but a higher fixed cost (irrespective of distance) than road freight. In addition, length of haul is important in relation to the decarbonisation of road freight as the range of battery electric HGVs that are available on the market have a more limited range before recharging is required than a diesel HGV and so the longest trips cannot be achieved without re-charging. A zero emission alternative for the heaviest HGVs may be available using hydrogen fuel cells as long as the electricity required to produce the hydrogen is from renewable sources.

FAME will need to be able to produce outputs such as tonnes lifted and tonnes moved by mode and between geographic zones so that they are immediately both understandable and relevant to users, whether they are modellers, analysts, economists or policy-makers. Cost models will be needed for both diesel and zero emission vehicles (probably battery electric and hydrogen) to simulate the costs of each of these propulsion types and resulting assigned flows should assist in determining where alternative fuelling infrastructure is likely to be needed compared to the existing position where diesel is effectively assumed to be always available; as many road freight transport operators will need/require refuelling infrastructure at their bases the larger private sector companies are likely to be already planning for facilities where good connections to the electricity grid are available. This would then need to be supplemented by public facilities at strategic locations on the Strategic Road Network. GBFM v6.2 will be used for analysis of these issues in 2023 for a project MDST is carrying out for Midlands Connect (funded by DfT). Because modelling behaviour will be based upon the cost of different transport solutions it will also be possible to output the commercial cost of freight transport (i.e. the commercial cost to the economy) as well as outputs that include externalities.

3.5 Modes of freight transport

Introduction

Freight transport is often defined in terms of the mode of freight transport because this determines the impact on transport networks, the relative economics of the freight transport movements and their wider externalities and, for domestic freight transport movements within Great Britain, the key modes are road, rail and waterborne freight.

Road freight is by far the most important mode of domestic freight transport as, ignoring pipelines for which there is no consistent data throughout the period, it has accounted for about 77% of tonnes moved and 89% of tonnes lifted during the period 2010-20.

FAME will, however, need to be able to test the impact of interventions on modal shift to rail and waterborne freight. This is a core functionality of GBFM v6.2 and is achieved by allowing traffic to switch from road to rail if it is cheaper in general cost terms and providing outputs in terms of quantified user and non-user benefits.

Road

The vast majority of road freight lifted and moved is carried in heavy goods vehicles (HGVs), which are defined as vehicles over 3.5 tonnes gross vehicle weight (i.e. the weight of the vehicle plus its maximum load). Although there are a variety of types and sizes of HGV, the main distinction is between a rigid vehicle (mainly used for deliveries in urban areas and in the construction industry) and an articulated tractor and trailer combination. The main type of HGV used for long distance road haulage (and therefore seen on motorways) is the articulated combination of a tractor and 13.6-metre trailer.

There has been an increase in light goods vehicles (LGVs or so-called “white vans”) traffic (under 3.5 tonnes gross vehicle weight), but while this is partly due to an increase in parcels traffic as consumers and businesses buy goods on-line - and therefore related to so-called ‘last mile’ deliveries - much of the growth seen since the advent of on-line shopping in 2000 has been due to increased service-related activities[13].

Road freight is by far the most important mode of freight transport and so most attention needs to be paid to the simulation of the economics of this mode both for HGVs and LGVs. Within FAME, just as

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[13] The Committee on Climate Change reported in its 2018 Progress Report to Parliament that around 60% of the growth in LGV traffic since 2000 can be attributed to growth in GDP and self-employment in sectors associated with high van use, whereas 22% can be attributed to online retail parcel deliveries.

in GBFM, there needs to be provision for the translation of tonnes transported into HGV and LGV units as these are the units that define costs and capacity required.

Rail

Rail freight transport can be cost-effective, even over short distances (i.e. less than 100km), for full trainload consignments moving between two rail connected sites (such as shipments of quarried material from a rail-connected quarry to a rail-connected port). It can also provide economic and flexible transport chains for higher value goods when transported in containers within intermodal transport chains, particularly when at least one end of the transport chain is connected to the rail network (such as at a container port).

Rail freight is the most important inland mode of freight transport to secure modal switch away from road freight, while also providing an opportunity to reduce transport costs. Significant attention needs therefore to be paid to the simulation of the economics of this mode, particularly in relation to the movement of intermodal traffic to and from both ports and rail connected distribution parks (or Strategic Rail Freight Interchanges, SRFIs).

Within FAME there needs to be provision for the translation of tonnes transported into trains as these are the units at define costs and capacity required.

Maritime

Maritime freight transport via sea ports is essential for connections with Northern Ireland, to trade with the European continental mainland, Ireland and the rest of the world. A wide variety of modes of appearance are used to transport goods by sea (i.e. the mode of transport as it ‘appears’, and is handled, at the port), from container ships (load on load off or LOLO) and roll-on roll-off (RORO) ferries carrying high value consumer goods, to bulk carriers transporting petroleum products, crude oil, grain, biomass, bulk steel and a wide variety of other goods.

As there are many scheduled routes for short sea unitload traffic, each with their own geographic advantages, and using different modes of appearance (accompanied RORO, unaccompanied RORO trailers, unaccompanied RORO port-to-port trailers and shortsea LOLO) a key focus of FAME should be on simulating the traffic flows on each route and by mode of appearance. For example, the extent to which traffic in this market is focused on the Short Straits between Dover/Eurotunnel and Calais is likely to be a key policy issue from the point of view of resilience and environmental impacts. In addition, maritime costs per tonne or per unit are heavily influenced by economies of scale and therefore modelling within FAME needs to take into account the size of ship (and therefore capacity per crossing) the routes available (and the number of round trips available) and therefore unit costs.

Where short term congestion causes (say) the closure of a particular port, the impact of this has been modelled in the past using GBFM v6.2; this is achieved by increasing the cost of using a particular piece of infrastructure so that traffic is forced to choose its next best alternative taking into account door-to-door generalised costs. Capacity constraints (at the shipping service and port level) have also been used to ensure that demand through a particular port on a particular service is not exaggerated.

Waterborne freight

Waterborne freight is made up of coastal shipping (freight movement by sea between two ports), one-port traffic (freight movement between a coastal port and an offshore installation, such as an oil platform or a wind farm) and inland waterway traffic (freight movements along a canal or river).

Coastal shipping is relevant to the movement of bulk commodities such as aggregates and petroleum products, particularly when the origins and destination of the cargo are both at ports (e.g. the movement of petroleum products between refinery and a coastal tank farm). Coastal shipping can also be relevant to the transport of containers between ports.

The narrow-gauge canal network has almost no role in the movement of freight transport because of the small size of the narrow boats, the slow door-to-door transit time and the lack of geographic flexibility. However, other larger-gauge inland waterways are relevant to freight transport: the large-gauge Manchester Ship Canal provides access to Greater Manchester from the Mersey for more economically competitive sea-going vessels, and larger barges operate on the Humber and related canals and the Thames; some of the major river estuaries have inland ports (e.g. a large number of wharves on the Thames) which mainly accommodate cargoes such as aggregates (particularly sea-dredged aggregates).

FAME should seek to simulate the movements of traffic both coastwise and on major inland waterways and particularly for higher value container traffic which could switch from both road and rail. While GBFM v6 was designed to focus on road and rail for domestic traffic, it has also been used to simulate the potential policy impact of measures to promote greater use of inland waterways and coastal shipping for a study on a behalf of the DfT in 2018.

Air

Air freight is a specialist mode of freight transport, mainly for the inter-continental transport of relatively low volumes of very high value or urgent goods and documents. It is much more expensive per tonne than other freight transport modes and is therefore only used where the cargo needs to be transported very quickly (e.g. days rather than weeks between China and the UK).

There is almost no domestic air freight traffic, except for the movement of low weight and 'urgent' post and documents and air freight represents less than 1% of total international freight transported in tonnage terms, with 4% by rail via the Channel Tunnel and 95% by sea via ports.

Air freight is not generally actively modelled except where the relevant commodities are distributed by road (or, in theory) rail to/from airports and therefore have an impact on 'inland' transport networks.

In conclusion, FAME should probably not seek to actively simulate air freight transport, except as the origins and destinations of road (and, in theory rail freight) because it is low volume and is mainly used for inter-continental freight movements rather than intra-European or domestic movements in competition with road or rail.

Pipelines

Pipelines provide a specialist mode of transport for the cost-effective transport of very large volumes of bulk liquids and gases between ports and manufacturing sites, refineries and power stations and, in the case of natural gas, for the distribution of the product from its main sources and final consumers. Pipelines have a very high up-front capital cost, but a very low variable cost per tonne moved. They are only relevant and economic for specific very high volume flows of gases and liquids and are not generally actively modelled except where the relevant commodities are distributed by road or rail to/from storage terminals and therefore have an impact on road and rail networks. The pipeline network is essentially static in terms of its extent, although it is possible that an additional network is required for the transport for hydrogen in the event that the 'hydrogen economy' becomes a reality.

In conclusion, FAME should probably not seek to actively simulate pipeline transport, except as the origins and destinations of road and rail freight; this may need to allow for 'new' origins and destinations to emerge from any development of the hydrogen economy.

Active modes

Cargo-bikes and portering (deliveries on foot) are relevant to final deliveries and collections in the UK's urban areas and have traditionally been used by postal services. However, they are likely to be insignificant in terms of tonnes lifted and tonnes moved compared to road and rail freight and no statistics are available at a national level for active modes, which makes the simulation of the baseline position difficult.

Conclusion on modes

The modes of transport have different strengths and weaknesses but for domestic freight road is competing with rail and, to a lesser extent, coastal shipping. For international freight transport, maritime transport has the highest market share in terms of tonnage, but air freight is used for the transport of very urgent and high value inter-continental cargo and the Channel Tunnel fixed link competes with cross-Channel ferry services for traffic to and from the European continental mainland.

3.6 Freight market structure

Road haulage

There were about 59,000 road freight enterprises at the end of 2020, operating a total of 395,000 registered and taxed HGVs under 69,000 operating licenses.

Some 45% of road freight lifted is transported by vehicles operated by the owners of the goods. Operator licence restrictions prevent these 'own account' operators from conveying goods for other organisations, thereby limiting opportunities for backloads. The other 55% of freight lifted is contracted out to specialist road hauliers and third party logistics operators (public or third party haulage) on a 'hire and reward' basis. Reasons for shippers adopting an out-sourcing strategy for their road haulage requirements include:

- Economies of scale: Larger 3rd party operators can operate more efficiently due to, amongst other factors, managing large distribution centres shared between multiple shippers, more efficient HGV deployment (including greater opportunities to obtain return loads, to operate trucks full in both directions), shared back office costs and the use of sophisticated IT inventory systems;
- Quality: they are perceived as offering a higher quality of service than in-house transport operations as a result of competition to win and retain business;
- Innovation: they can introduce new ideas and working practices, overcoming in-house management inertia, and remove restrictive working practices.

The road freight transport market provides an example of near perfect competition as there are a large number of buyers and sellers operating in the market, road haulage costs are well-understood and there are few barriers to entry, particularly in terms of capital investment and regulation. The average fleet is relatively small, with an average of 5.7 vehicles per operating license at the end of 2020.

In this environment, road haulage operators have to be highly efficient and cost-effective in order to remain profitable. The average return on sales is often reported as being 1-3% in any given year.

One high-profile cost is the wages of HGV drivers, where a combination of an ageing workforce, Covid leading to some (mainly EU national) drivers leaving the UK market and Brexit limiting potential for importing labour from the EU led to short term lack of capacity in 2020-21. It may be beyond the scope of a model framework such as FAME to simulate the HGV driver labour market, but it would be possible to produce such a model in the same way that fleet model seeks to simulate the size and technological composition of the HGV or LGV fleet. The more traditional approach is to assume that driver wages would need to increase to attract more labour into the relevant market and this additional cost would have an impact on modal share and costs borne ultimately by consumers.

Rail freight

The rail freight sector in Great Britain is effectively the only fully privatised part of the railway industry, in that private sector freight operating companies (FOCs) are licensed to operate freight services on the British network and compete for business as traction and wagon providers in an open competitive market at their own commercial risk. Given the higher barriers to entry and the number of players, the rail freight industry is competitive but also tends towards oligopoly.

The demand-side risk (i.e. seeking to fill trains with traffic) is usually taken by ‘aggregators’ of traffic, some of which are large-scale road hauliers. The most notable are Malcolm Group, Russell, Maritime, Culina (Stobart), Freightliner and GB Railfreight, of which only the last two are also FOCs.

Rail freight services are therefore a response to demand, rather than (at least in the short to medium term) operating regardless of the number of passengers carried. There are currently seven competing FOCs which compete for traffic with each other, as well as with road haulage and coastal shipping in some market sectors.

The rail infrastructure providers (principally Network Rail – see following section) supply timetabled freight paths to the FOCs on non-discriminatory terms but on the basis of the operators having ‘grandfather rights’; track access charges are paid to Network Rail for trains that operate. The Office of Rail and Road, the independent regulator, provides impartial oversight in terms of charges and network access, thereby ensuring open competition.

Shippers or their logistics providers may decide to use rail where the freight flow is large enough to justify a regular trainload (and therefore it is worth taking the risk to ‘fill’ the trains) and where the mode can meet the required service levels (e.g. transit time, frequency). If the freight flow is suitable for rail freight and an adequate level of service can be provided by rail, then the key decision-making factor is then cost. Rail is likely to have to be cheaper than road where the shipper is accepting service levels that are lower than could be provided by road.

Unitload shipping services

Container shipping services carrying LOLO containers provide cost effective transport between the UK and the rest of the world and can be categorised as follows:

- Coastal services between two or more UK ports;
- Short sea services between the UK and the rest of North West Europe, Ireland, Scandinavia, the Baltic, the Atlantic coast of Europe and the Mediterranean basin; and

- Deep sea services between the UK and the rest of the world.

RORO services provide frequent maritime transport links between Great Britain and the European continental mainland and Ireland and the overall market is usually split between:

- The GB-Continent market, which is then split further into the Short Straits (between Dover and the Region Hauts-de-France[14]), the North Sea corridor (between GB ports in the Thames to Forth range to the Near Continent, Scandinavia and the Baltic) and the Western Channel (between GB ports in the Newhaven to Plymouth range, to France and Spain).
- The GB-Ireland market, which is then split further between the Northern Corridor (GB ports to Northern Ireland), the Central Corridor (Lancashire and North Wales ports to Dublin) and the Southern Corridor (South West Wales ports to southern Ireland).

Bulk shipping

Bulk shipping provides port-to-port shipping services transporting unpackaged dry bulk cargoes (such as coal, iron, ore, cement and grains) and liquid bulk cargo (such as crude oil, chemicals, liquid natural gas and refined petroleum products). The ships are usually specialised and so transport large volumes of a homogenous cargo between specialised port handling and storage facilities.

Typical flows in the UK might be the transport of refined petroleum products by a petroleum products tanker from a coastal oil refinery to a coastal tank farm (a storage facility for bulk liquid products) or the shipping of cement in a bulk carrier from a port close to a cement production facility to a port for storage and then use in development projects in the surrounding region.

These bulk shipping services are usually provided by the shipping company to a shipper on a single contract (or voyage charter) rather than on a regular scheduled basis, with the contract stipulating the movement of the cargo between two ports for a given contract value.

3.7 Infrastructure used by freight transport

Introduction

The road and rail networks are predominantly publicly owned and managed and freight transport operators generally share use of the infrastructure with passengers. The most important types of privately-owned infrastructure in relation to freight transport are distribution centres, ports and airports. Distribution centres are commercial developments and, although some smaller ports are owned by local authorities and there are a number of ‘trust ports’ such as Dover, Port of Tyne and Milford Haven (which are required to re-invest any financial surpluses), the major UK ports are privately owned following a programme of privatisation in the 1980s and 1990s.

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[14] Formed from a merger of the former regions of Nord Pas de Calais and Picardie, with the new region coming into existence on 1 January 2016.

The road network

The highway network in Great Britain is mainly owned and operated by an arm of the state, with National Highways, Transport Scotland and the Welsh Government owning and operating the strategic highway network in each country and local authorities owning and operating other roads.

The highway network is principally funded from general taxation. The exceptions to this are the direct charges levied to use a number of major estuary crossings such as the Dartford Crossings and the M6 Toll and which are funded either by borrowing or a PFI scheme. There are some private highways in and around ports, airports and logistics parks; these were originally funded and are maintained by the facilities owner, even if the general public can in some circumstances drive on them. National Highways, as a DfT owned company, is subject to economic monitoring by the Office of Rail and Road (ORR).

The Strategic Road Network in England (i.e. defined as that owned and managed by Highways England) consists of about 3,000km of motorways and 4,100km of trunk A roads. While it represents only 2% of the total road network, it accommodates a large proportion of total HGV tonne kilometres because a high proportion of freight traffic is strategic in nature and moving over long distances.

Distribution centres

Within the general cargo and consumer goods sectors, the 'hub' of most logistics operations is the distribution centre and these have tended to be located on greenfield sites close to, or with easy access to, the strategic road network to increase the efficiency of road-based distribution operations and avoid conflicts with local residents. There have traditionally been two types of distribution centre (DC):

- National Distribution Centres (NDCs): these act as inventory holding points for imported and nationally sourced goods, before re-distribution to subsequent stages in the supply chain. Average dwell time varies considerably but may average 4–6 weeks. They are termed 'national' because they serve the whole of Great Britain (and often Ireland) from the one site and are normally associated with manufacturers, with suppliers to retailers such as importers of electrical goods, beers/wines/spirits or clothing and major retailers. NDCs have traditionally been located in the Midlands, as they are centrally located to serve domestic suppliers, ports and Regional Distribution Centres, thereby minimising overall road transport costs. Outbound flows were typically to Regional Distribution Centres or retail outlets, although direct deliveries to homes are becoming increasingly important due to the increasing levels of e-commerce.
- Regional Distribution Centres (RDCs): these receive goods from NDCs or direct from suppliers, before re-distributing the goods to retail outlets and, increasingly, direct to homes. They have a regional hinterland and are normally associated with retailers which receive inbound goods from suppliers and their own NDCs before consolidation into loads for individual retail outlets throughout the region. Dwell times are much shorter; perishable and time sensitive goods will be

redistributed within 24 hours without passing through pallet racking systems and with a simple transfer between vehicles (a process called 'cross docking').

With the increasing importance of e-commerce, there is now a third category which is the e-commerce fulfilment centre which has a regional focus and with HGVs inbound and then LGVs outbound to make ‘last mile’ deliveries.

There is a concentration of distribution centres (mainly NDCs) in the so-called logistics ‘Golden Triangle’ located, in general terms, in the East and West Midlands and South Yorkshire, but there are also significant concentrations located within or close to the major British conurbations.

The concentrations of distribution centres in different regions reflects their competitiveness in terms of total transport costs for inbound and outbound cargo, land values and the cost of labour. The Midlands and southern parts of the North of England tend to be the most favoured areas for NDCs because these areas minimise the overall costs when goods have to be received from both overseas and around Britain and then distributed to all other British regions.

The provision of warehousing is a purely commercial function undertaken by commercial property developers, often in association with pension/investment funds, although some commercial property developers such as Goodman and Pro Logis are also investment funds in their own right. Developers identify and acquire sites, design and build the distribution centre units, which are then let to long-term occupiers. The consequent annual rental payments represent the developer’s investment return, or alternatively the completed and occupied unit may then be sold to a pension/investment fund (sale proceeds minus development costs representing the developer’s return).

Warehousing is therefore the key fixed infrastructure required by (and used by) the general cargo/consumer freight sector, even if they are delivered and funded by long term private sector investment. They are therefore commercial investments intended to make a financial return for the investor. As with all commercial investments, the decision on whether to proceed will take into account the capital costs alongside future revenue streams, the likely payback time and overall financial return.

However, delivery of distribution space is ultimately reliant on the planning system; land needs to be allocated through Local Plans and consents granted at commercially attractive, locations. These are generally close to strategic transport routes, to the markets to be served and to a labour supply. Conflicts often emerge, with many sites that could be competitive geographically.

Rail infrastructure

The vast majority of the British rail network is owned and operated by Network Rail. Network Rail is a public sector body directly owned by the Department for Transport, however it is subject to independent economic and safety regulation by the Office of Rail and Road (ORR). Its revenue comes from three main sources, namely track access charges paid by the passenger and freight operators for using the network, a direct grant from the DfT and property/rental income. The two principal track networks not owned by Network Rail are HS1 and the Channel Tunnel, both of which are operated under private sector concessions.

Some 92% of the network is shared by freight and passenger trains and where there is congestion on the network this can lead to a lack of capacity for new rail freight services. As rail freight services are provided in response to demand, rather than being timetabled in advance of demand as is the case for passenger services, timetabling of additional passenger services can lead to a reduction of capacity for freight on the network.

Rail freight terminals

Rail freight terminals are needed to allow the transfer of cargo between rail and, in particular, road transport. As per rail freight services there are two types of rail freight terminal, namely:

- Bulk terminals; and
- Intermodal rail freight terminals and Strategic Rail Freight interchanges (SRFIs).

Bulk rail terminals are normally located on private sidings that are either owned or leased on a long-term basis, by the shippers and receivers of the cargo. The terminals are used for the transfer of bulk commodities to and from rail where rail is most likely to be the most cost effective mode of transport for long distance transport (e.g. for the transport of stone between quarries and major cities for construction projects or for the transport of iron ore from a port to a steelworks). The loading and discharge equipment will have been funded by the cargo shipper and/or receiver. Such facilities therefore rely on significant long term investments from the private sector in the loading/discharge equipment at the private sidings.

Intermodal rail freight terminals are designed to transfer container units between rail and road, and they generally consist of sidings to accommodate trains, special cranes for loading and unloading the units and space for storage. There are existing terminals at the main deep sea container ports as well as some short sea container ports (principally investments by the ports themselves) and in the British regions with major population centres (i.e. Greater Manchester, West Yorkshire, Liverpool, the West Midlands, Bristol, London, South Yorkshire and the Central Belt of Scotland). Most of these terminals, which were originally developed by British Rail in the 1960s and 1970s, have no distribution centres located on the same site.

Rail freight can offer very competitive transport solutions, when compared with road transport, even over short distances of 100km or less. However, two conditions are required to render such flows competitive:

- The ability to move the product directly between two rail-served facilities i.e. without the requirement to use road transport for part of the end-end journey; and

- The ability to move large quantities in one move on a frequent and regular basis to provide the sufficient volume of traffic to fill a full-length train and provide efficient use of assets.

Where one end of the supply chain is not rail-served, there is a consequent need to use road transport to complete the trip (i.e. to move the cargo from shipper to a rail terminal or from a rail terminal to the final customer) and this introduces additional costs compared with one where both ends are rail-served (handling costs and road haulage). Under this operating scenario, the break-even distance (with road transport) increases to around 250km. Where neither end of the transport chain is rail-served and road transport is required at both ends, this distance rises to around 400km. This explains why intermodal container trains from Southampton or Felixstowe will serve destinations from the Midlands northwards (final trip to the end-user generally being by road), with inland destinations in the South East being served by road transport.

Strategic Rail Freight Interchanges (SRFIs)

In the intermodal sector, therefore, the key factor in attracting traffic away from road transport, particularly over distances less than 250km, is the development of large-scale distribution centre capacity at sites with intermodal rail terminals. In planning terms, these are called Strategic Rail Freight Interchanges (SRFIs). When large distribution centres are located on rail-served sites, rail is able to offer significant cost advantages over road transport and the concentration of large-scale distribution centres on a single site also generates the requisite volumes of cargo to fill a full-length train.

SRFIs are large developments (over 60 hectares) of modern large-scale distribution centres co-located on the same site as an intermodal terminal, serving the on-site distribution centres and the wider region. They need to be located on main lines with a loading gauge that can accommodate cost-effective intermodal trains and be located close to the strategic highway network and close to major urban conurbations; the latter provides both consumers for the cargo passing through them and a local source of labour. Suitable sites for SRFIs are very limited and are often located in the greenbelt. Their development also relies on train paths being available on the network and terminals being available at SRFIs; however, freight services struggle to secure capacity on the network in some locations in competition with passenger services and the planning system has also found it difficult to provide SRFI capacity in key locations such as the South East. Given the above, the Government has attempted to promote their development by classifying them as Nationally Significant Infrastructure Projects (NSIP) and including them in the National Planning Statement for National Networks policy statement.

As for stand-alone distribution centres, SRFIs are funded by commercial property developers on a commercial basis and are essential to securing a shift of traffic from road to rail over medium- to long-distances. The relatively large distribution sites required by SRFIs generate a critical mass of rail freight traffic for the economic operation of rail freight services and also reduce operational costs for the operators of distribution centres. They are therefore key fixed infrastructure assets that are delivered and funded) by long term private sector investment that is intended to provide a financial return for the investor.

However, delivery is ultimately reliant on the planning system; land needs to be allocated through Local Plans and consents need to be granted at the commercially attractive locations. These are generally close to strategic transport routes, markets to be served and a labour supply. Conflicts therefore often emerge as they are not always popular with local residents and politicians, with many geographically competitive sites being located in the greenbelt or competing with proposed residential developments.

Ports

Ports in the UK fall into one of three categories, namely:

- Privately owned ports – usually by large publicly quoted companies, investment funds or multi-national port owning organisations;
- Trust ports – owned by an independent statutory body; and
- Municipal ports – owned by a local authority.

Most of the largest ports (in terms of traffic handled) are privately owned or operated by Associated British Ports, Forth Ports, Peel Ports, PD Ports, Hutchison and DP World, while smaller ports tend to be Trust or Municipal. The notable exceptions are the larger ports of Dover, the Port of Tyne, London and Milford Haven (all trust ports) and Portsmouth (a municipally-owned port).

Irrespective of ownership, ports generally have two key functions, namely:

- Commercial – generating revenue from berthing vessels, handling cargo and renting land/facilities; and
- Conservancy – the safe movement of shipping within their respective ports.

There are a number of examples, however, where the (trust) port authority only has a conservancy role, with the cargo handling facilities contained within them being owned by private companies. These ports, all of which have trust port status, include Harwich Haven Port Authority (providing conservancy for the estuary upon which the ports of Felixstowe, Harwich and Ipswich are located) and the Port of London. All ports, regardless of ownership, are operated on purely commercial terms without any Government or state support. Revenue must cover costs and investment in infrastructure (see below) has to be funded on commercial terms. In that respect, ports operate in an open market, competing with each other for traffics and are able to charge whatever the market will bear.

There are broadly three types of port infrastructure, namely:

- Liquid or dry bulk – jetties or quays and associated discharge/loading equipment, often associated with a nearby production facility such as an oil refinery or steelworks.

- Unit load/unitised traffic – roll-on roll-off (RORO) ferry berths and Lift-on Lift-off (LOLO) quays plus associated craneage; and
- Semi-bulk /general cargo quays plus associated loading/discharge equipment e.g. for the specialised handling of steel and forest products

Overall, and on a similar basis to distribution centres and SRFIs, ports are key fixed infrastructure assets that are delivered through long term private sector investment. As with all commercial investments, the decision on whether to proceed will take into account the capital costs alongside future revenue streams, the likely payback time and overall financial return. Securing traffic on long term contracts are therefore important for ports as they will effectively help to secure funding for investment. Again, delivery is ultimately reliant on the planning system; land needs to be allocated through Local Plans and consents need to be granted.

FAME could seek to measure port capacity for each port facility on a terminal by terminal basis; MDST has developed such a methodology for its GB Ports Supply and Demand Model, which was used for the DfT about 17 years ago to develop port traffic demand forecasts to assess whether there was a case for further port terminal investment. Any such assessments for the DfT could, if published, lead to challenge from the private port companies if these judgments were perceived as having an impact on shareholder value.

Airports

The most important airports for handling freight – London Heathrow, East Midlands, London Stansted, London Gatwick and Manchester - are either privately owned or operated on a commercial basis.

Unlike ports, much of the infrastructure at airports is designed to meet passenger demand; however, specialist air cargo distribution centres are required by air freight forwarders for the sorting and consolidation of air freight into air container loads and these may be located in the vicinity of the airports rather than actually within the airport itself. Otherwise, airport infrastructure is developed on a commercial basis, with delivery reliant on the planning system when additional land is required.

Waterborne freight network

The UK has an indented coastline, with deep water access to its major estuarial ports and wharves on the Forth, Tees, Tyne, Humber, Harwich Haven and Thames on the east coast, the Solent on the south coast and on the Severn estuary, Milford Haven, Mersey and Clyde on the west coast. Many of these sea ports are privately-owned since a round of privatisations in the 1980s and 1990s.

Short sea and coastal shipping movements along these major estuaries are recorded as inland waterway movements for statistical purposes and there are also numerous (mainly privately owned) wharves on major rivers, such as the Rivers Thames, Humber, Hull and Trent. Significant movements of freight on man-made canals are currently limited to traffic to and from wharves on the Manchester Ship Canal.

There are a large number of wharves on the Thames which could be safeguarded through the planning system against, in particular, residential development so they are available in the future for the loading and unloading of cargo.

As for ports, formal assessments of freight capacity at wharves would be subject to scrutiny from the interested private sector operators.

Network capacity constraints

The modelling of freight capacity constraints or pinchpoints requires a measure of demand (an essential output from a freight transport model), an assessment of the capacity of the links or nodes and, for road and rail networks, passenger demand. For this reason freight transport models, including GBFM v6.2, often focus on freight and provide outputs that are then used as inputs to another model which contains measures of overall capacity by link and node and also passenger demand. MDST itself has developed a Rail Capacity Model for the GB rail network, so that freight (and passenger) demand can be assessed against available capacity at a strategic level; MDST also regularly provides outputs from GBFM v6.2 as an input to highways models that have been built using software such as PTV Visum and SATURN.

Any capacity constraints in the rail network lead to a switch to greater use of road freight services because a regulated timetable will not allow additional rail freight services to run and there is therefore suppression of demand for rail freight; this is reflected in the work MDST has carried out for DfT on HS2 using the Rail Capacity Model. A lack of capacity on the highways network, on the other hand, leads to slower journey times which result in higher generalised costs and therefore some switch from road to rail.

The economic impact of these delays and congestion due to pinchpoints and lack of capacity can be measured through calculations of the change in user (industry) costs and non-user (external) costs of each mode of transport and this is the approach that is taken in GBFM v6.2. As a general rule, the value of the cargo is not relevant to a freight transport model, but there is an argument that for some very urgent cargo the impact of the delay is very important either because:

- The cargo is of intrinsic value: an example is a perishable commodity which has a finite shelf life;
- The delay has a direct and very severe economic impact: an example would be where a delay to a consignment of parts leads to the full closure of an assembly plant.

The difficulty for the development of the FAME framework would be that it is difficult to adopt a generalised approach to the value of the cargo when too little is known about the urgency/importance of individual consignments and the commodity data available is likely to be highly aggregated.

4 STATE OF THE ART & THE FREIGHT TRANSPORT MARKET: SUMMARY OF ISSUES

4.1 The key issues

Examination of continental, national and regional freight modelling over the last 20 years suggests that, while the approach to domestic demand has been relatively straightforward, there has been limited progress in linking such exercises with either capacity or appraisal and with the dynamics of international trade.

Freight demand is handled almost entirely by the private sector using both mobile assets (trucks, trains, ships and planes) and fixed infrastructure assets such as warehousing, port and rail terminals. The private sector's main interest in terms of the capacity of its own infrastructure is in ensuring that demand will exceed the extra capacity they plan to introduce. It will have the opposite concern with respect to public sector road and rail network capacity.

A major challenge facing public sector decision makers has been that road and rail networks are shared with passengers (who dominate the demand for road and rail track capacity) and private sector investment decisions (e.g. on warehousing location) often appear to be in conflict with public sector network interests (the role of highways authorities in assessing planning applications).

It is the interaction of private sector cost structures (the basis for modelling how freight is moved) and public sector networks that will dictate how the private sector invests and thence the flow of freight across the networks. Only by being able to model these interactions can the impact of a given intervention or policy be determined in terms of public interest value (the basis of WebTAG), private sector reaction or tax or toll revenues .

Private sector reaction will include decisions on port investment, warehouse location and modal choice which themselves affect the geography of freight flows.

A number of specific competition issues arise with respect to how these manifest themselves in practice. For example, some private sector actors will contract between each other in such a way as to develop 'private' networks which are not 'open access'. A shipping line may contract for an intermodal train service that is not available to its competitors. Warehousing and storage facilities are invested in for strategic advantage. These need to be appreciated and allowed for in the way models are designed (however imperfectly). It would otherwise be difficult to gain the confidence of private sector organizations and their associations in buying into the conclusions and interpretation of modelling exercises.

MDS Transmodal has developed rail capacity modelling (which lies outside of GBFM but uses its outputs) which has been employed by the DfT, Network Rail and some sub national transport bodies. Rail capacity can be determined in absolute terms in defining junctions as 'full'. Appraisal can therefore be conducted by determining the user costs of there being inadequate capacity to move goods by rail, which can potentially raise both user and non-user costs due the cargo switching to road.

By contrast, the right of any user to enter the road network (however congested) means that conventional transport modelling involves volume sensitive speed-flow curve analysis to determine the impact of more traffic on existing road users. In practice, a reasonable estimate of the user costs of changes in road freight (by volume or routing) can be made by taking account of the existing performance of the network (i.e. mean speeds by leg) because those volume changes will be small relative to total traffic on the road network. Non-user (congestion) costs can be estimated by examining current mean speeds by leg and employing some generic assumptions with respect to where each leg is in the speed flow relationship.

Over a quarter of all freight moved across the domestic network has passed through a port so that appreciating the impact of international flows on demand is important. In so far as international freight flows are concerned, over the longer term these have changed quite significantly and have not grown at a steady rate. A period of 'globalization' peaking some 17-20 years ago was followed (at least for the UK) by a period of relative stagnation; UK port throughputs peaked around 16 years ago. Our experience has been that this demand is best modelled globally at a country x commodity level.

Similarly, shipping networks and therefore the location of entry points into Great Britain need to be seen at a global level because the suppliers of those networks operate at, at least a European, if not global level. For example, one of the major European ferry operators now provides RORO services between the Iberian Peninsula and Great Britain by transhipment in Ireland while only around half of all deep-sea container services to North West Europe now also call at a UK port.

The interaction of these networks and port assets will dictate how and where freight traffic arrives in Great Britain.

The objective of a modelling exercise will be to provide credible outputs to a wide range of interested parties, including highway and rail network authorities, ports and freight transport companies and their associations.

4.2 Comparison between FAME and GBFM v5 and v6.2

In an attempt to assess the extent of the ambition with FAME (and therefore the inherent risks of its full-scale implementation), Table 1 provides a summary of a comparison between FAME (as set out in the Terms of Reference for this study and with a focus on its core functionality as described for the 'National Freight Transport Model') and GBFM v5 (which the DfT already has a free licence to use) and GBFM v6.2 (as the most recent version of the most widely used freight transport model in the UK).

Table 1: Summary of features of GBFM v5, v6.2 & FAME

Feature of model(s)	GBFM v5	GBFM v6.2	FAME (based on Terms of Reference)
Geographic scope in UK	Intra GB NI <-> GB	Intra GB NI <-> GB	Intra GB & intra-NI NI <-> GB NI <-> ROI
Number of zones	2,600 zones	7,183 (MSOA), but focused on England	To be decided
Estimated model run time on typical reasonably powerful PC	1.5 hours	5 hours	Objective of 3 hours, but will inevitably vary depending on the scenario to be modelled
Modes	Road, rail, short sea unitload shipping/ports	Road, rail, short sea unitload shipping/ports,	Road, rail, maritime, unitload, waterborne freight, air
Road freight	HGVs only, with 5 different sizes	HGVs (only one size) & LGVs	HGVs of various sizes & LGVs
Road freight technology	Diesel	Diesel, electric, hydrogen	Diesel and zero emission vehicles
Units of freight	Tonnes, units, trains	Tonnes, units, trains	Tonnes, units, trains
Largescale warehouses	Not included	Tonnage linked to warehouses	Warehouses to be included
Ports & Channel Tunnel	Tonnage/units linked to individual ports	Tonnage/units linked to individual ports	Ports to be included
Time period	Annual, but can be disaggregated using factors	Annual, but can be disaggregated using factors	Seasonality mentioned, which suggests that annual not sufficient
Time horizon	Annual, but to any reasonable future year	Flexible, but to any reasonable future year	"Near future" (over next 15 months) & 2063 (40 years)
User & non-user costs for appraisal	Yes	Yes	Yes
Assignments to road & rail networks	Yes for road, no for rail	Yes for both road and rail, but requires 'manual' interventions for rail	Yes
Traffic by short sea unitload port	Yes	Yes	Yes
'Scenario studio' (to be further defined)	No	No	Yes
Non-modelling tools (to be further defined)	No	No	Yes

Feature of model(s)	GBFM v5	GBFM v6.2	FAME (based on Terms of Reference)
Infrastructure capacity	No	No for road, yes for rail & unitload ports	Capacities at ports and on rail, HGV parking/roadside services locations
Road fleets	No	No	UK registered, foreign, temperature controlled, non-temperature controlled

The overall conclusion from this analysis is that, while GBFM v6.2 could be enhanced in some areas (e.g. ensuring that Scotland, Wales and Northern Ireland have the same zoning scheme as in England and also modelling flows in Northern Ireland on the same basis as in Great Britain), the core elements of the National Freight Transport Model component of FAME as a 4 stage transport model would essentially duplicate many elements of the core functionality of GBFM v6.2.

Additional elements of the National Freight Transport Model, such as incorporating network capacity and demand for all modes will make the core model more complex and therefore more risky. The wider FAME, as described in the Terms of Reference for this study, would offer a more 'controlled' environment for a large organisation like the DfT to organise input assumptions and re-use scenarios (via what the Terms of Reference call the 'Scenario Studio'), as well as provide the opportunity for additional non-modelling tools to be developed and deployed.

5 OBJECTIVES FOR & USERS OF THE FAME

The DfT's overall objective in seeking to develop FAME is to increase its internal collaboration and capabilities in multi-modal freight analysis and scenario developments to enable a better understanding of freight demand, movements, forecasts, and its impacts on transport networks, the environment, the economy and transport users.

Based on our interpretation of this overall objective and subsequent discussions with DfT, we have inferred that FAME needs to enable the DfT to:

- Store and analyse freight data in a consistent way, while making it accessible to a wide range of Government staff;
- Run "what if?" scenarios related to freight transport using a state-of-the art freight transport model (sometimes to have results available quickly to address urgent policy questions);
- Have access to the results of "what if?" scenarios which have previously been run;
- Manage input assumptions to scenarios;
- Summarise and visualise the results of scenarios via a dashboard;
- Carry out appraisal of the potential benefits to the freight industry from new infrastructure;
- Ensure that officials from across the devolved administrations are able to access and use FAME.

The needs of different types of user, including representatives of the freight transport industry, are summarised in Table 2 below.

Table 2: FAME- key needs by type of user

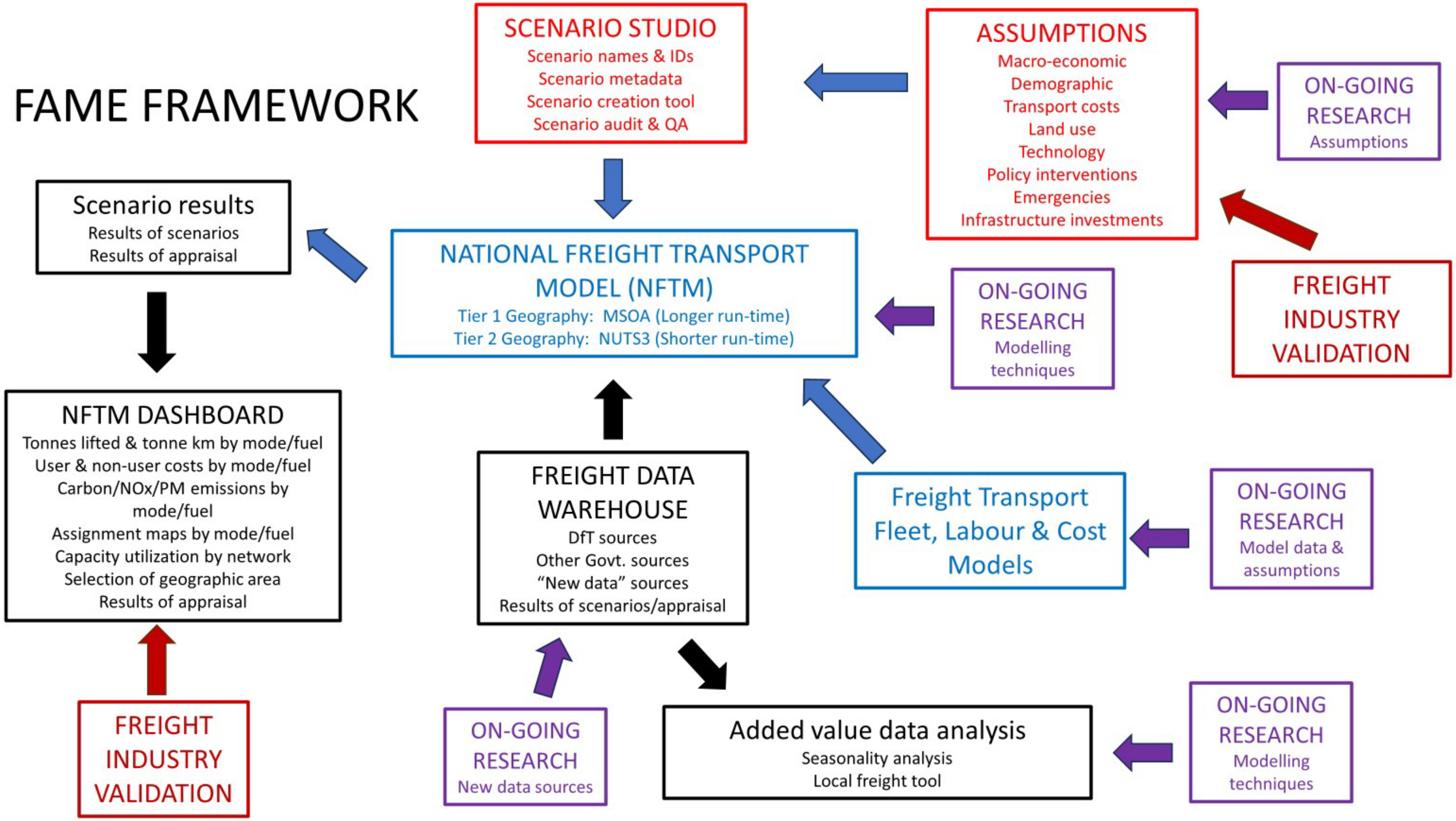
Type of user	Key needs
Government policy makers	Translate potential measures into quantified scenarios Test and analyse the impact of potential measures on the freight market
Government economists & analysts	Test and analyse the impact of potential measures on the freight market Examine historic trends in freight transport data
Government transport modellers	Test and analyse the impact of potential measures on the freight market Carry out quantitative appraisal of potential transport infrastructure schemes
Government statisticians	Store official data in an accessible way to facilitate the work of economists, analysts & policy makers Enable economists, analysts & policy makers to use official data effectively
Freight industry	Feel confident that the assumptions that are used to inform the work of the DfT are realistic Feel confident that the high level results that emerge from the modelling of key scenarios are realistic

6 SUMMARY OF THE FAME FRAMEWORK

6.1 Introduction

The proposed framework, which is designed to meet the objectives and user needs set out in section 5 above, is summarised in the following flow diagram (Figure 1) and this framework revolves around a National Freight Transport Model (NFTM). The framework allows for inputs from on-going research activities and also for validation by the freight industry.

Figure 1: The FAME Framework



6.2 Description of elements of FAME Framework

National Freight Transport Model (NFTM)

The NFTM (shown in blue in the flow diagram) would consist of a core 4-stage freight transport demand model, with additional sub-models. The sub-models would provide inputs on:

- The HGV/LGV fleets;
- The HGV/LGV driver market;
- Transport costs for each mode of freight transport, type of vehicle and fuel type.

The model would have two tiers of geographic zoning to reflect the needs of different users:

- Tier 1: full-scale runs with the detailed geographic zoning system (with a longer run-time);
- Tier 2: 'concise' runs using a more aggregated zoning system when quick answers are needed to respond to more urgent questions (with a shorter run-time).

A programme of on-going research would be introduced to improve, where necessary, the modelling techniques and to update the baseline sub-models.

Runs of "what if?" scenarios using the NFTM would only be carried out based on scenarios that have been created within the Scenario Studio.

Scenario Studio

The Scenario Studio (shown in red in the flow diagram) would provide access to assumptions and parameters from previous scenarios that have already been run (and therefore already subject to Quality Assurance processes) and provides the ability to generate further scenarios within certain pre-defined parameters. The available parameters and potential scenarios are informed by assumptions on a wide range of factors that can be changed and therefore allow new scenarios to be tested and a comparison made with the base case. These factors, which may include forecasts for future years, would be as follows:

- Macro-economic indicators;
- Demography;
- Freight transport costs by mode, type of vehicle and fuel type (with baseline costs linked to the relevant sub-models);
- Land use (e.g. warehouses);
- Technology (e.g. diesel, battery electric, hydrogen propulsion);
- Policy interventions (e.g. road pricing, change in tax on diesel);
- Emergencies (e.g. severe congestion at a major port);
- Infrastructure developments (e.g. addition of new road link).

A programme of on-going research would be introduced to consider potential assumptions for future years that can be used in scenarios. These assumptions could be validated by representatives from the freight industry.

Any existing or new scenario would have a unique identifier and would be given a name to summarise its purpose, with a list of assumptions and metadata to describe what the assumptions are related to.

The input scenarios would, generally, be subject to QA before they are tested using the NFTM, although built in parameters would be designed to prevent testing of completely unrealistic scenarios.

Key users: DfT transport modellers, economists and analysts, often with direct input from policy specialists.

Freight Data Warehouse

The Freight Data Warehouse (shown in green in the flow diagram, along with other non-modelling tools) would be a repository of relevant freight data and also of detailed data outputs of scenarios from the NFTM. It would therefore include all of DfT's official freight statistics, as well as any other relevant data from external sources, in a format that makes them accessible for use and further analysis without any use of the NFTM. This data would also provide inputs to the NFTM for the development of origin-destination matrices and traffic generation.

The Freight Data Warehouse would store the results of scenarios run by the NFTM so that they are available to users for further analysis.

Data from the Freight Data Warehouse can be further disaggregated by means of Value Added Data Analysis, such as to break down data from the modelled scenarios by season, time of day and very detailed (local) geography.

A programme of on-going research could be developed to investigate and develop potential new sources of freight transport data for inclusion in the Freight Data Warehouse and to enhance the techniques used for Value Added Data Analysis.

Key users: DfT statisticians, economists, analysts and transport modellers.

NFTM Dashboard

A dashboard (shown in green in the flow diagram) would provide visual summaries of the results of scenarios compared to the base case which could be used as a sense check of results by modellers, analysts, policy specialists and economists and could also be shown to senior civil servants and ministers as high-level summaries of results.

The results presented would include changes in freight transport required (tonnes lifted and moved by mode, type of vehicle and fuel type) and in terms of user and non-user costs, as well as carbon emitted and other environmental emissions. The NFTM Dashboard would also include assignment maps to help visualise changes in flows on transport networks at varying levels of geographic detail so that change can be seen at both the UK level and at more regional and local levels. The NFTM Dashboard would also, where a scenario was testing the impact of a new infrastructure scheme, provide the results of appraisal in terms of the net present value of benefits.

The NFTM Dashboard would also allow the results of key scenarios of long term policy significance to be validated by representatives of the freight industry.

Key users: *all users, including policy specialists, senior civil servants, ministers and representatives of the freight industry.*

7 NATIONAL FREIGHT TRANSPORT MODEL: SCOPE

7.1 Introduction to the scope of the NFTM

When designing a model such as the NFTM, it is important to understand what the users would want to achieve, which is likely to include:

- What functionality the model should have and what modelled responses should be expected given specific inputs;
- What scenarios are users likely to want to run.

Constraints such as acceptable model run-times and the capability of the computers used to run it also have an impact on design.

In addition, the need to have a road network capacity-based feedback where road costs increase with increased congestion (as specified in the Terms of Reference for FAME) would take longer to run than a scenario without any consideration of congestion.

A reasonably powerful multi-core desktop personal computer would be required and DfT have indicated that a 5 Core Xeon CPU 2.3GHz computer with 64 GB of RAM would be available for use with FAME.

7.2 Definition of 'freight' transport

Freight transport can be defined as the carriage of goods between an origin and a destination for commercial reasons because goods available at one geographical location are required at another location for processing, sorting or consumption. This definition therefore excludes some movements of commercial vehicles – principally light goods vehicles (LGVs) which are being used to carry out services (e.g. photocopier repair services) or for passenger trips (e.g. going the supermarket) – from the scope of FAME.

Passenger cars are not included within FAME. Therefore there is a need for an external source of car movements and an external road traffic assignment model in order to represent congestion. All journey purposes for vans (LGVs) would also need to be included for such a road assignment. Freight-carrying vans would naturally sit within FAME. However other journey purposes are not related to freight and would naturally sit outside of FAME. These could be modelled as an extension to passenger modelling, particularly for van movements carrying passengers. Those van movements associated with carrying out services could be modelled separately. Failing that, a simple but unsatisfactory approach could be to represent them separately in the base year (based on a van survey) and then apply a modelled response based on the average of the model representing freight-carrying vans and the passenger model.

Recommendation: The FAME should focus on the movement of goods and therefore exclude the movement of commercial vehicles for other purposes such as servicing and passenger trips.

Freight transport can generally be categorised by its:

- Origin or destination, with a particularly important distinction being between domestic transport (i.e. within the UK) and international freight between the UK and other countries, whether the European Union or with non-EU countries;
- Mode of appearance (principally bulk or non-bulk for land-based transport);
- Mode of transport (road, rail, inland waterway, coastal shipping, air, pipeline etc.)

The FAME needs to be able to take a holistic view of freight being moved by volume (tonnes) within, to, from and through the whole of the UK and then break the aggregate volume of freight down by geography, mode of appearance and mode of transport.

Recommendation: The FAME should be holistic in its scope to cover the movement of all goods by volume (tonnes) that is to, from, within and through the relevant geography.

The above recommendation does not, however, mean that all modes need to be treated in the same way and given exactly the same level of attention because of their relative importance and in order to not unnecessarily increase the complexity of the freight model.

7.3 Modes of freight transport

In terms of mode of transport, a priority order of modes (most important first) from a modelling point of view for inclusion in FAME would be as follows:

1. Heavy Goods Vehicles (HGVs) carrying cargo and their empty returns: freight transported by road in HGVs is by far the most important mode of domestic freight transport as (ignoring pipelines) it accounts for about 77% of tonnes moved (tonne kms) and 89% of tonnes lifted. Within FAME there needs to be provision for the translation of tonnes transported into HGV units as these are the units at define transport costs and capacity required.

2. Movements of trains carrying cargo and their empty returns: Rail freight is the most important inland mode of freight transport to secure modal switch away from road freight, while also providing an opportunity to reduce transport costs. Significant attention needs therefore to be paid to the simulation of the economics of this mode, particularly in relation to the movement of intermodal traffic to and from both ports and rail connected distribution parks (or Strategic Rail Freight Interchanges, SRFIs). Within FAME there needs to be provision for the translation of tonnes transported into trains as these are the units at define costs and capacity required.

3. Shipping movements: Maritime freight transport via sea ports is essential for connections with Northern Ireland, and to trade with the European continental mainland, Ireland and the rest of the world. A wide variety of modes of appearance are used to transport goods by sea (i.e. the mode of transport as it 'appears', and is handled, at the port), from container ships and roll-on roll-off ferries carrying high value consumer goods, to bulk carriers transporting petroleum products, crude oil, grain, biomass, bulk steel and a wide variety of other goods.

4. Light Goods Vehicles (LGVs) carrying freight and their associated empty movements: An important element of road freight transport in terms of observed vehicle movements on the highways network, even if tonnes lifted are less significant than for HGVs.

5. Freight on inland waterways: The narrow-gauge canal network has almost no role in the movement of freight transport because of the small size of the narrow boats, the slow door-to-door transit time and the lack of geographic flexibility. However, other larger-gauge inland waterways are relevant to freight transport, such as the large-gauge Manchester Ship Canal and larger barges operate on the Humber and related canals and the Thames. In addition, some of the major river estuaries have inland ports (e.g. a large number of wharves on the Thames) which mainly accommodate cargoes such as aggregates (particularly sea-dredged aggregates). FAME should seek to simulate the movements of traffic on these major inland waterways.

6. Air freight: This mode represents less than 1% of total international freight transported in tonnage terms, although it is more important by value. Domestic tonnages are very low. Air freight is not generally actively modelled except where the relevant commodities are distributed by road to/from airports and therefore have an impact on 'inland' transport networks. FAME should not seek to actively simulate air freight transport, except as the origins and destinations of road freight because it is low volume and is mainly used for inter-continental freight movements rather than intra-European or domestic movements in competition with road or rail.

7. Pipelines: This is a specialist mode for the cost-effective transport of very large volumes of bulk liquids and gases between ports and manufacturing sites, refineries and power stations and, in the case of natural gas, for the distribution of the product from its main sources and final consumers. They are not generally actively modelled except where the relevant commodities are distributed by road or rail to/from storage terminals and therefore have an impact on road and rail networks. FAME should therefore not seek to actively simulate pipeline transport, except as the origins and destinations of road and rail freight; this may need to allow for 'new' origins and destinations to emerge from any development of the hydrogen economy.

8. Cargo bikes: Cargo-bikes are relevant to final deliveries and collections in the UK's urban areas and have traditionally been used by postal services. However, they are likely to be insignificant in terms of tonnes lifted and tonnes moved compared to road and rail freight and no statistics are available at a national level for active modes, which makes the simulation of the baseline position difficult.

9. Portering (i.e. walking to carry out urban deliveries): This mode is relevant to final deliveries and collections in the UK's urban areas and has traditionally been used by postal services. However, it is likely to be insignificant in terms of tonnes lifted and tonnes moved compared to road and rail freight and no statistics are available at a national level for active modes, which makes the simulation of the baseline position difficult.

10. Drones: These encompass relatively innovative means to move goods, such as unmanned aerial vehicles (UAVs) and robots making deliveries at street level. They are focused on making last mile deliveries, often using zero emission and digital technologies while minimising labour costs. While generating significant publicity, drones are unlikely to be significant in terms of tonnes lifted and tonnes moved compared to road and rail freight and no statistics are available at a national level, which makes the simulation of the baseline position difficult.

HGVs often act independently of other modes, but most other modes are dependent on road for local hauls. Rail is dependent on HGVs for local hauls between rail terminals and freight original origins and final destinations, unless the terminals are located on site at the port, warehouse or industrial site. Shipping is normally dependent on road or rail for inland delivery. Air is likewise dependent on HGVs or vans. This means that many transport chains are intermodal and rely on co-operation between modes.

The more modes and vehicle types that are included in the model, the more complicated it becomes – both to design and build, and to interpret the results. The complexity of modelling deep sea (inter-continental) as well as short sea (intra-continental) shipping movements, for example, are considered later in this report.

However, modelling approaches that start with a single mode are unsatisfactory; it is important to start with the freight itself, just as one would start with a passenger facing a range of complex and simple options to satisfy a given journey requirement.

The geographic detail of FAME is considered further below, but active modes and drones are considered to be too focused on last mile movements in urban areas to be actively modelled within the NFTM itself. Modelling approaches could be developed as Value Added Data or non-modelling tools, particularly as they are most appropriately analysed or modelled at a local level.

<u>Recommendation:</u> The FAME should be multimodal (to allow competition between modes) and intermodal (to allow, where appropriate, cooperation mainly between road and other modes). It should actively model road (HGVs and LGVs), rail, shipping and inland waterway freight transport and also model air freight and pipeline traffic at the point at which it generates road and rail movements.

7.4 Geographic scope

Great Britain (GB, made up of England, Wales and Scotland) is a naturally bounded island and therefore works well as the main area of interest for a model, within which transport will be principally by road and rail and mainly conducted by vehicles registered in GB. Connections to Continental Europe, the island of Ireland (both Northern Ireland, NI, and the Republic), and the rest of the world enable freight to arrive and depart through ports and the Channel Tunnel. There are several data sources that are at the GB level (e.g. Network Rail data), which makes it simpler to populate a model with data.

However if FAME is to represent the UK, trips within NI and between NI and the Republic of Ireland must be included as well as trips between GB and NI. There is dynamic competition between ferry services between GB and both the Continent and the island of Ireland. FAME should, therefore, represent this competition so that scenarios affecting these shipping routes can be modelled.

There is also similar competition in the inter-continental (deep-sea) shipping market to serve the UK. This competition could also be represented in the model, although that is a more complex market to represent.

There are various islands that are either part of or associated with the UK such as:

- Anglesey
- Skye
- Other Western Isles
- Northern Isles (Orkney and Shetland Islands)
- Isle of Wight
- Isle of Man
- Channel Islands

Islands such as Anglesey and Skye that are connected by road can be considered effectively part of the mainland. Nearby small islands that have frequent short-distance ferry services connecting to one mainland port can also be considered part of the mainland with the ferry being considered a part of the road network. Alternatively traffic for these islands can simply be represented as additional traffic at the mainland port.

However this may be less suitable for the Western Isles and the Isle of Wight (and potentially the Orkney Islands and the Shetland Islands) which are not very small and have multiple ferry connections to the mainland, and would be likely to contain multiple zones within the NFTM.

A decision could be made that FAME is intending to model the mainland and that these other islands can be represented with their freight modelled at the mainland ports or the ferry routes could be included in the costs of transport between zones on these islands and the mainland.

The Isle of Man and the Channel Islands are less geographically and politically connected to the UK, but their supply chains link them to the UK.

Recommendation: FAME and the NFTM should include the whole of Great Britain and its associated islands (Anglesey, the Western Isles, Northern Isles, Isle of Wight, Isle of Man and the Channel Islands). As the scope of FAME and the NFTM is intended to cover the whole of Northern Island, it should also include all freight movement between NI and the rest of the world and within, to, from and through NI. As ferry services to/from NI ports compete with those that operate to/from ports in Ireland, all RORO services should be included and actively modelled in the NFTM.

7.5 Zoning structure

UK zoning structure

There are several considerations when choosing a zoning structure. It is helpful if:

- There are a sufficient number of zones such that representing transport as going to and from the centroids of those zones reflects reality reasonably well at the strategic “zoomed out” level.
- There are not so many zones that the model takes many hours or days to run.
- The zones reflect an existing zoning structure such that some data will already be available at that level, such as traffic, employment or population.
- The zones reflect boundaries that will be of interest to the users of the model. For example, the model’s zones should be able to be aggregated into ITL (NUTS) 1 regions because some of the model’s summary outputs may be required at that regional level.
- The zones are broadly of the same “size” in terms of traffic generated and consumed, rather than being just the same geographical size.

Ports are best represented as point zones without any land area such that the port traffics can be isolated from other activities near to the port. This can also apply to rail freight (and potentially other) terminals and rail connected clusters of large-scale warehouses, along with airports and inland tank storage sites that are linked to pipelines.

Individual large-scale warehouses and other freight generating sites do not warrant point zones. However there is an argument that the zone they are in could be split up to give them their own zone with a defined area, particularly if the zone they are in is spatially large.

Middle Layer Super Output Areas (MSOA) are a geographic hierarchy designed to improve the reporting of small area statistics in England and Wales. There are 6,856 MSOAs in England and 408 in Wales[15]. They each have a similar population and aggregate into Local Authority Districts. These are a suitable zone structure for England and Wales for the NFTM, and are the main basis for the zones in MDS Transmodal's GB Freight Model (GBFM) v6.2.

From a modelling perspective it would be sensible for Scottish and Northern Irish zones to have similar population sizes, but the statistical zoning structures are different. Scotland has 1,279 Intermediate Zones which suggests a smaller population per zone than MSOAs. Northern Ireland has 850 Super Data Zones, which again suggests a smaller population per zone than MSOAs.

Lower layer Super Output Areas (LSOAs) would be another option if smaller zones were required. There are 33,755 LSOAs in England and 1,917 in Wales. However, this number of zones in a model would probably result in very long run times, given the likely complexity of its functionality.

If faster running times were a priority, then the model could operate at (for example) postcode district level, where there are 2,979 zones in the UK. However postcode districts do not neatly aggregate into larger zone systems such as Local Authority Districts, Counties and Unitary Authorities. For quick run times, Local Authority Districts (ITL (NUTS) 3) could be used as zones, with a total of 374 such zones in the UK.

"Last-mile" LGV traffic (both between zones and within zones) can be estimated using survey results which provide origin, destination and journey distance. When heavy freight (typically HGV) traffic to edge-of-town warehousing sites changes, the onward "last-mile" traffic should also change.

<u>Recommendation:</u> At least two tiers of geographic zoning should be adopted within the NFTM so that the model could be run with different run-times. Tier 1 would provide full-scale runs with the detailed geographic zoning system (with a longer run-time), which would correspond to MSOA in England and Wales, Intermediate Zones in Scotland and Super Data Zones in Northern Ireland (a total of 8,985 zones)[16]. Tier 2 would allow 'concise' runs using a more aggregated zoning system when quick answers are needed to respond to more urgent questions (with a shorter run-time), with 374 ITL (NUTS) 3 zones corresponding to local authority districts. Added Value Analysis

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[15] https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeographies/census2021geographies

[16] A run of GBFM v6.2, with its >7,000 zones, takes about 5 hours and so it is unlikely that running the NFTM with Tier 1 zoning would be completed within 3 hours.

(external to the NFTM) should be used to break down baseline inputs to the model and the results of scenarios to reflect greater geographic granularity at a local level.

Overseas zones

As competition between European shipping routes is to be modelled, overseas zones are required, but these do not need to be as small as the UK zones. ITL 1 regions of Continental Europe (or groups of them) and ITL 3 regions of Ireland would probably be sufficient and is already used successfully with GBFM v6; road freight data is available from Ireland's statistical office at the ITL 3 level.

Similarly, as competition between deep-sea container shipping routes is to be modelled, the cargo should be split into its origin or destination world regions such as North America and the Far East.

Recommendation: Geographic zoning outside the UK should be at a less detailed geographic level, based on ITL 3 for the Republic of Ireland, ITL 1 for European regions (plus point zones for ports), and world regions for locations beyond Europe.

7.6 Time period and base year

Time period for NFTM

Many data sources are only available annually and the NFTM may therefore be best suited to working and producing outputs at the annual total level. Annual outputs can be broken down into daily or hourly periods using standard blanket conversion factors derived from the DfT table TRA0308 for HGVs or LGVs. Although these conversion factors should be reasonably accurate they do not take into account any local issues that might result in a significant difference from the mean; this might relate to HGVs and LGVs starting journeys earlier to avoid specific congestion hotspots or to enter a city centre during a relatively narrow time window before it becomes pedestrianised. In addition, using blanket values for all HGVs does not account for the fact that some journeys such as long distance HGV trunking are more common at night than local deliveries in a small HGV.

The detailed rail data available from Network Rail describes the timing of every rail freight movement, so annual movements can be translated into any hourly periods with different scale factors for different market sectors or locations on the network. There is, for example, not much freight travelling into London between 08:00 and 09:00 to avoid the busy commuter period.

It would be possible to run the NFTM for different time periods, just as GBFM v6, for example, has been calibrated to, and run for, three month periods when using the short sea unitload module for clients. However as it covers the whole country, it is not straightforward to represent (say) a 3-hour period, because, unlike local models, long-distance journeys that start in one 3-hour period will arrive in a different 3-hour period. One option could be to add a further attribute based upon survey data that described the percentage of cargo movements in a given time period between regional groups of zones.

If there was a focus on a particular local area for a scenario, FAME outputs could be scaled to the time-of-day proportions observed in that local area, instead of the national average values. However this scaled output would then only be appropriate for that area in question.

Recommendation: The NFTM itself should be developed for, and calibrated to, annual freight traffic movements. Added Value Analysis (external to the NFTM) should then be used to break down baseline inputs to the model and the results of scenarios to reflect issues such as seasonality and time of day.

Base year

The base year for the model should be the most recent full year for which the main sources of data are available, but avoiding non-typical years. Given the impact of Brexit and the Covid-19 pandemic on transport movements in 2020 and 2021, a model could be developed for a base year from 2022 and the relevant data for that year is already available. Given the likely timescale for any development of the NFTM and FAME, 2023 or 2024 is likely to be a suitable base year.

Recommendation: The NFTM should be developed for the most recent typical year and therefore avoiding years in which exceptional events had a significant impact on the freight market. This means that 2022 would be a reasonable year or, given likely timescales for the development of the NFTM/FAME, 2023 or 2024 would also be appropriate.

7.7 Modes & vehicle types

Many of the modes described in section 7.3 above can be broken down into several vehicle types based on size and the technology available for propulsion. As the transport sector seeks to move as rapidly as possible towards Net Zero, it has become increasingly important to be able to model the various alternative zero emission technologies that are (or may become) available. This is after several decades of stability based principally on diesel internal combustion engine technology.

Road freight vehicle types

HGVs on roads are the dominant carrier of freight in the UK, while LGVs (vehicles not exceeding 3.5 tonnes gross vehicle weight) also carry a significant amount of freight, particularly in urban areas, and contribute more to congestion per tonne km than HGVs because more vehicles are required per (say) 100 tonnes of cargo carried.

There is a question as to how and whether HGVs should be disaggregated in the model. In GBFM v6, HGV traffic is not broken down into HGV type; the output is in tonnes and HGV PCUs. If there is a need to disaggregate GBFM outputs, vehicle type splits by origin region and destination region are derived from CSRGT. This gives a reasonable split assuming there is no change in the vehicle mix from the base year but precludes investigation of scenarios that may alter this HGV type split.

Earlier versions of GBFM, including v5, did include modelling of HGV type choice (with five HGV types), whereby costs could be increased for one HGV type and this would encourage a switch to other HGV types using a Logit-type approach.

It would probably be desirable for FAME to have the capability of choosing HGV type to be able to make a distinction between HGVs carrying out trunk hauling on motorways (more appropriate for OGV2 vehicles, which are the largest rigid vehicles and all articulated HGVs) and HGVs making deliveries in congested urban areas (often more appropriate for smaller OGV1 vehicles, which are the smaller rigid vehicles). This is particularly important because OGV1s have a lower gross vehicle weight and have shorter average lengths of haul which means that battery electric technology is a viable alternative to diesel, whereas the heavier OGV2 vehicles are generally considered to be more difficult to decarbonise using existing battery technology in the short term because of higher gross vehicle weights and longer average lengths of haul. Having two different sizes of HGV would also allow a response to changes in costs or conditions for specific vehicle types, such as vehicle size limitations in urban areas. LGVs carrying freight need not be disaggregated into different vehicle types, particularly as vans carrying freight will mainly be of the standard Transit type rather than smaller vehicles.

Having an even greater disaggregation into (say) five different types of HGV, would be possible based on the baseline data from CSRGT, but would make the NFTM more complex and may lead to relatively spurious or even inexplicable responses.

Recommendation: The NFTM should include two types of HGV (OGV1 and OGV2) and LGV, with the capability for switching between vehicle types based on costs and, where appropriate, type of duty cycle (urban versus trunking) and to take account of vehicle size limitations.

Fuel types

For HGVs, the main future propulsion options are likely to be:

- Diesel;
- Battery electric (either recharging when required, or with battery swapping to speed up “recharging” times);
- Hydrogen (either fuel cell or internal combustion engine);
- Overhead electric wires.

Other possible fuels include biomethane, biodiesel, methanol, and ammonia. The exact solutions that will have emerged for road freight by (say) 2050 are uncertain.

The use of battery electric and hydrogen fuels mirror, if only in general terms, refuelling with diesel in that vehicles have to stop to refuel and the source of energy can be universally available if appropriate refuelling infrastructure can be provided in suitable locations. Overhead electric wires would be a very different approach, with fixed infrastructure needing to be provided probably on only certain sections of the highways network and the HGVs being equipped with batteries that can be charged while the vehicles is “under the wires” and they can operate autonomously off the wired network. Additional charges would probably need to be levied on HGVs’ use of the new wired network. This would require a different modelling approach and increase the complexity of the model.

Currently the vast majority of HGVs are diesel powered, so fuel type has not been a significant issue in the past. But given Government policy on decarbonisation, it will be important for the NFTM to be able to choose the means of propulsion and respond to changes in the costs of using each propulsion type. Also, given Government policy, it will need to be possible to limit the availability of diesel vehicles as a result of regulation.

Cost models for each means of propulsion will therefore be needed, with the choice between the individual means of propulsion being made through a Logit or similar algorithm.

For LGVs, journeys are generally shorter and the main options are diesel and battery electric.

Recommendation: The NFTM should include provision for cost models to be developed for different means of propulsion for HGVs and LGVs, including diesel, battery electric and hydrogen. Developing modelling techniques to account for overhead electric technology would make the model more complex, but could be incorporated into the model if the DfT needs to take a technology-neutral approach given the current uncertainties about whether the technology would be viable.

Rail haulage

There are several different types of train that can be used for carrying cargo. The main variables are:

- Choice of wagons: This is dependent on the mode of appearance of the cargo being carried. For example intermodal containers need to be carried on flat wagons, while bulk cargoes have bespoke, cargo-specific wagons. Wagons need to be chosen that (when loaded) will fit within the loading gauge of the route (not be too wide or high for the route) and which can be accommodated within the maximum axle weight limits of a section of track.
- The number of wagons: Longer trains are generally more efficient if carrying large volumes of cargo because it reduces the average cost per tonne of cargo transported, but there is no point in having a long train if the tonnage of cargo being carried is low. Longer trains result in increased trailing weight which affects their acceleration performance and therefore the amount of network capacity they require.
- Choice of locomotive: A locomotive of sufficient power is needed to haul the wagons along a defined timetabled path through the network, without holding up other trains.

The NFTM could attempt to consider all these aspects in detail, but a simpler approach could be to assume standard trains across the network for intermodal containers and for bulk trains separately, assuming standard train lengths, wagon types and choice of locomotive. However, flexibility should be incorporated into the cost models to allow for changes in parameters such as train length as increasing train lengths permit a cut in unit rail costs and is an important intervention option.

Rail has the same fuel types and propulsion options as HGVs.

Recommendation: The NFTM should include provision for cost models to be developed for standard intermodal and bulk rail freight trains separately and allowing for changes in parameters such as assumed train length. The NFTM should also include provision for cost models to be developed for different means of propulsion for trains, including diesel, overhead and battery electric and hydrogen.

Inland waterway transport

Inland waterway transport can be considered conceptually similar to rail, but it is likely to be appropriate to assume that the barges/ships operating on each waterway are able to take advantage of the maximum vessel dimensions for each waterway/wharf and also to allow different propulsion options. Similar to rail, a distinction could be made between barges carrying containers and those carrying bulk commodities such as aggregates.

Recommendation: The NFTM should include provision for cost models to be developed for standard intermodal and bulk barges separately. The NFTM should also include provision for cost models to be developed for different means of propulsion for barges, including diesel, battery electric and hydrogen.

Shipping

This also applies to shipping, with maximum ship size restrictions affecting the size of ships that can access particular ports. Further details are provided on the modelling of shipping in section 2.7 below, but we would propose that the economics of individual short sea unitload services and generic deep sea container services to/from specific UK ports (but not bulk shipping) are actively modelled and this would determine the cost models that would be required.

Recommendation: The NFTM should include provision for cost models to be developed for individual short sea unitload vessels (ferries, RORO vessels and LOLO vessels) serving specific routes, as well as generic deep sea container (LOLO) services between world regions and specific British deep sea container ports, as well as allowing for transhipment and inter-lining at major container ports in North West Europe and the Mediterranean. These models would need to take account of maximum ships sizes at each relevant port. The NFTM should also include provision for cost models to be developed for different means of propulsion for ships, including diesel, battery electric, hydrogen, methanol and ammonia.

Other modes

For freight transported by air and by pipeline (as specialist modes which do not generally compete with other modes) we have recommended above that they should not be actively modelled. Airports and terminals served by pipelines should be regarded as origins and destinations within the model, with provision for growth in total traffic based on exogenous factors such as trade growth, before being distributed to/from final origins and destinations within the NFTM by road or rail.

Similarly, we have recommended above that modes such as cargo-bikes, drones and portering should not be included within the NFTM because these modes are used for so-called “last mile” deliveries and “first mile” collections at a very local level, which would be very complex to model when the geographic scope of the model is for the whole of the UK. Their market penetration is currently very small in terms of tonnes lifted or tonne kilometres, and they are only likely to serve niche markets or relatively small areas of cities.

7.8 Service networks

Road

The Terms of Reference for FAME implied there was a need for FAME to take account directly of road network capacity, but this can only be determined by including passenger traffic which is beyond the scope of FAME. Freight models are usually used to provide inputs in terms of road freight traffic for highways models, which combine passenger and freight traffic to determine capacity utilisation on road networks. In order to include a road network and take account of traffic conditions within the NFTM directly would require inputs on passenger traffic and would require iterations of the model to reach an equilibrium position between demand and capacity, leading to long run-times.

There is, however, a need within the NFTM to input origin-destination (OD) journey times on a road network, distances and tolls (i.e. "skims") for an average journey for each road vehicle type modelled. Such "skims" are often available with highways models for the AM peak, Interpeak and PM peak, Interpeak can normally be considered representative of the average for freight.

We assume that the National Transport Model (NTM) incorporates a road network that would be able to provide such base-year skims for HGVs and for LGVs for use within the NFTM. Similarly the NTM may be able to assign any OD road results emerging from FAME onto the road network. There may therefore not be any need for a road network to be incorporated into FAME itself.

For future years, there is the option of using the NTM to generate different skim matrices. For these to be valid, assumptions need to be made in NTM about future passenger and freight traffic growth, and the likely building of new roads. This is often difficult to specify far into the future, such that if the objective of a FAME model run is not particularly focused on the future road network, it can be simpler to ignore any changes to the skims from those in the base year, or choose skims from a near-future year incorporating known road network developments.

Instead of an NTM road network, outputs could also be assigned to the Ordnance Survey Highways Network, and this network could also potentially provide skims as inputs to FAME. However, this may mean a feedback mechanism between highway capacity and traffic volumes was not available.

Recommendation: The NFTM should not include a road network itself but should take skims from the National Transport Model (NTM) or Ordnance Survey Highways Network to ensure that base year road network conditions and travel times are taken into account within the freight model. In the event that the impact of freight traffic on road network capacity is required, output from the NFTM should be use as an input to the NTM for road assignment along each road, by direction. If this is not practical, a road assignment could instead be made to the Ordnance Survey Highways Network, using average HGV link speeds rather than modelling congestion (which would involve including forecast passenger traffic and road network capacities throughout the network).

Rail

Road OD times and distances can normally be estimated straightforwardly by using the average speed and distance across each road link, and building up a journey using the Dijkstra algorithm; this finds the lowest generalised cost from A to B through a network.

Ideally a rail network would be treated in a similar way to a road network and skim matrices could be provided for rail freight trains based on finding the lowest generalised cost route through a rail network. However the routing of trains is more complicated due to various issues:

- Some routes can accommodate longer, heavier, wider, higher trains than other routes;
- Some routes are not electrified and therefore cannot accommodate electric trains;
- Some routes are very congested and are therefore best avoided, particularly during the day;
- The freight trains on some routes will be forced into passing loops or made to wait at junctions to allow other trains to pass thus increasing journey times;
- Freight Operating Companies (which operate the locomotives) may choose to take a particular route so as to be able to stop at their depot for a crew or locomotive change.
- The shortest route may involve reversing (where the locomotive detaches from the wagons and rejoins at the other end of the train), which can take a long time or be impractical on the main line.

Options for estimating rail skim matrices include:

- Using the road distance as a proxy;
- Ignoring some of the limitations of the rail network and finding the shortest path anyway;
- As above (finding the shortest path) but incorporating a cost for reversing movements.

If there are a limited number of rail services to be considered, then instead of a network, the option to use rail can be represented by a list of costed services from origin terminal to destination terminal. However these services have to be specified and input into the model, and the model would then be unable to easily generate new services itself, which may or may not be a problem depending on the question being asked of the model. A separate module could be tasked with choosing appropriate services.

Recommendation: The NFTM should include the full network of existing intermodal and bulk rail freight services in the base year, with a provision for the manual addition of new services for specific scenarios to ensure that any new services reflect commercial and operational reality in the market.

Short sea unitised shipping service networks

A network of services could be built for ferry, RORO and LOLO services linking Great Britain to Ireland and the continental mainland. However, as with rail, it may be simpler to provide a costed list of the ferry options available to traffic from British port to Continental (and Irish) port. It would also be possible to allow the model to generate its own services if the ferry port options on both sides of the Channel (and Irish Sea) were given but such an approach would not necessarily reflect the services that operate in the base year. The model would be more controlled if the ferry services were specified (to reflect the services that actually exist plus 'missing links', even if the latter could be difficult to identify without a sound knowledge of the underlying economics and market mechanisms), and for most likely scenarios this would be preferable. If the model were allowed to generate an unlimited number of services, port capacity should be considered as a further live parameter (see section 9.9).

Recommendation: The NFTM should include the full network of short sea unitised shipping services in the base year (ferries, short sea RORO and short sea LOLO), with a provision for the manual addition of new services for specific scenarios to ensure that any new services reflect commercial and operational reality in the market.

Deep sea container shipping service networks

It would also be possible to have a deep-sea shipping network of services for container ships, taking into account vessel operating economics, and this appears to be a clear requirement of the NFTM from the DfT because of the importance of the UK's container supply chains for high value non-bulk goods with the rest of the world. However, such a network of services would be complex to model because imported consumer goods from (say) China can be transported to the UK in a number of different ways, as follows:

- On direct deep sea container services between China and deep sea container ports such as Felixstowe, Southampton, London Gateway and Liverpool;
- On feeder container services to a large number of container ports around the UK via a continental transhipment port, such as Rotterdam (with capacity shared in some cases with short sea containers);
- On deep sea container services where the containers have been transferred between deep sea services at transhipment ports in the Mediterranean or on the Atlantic coast of Europe.

The routing of traffic is determined mainly on the basis of door-to-door costs but is also affected by the specific strategies of individual shipping lines (e.g. where the lines' have commercial or ownership relationships with particular container terminals) or their relevant market position in particular trade corridors. It would only be realistic to model these networks based on generic container shipping costs between world regions and the UK, while allowing for transhipment and inter-lining to minimise costs and with calibration of results to the port traffics observed at each relevant port.

Recommendation: The NFTM should include a generic network of existing deep sea container services in the base year (world region to UK port), with a provision for the manual addition of new generic services for specific scenarios to ensure that any new services reflect commercial and operational reality in the market.

Bulk shipping

Bulk shipping tends not to operate as pre-defined services. From a modelling perspective, cargo demand could generate its own bulk shipping options to get to/from the UK if the other end was known. It would need to take into account vessel operating economics as the issue of scale economics is important and explains, for example, the importance of the North German and Benelux ports in the deep-sea bulk markets despite the onward transhipment costs to the UK. However we would recommend that this functionality should be beyond the scope of FAME with the traffic "appearing" at the relevant ports for subsequent inland distribution by the NFTM.

Recommendation: The NFTM should be designed to only model the inland distribution of bulk cargoes, with the cargo arriving at or departing from the relevant ports in the base case (i.e. no active modelling of European and global shipping economics).

Inland waterways

There are only a few waterways in the UK that carry commercial freight so overall they are less significant than road or rail. There are similar issues to the rail network in terms of ship size permitted on the canals and through locks. They could be treated in a similar way to rail services, with predefined costed terminal to terminal services input into the model, based on the maximum vessel size restrictions on waterways that are most relevant to freight movements.

Recommendation: The NFTM should include the full network of existing inland intermodal and bulk barge services in the base year, with a provision for the manual addition of new services for specific scenarios to ensure that any new services reflect commercial and operational reality in the market.

8 NATIONAL FREIGHT TRANSPORT MODEL: SUB-MODELS

8.1 Introduction

As well as the main NFTM there would also be sub-models, which would provide inputs on:

- The HGV/LGV fleets: Until relatively recently, there was no need for a separate sub-model for HGV/LGV fleets because there was only one propulsion technology (diesel) that was used and there were no restrictions to the supply of HGVs and LGVs to meet demand, so the market could be assumed to provide the vehicles required to carry the cargo demand. However, with the introduction of LGVs and HGVs with alternative sources of propulsion, fleet models for the mix of vehicles by type and propulsion are more relevant.
- The HGV/LGV driver market: Again, there was arguably no need for a separate sub-model for HGV/LGV divers until recently because, although the average age of British drivers has increased, there was a supply of younger drivers from the rest of the EU. However, due to the impact of Brexit and the Covid-19 pandemic, there is a greater justification for a driver model, particularly to provide estimates of potential future employment costs for drivers.
- Transport costs for each mode of freight transport, type of vehicle and fuel type.

8.2 Transport cost models

As freight is essentially a competitive market, decisions are mainly based on generalised costs and specific tolls which can be regarded as the economic rent that can be extracted by infrastructure owners.

The main components of generalised costs for road and rail operation are:

- The financial cost of the haulage: This includes fuel, drivers' wages, leasing the HGV etc. This is the dominant component of generalised cost for most cargo and is the key component.
- The time cost for the cargo: This is relevant for urgent cargoes such as parts to fix a broken industrial machine, perishable cargoes such as food and high value commodities for which the capital invested in the cargo is significant. However, it is of little importance for low-value cargoes that are not time sensitive such as aggregates from quarries or biomass to power stations.
- Reliability: The cost of reliability can be modelled by adding in the operating cost of different modes of transport of adding in safety factors (e.g. HGVs leaving 30 minutes earlier than 'necessary').
- Reputational cost for companies: public-facing companies may wish to use rail instead of road for environmental reasons. However, a difficulty would be determining which specific companies (and their specific flows) would be affected by what would be in effect, an increase in the road freight cost to reflect their environmental policies.

The financial cost of haulage can be represented using cost models for each vehicle type and means of propulsion – see below. The time (and reliability) cost for the cargo can be estimated based on commodity. Reputational costs will vary and are difficult to directly include in a model. They can most easily be represented by considering the market to include a spread of attitudes rather than all freight movers having the same response. A Logit model combined with matching the observed base year would be a good means of representing this variation.

8.3 Financial cost of transport

Cost models for road and rail haulage can be built up from the various components that haulage companies experience when carrying out their business including:

- Vehicle purchase (with financing) or lease;
- Fuel resource costs, with fuel consumption rates;
- Drivers' wages and other staff employment costs;
- Taxes and duties;
- Tolls and infrastructure charging;
- Insurance;
- Maintenance, Tyres, Oil and AdBlue;
- Driver equipment;
- Track access charges (currently just for rail);
- Costs for using terminals;
- For rail, an inconvenience cost needs to be incorporated representing the fact that rail services are not on-demand like HGVs are. This is related to service frequency; a high frequency open-access service has a low inconvenience cost.

Drivers' hours regulations should be accounted for within the cost model by ensuring that the operating hours of the vehicles are limited by the legal length of shift that can be worked.

Ship operating costs can be calculated on a similar basis (capital, insurance, maintenance, crew and overhead costs), plus port charges (economic rent) and stevedoring costs, except that:

- Scale is hugely important, as shipping operators deploy larger vessels to reduce unit costs and become more competitive, albeit larger ships typically need to spend more time in port unloading and loading;
- Costs vary by ship type and design;
- Speed is also a major factor given fuel costs can rise per nautical mile by the square of the speed increase.

Cost models would need to be developed for each mode, vehicle type and propulsion method included in the model, such that each option can be costed from A to B. There is a need to ensure these cost models are realistic by regularly validating them with the relevant sectors of the freight transport industry.

Representing the cost of large diesel HGV movements is relatively straightforward because they can refuel anywhere enroute, such that the routes and costs of journeys can be calculated from a distance, time and toll skim (OD matrix derived from a road network) combined with a cost model giving a cost per km and a cost per minute for operating an HGV, plus a consideration of loading, unloading and repositioning for the next movement.

Diesel rail journeys can be similarly costed out, although (if required) they need to include road hauls at the beginning and end of the journey to get from the original cargo origin to the origin rail terminal and from the destination rail terminal to the final cargo destination. There have been times when electricity prices have been at a level that rail traction suppliers have used diesel traction when electrified options were feasible.

Diesel inland waterway and shipping services can be similarly costed out.

It is already clear that some companies will value carbon emissions more highly than others in making decisions on mode and future fuel energy source because of their own trading strategy (e.g. in trading ‘carbon credits’). This will be important in modelling behaviour. Such valuations may also differ from those used for public interest appraisal.

Recommendation: NFTM transport cost models should be developed for diesel road freight vehicles for OGV1, OGV2 and LGV and for ‘standard’ intermodal and bulk rail freight services. Cost models should also be developed for inland waterway barges for containers and bulk shipments and for each short sea unitload shipping service (RORO and LOLO) between Great Britain and the European continental mainland and Ireland, as well as for deep sea container shipping services between Great Britain and (at least) each world region.

Non-diesel propulsion: hydrogen and battery swapping

Because there is no generally established practice yet in the freight industry, it is less clear how to represent other fuels and means of propulsion in a cost model, and simplifications and approximations will be needed.

Hydrogen and battery-swapping could probably be represented in the same way as diesel, with refuelling being carried out at any refuelling station enroute and only take a few minutes such that it can be ignored in the same way that diesel refuelling can be ignored. While the reality may be more restrictive, perhaps with more limited suitable locations for refuelling with hydrogen for example, it may be possible to ignore these location limitations for scenarios in the NFTM.

Non-diesel propulsion: battery electric (recharging)

For battery recharging, it is possible that a charging time would need to be included in the cost model. However, it would also be possible to simplify the scenario and assume that recharging technology improves (e.g. megawatt chargers are already under development) such that it can be done much more quickly and can be considered similar to diesel. Drivers could also recharge during their mandatory break times which, in some cases, could mean there was minimal (if any) extra delay due to recharging. It is therefore not valid to assume that short journeys never need recharging en route. It is unlikely that hauliers would be able to recharge at all of their customers' premises because expensive high-capacity recharging infrastructure would be required that may not be intensively used which would therefore not be viable to install; however, the larger distribution parks, major ports and industrial parks (with good connections to the electricity grid) might well be able to invest in such facilities.

Where payloads are, for a given maximum gross vehicle weight, reduced due to the requirements of a new propulsion technology (the need to carry the weight of a battery or pressurised gas tanks for hydrogen, for example), this can be reflected in a reduced maximum payload within the relevant cost model. This would mean that this mode/technology would be less competitive per tonne transported, leading to some switch to an alternative mode or technology. The cost models need to be kept under review as regulations are updated to take account of the impact of changing technologies; the DfT has, for example, increased the maximum payload for zero emission HGVs by two tonnes in early 2023 (subject to a maximum of 44 tonnes and no increase in tonnes per axle, which may in practice reduce the effect).

Non-diesel propulsion: overhead electrification

Overhead electrification of some key trunk road routes is, at least in theory (given the capital costs and potential safety issues involved), an option. This network would have to be built in conjunction with other technology as an HGV's battery could be recharged under the wires and then used for the route sections without overhead wires.

Overhead electrification would be expensive if the infrastructure were to cover a large proportion of the network. One option would be high-power short stretches of wired routes that could recharge HGV batteries on the move, as an alternative to HGVs having to stop to recharge. If an HGV were to travel along such an electrified route, the HGV cost model for battery HGVs could exclude the need to wait while recharging. However the electricity supplied through the overhead wires would probably need to be sold at a premium in order to cover the infrastructure costs unless it was funded by the public sector and regarded as a public good.

Non-diesel propulsion: cost of electricity

Diesel prices do vary across the country, but generally not significantly enough for there to be a need to represent this in a model. However electricity prices for recharging may be more varied by location;

- On a rural motorway next to the National Grid the extra electrical infrastructure needed may be minimal and many trucks could be recharged simultaneously.
- At long distances from the National Grid, new high-capacity electrical connections would be needed.

Diesel prices are not significantly influenced by the time-of-day or season of the year. However electricity prices for recharging could vary significantly if the country increases its use of renewable electricity:

- On sunny, windy days electricity prices are likely to be low due to high supply of wind and solar energy.
- On windless, cold, winter early evenings, electricity prices are likely to be high.

This detail is probably beyond the scope of the NFTM because it depends on the electricity charging regimes and becomes very complex, but in reality such factors could affect the way haulage companies choose to recharge their vehicles and could even affect the relative competitiveness of road haulage companies.

Non-diesel propulsion: taxation and economic rent

Taxes are currently applied to transport fuels (fuel duty) and for licencing vehicles (Vehicle Excise Duty). A component of these taxes is justified on the basis of emissions including carbon emissions. These emission-based taxes could be explicitly separated from other taxes in the cost models (and in reality), so that different carbon prices could be tested.

Where the private sector is involved then it is important to recognise the role of economic rent (port charges, warehouse rents etc.). It is also important to recognise that the owners of such assets may levy charges that could run counter to the policy objectives of (for example) road pricing. This means that, although the cost models should seek to provide 'standard' charges for the use of private assets, they do in reality vary according to the economic rent that can be secured due to its location, capability etc.

Recommendation: NFTM 'alternative fuel' transport cost models should be developed for road freight vehicles for OGV1 and OGV2 (battery electric, battery swap, hydrogen and overhead electric) and LGVs (battery electric) and for 'standard' intermodal and bulk rail freight services (overhead electric, battery electric, battery swap and hydrogen). Similarly, 'alternative fuel' cost models should be developed for inland waterway barges for containers and bulk shipments (probably battery electric and hydrogen) and for each short sea unitload shipping service (RORO and LOLO) between Great Britain and the European continental mainland and Ireland (battery electric, hydrogen, methanol and ammonia) , as well as for deep sea container shipping services between Great Britain and (at least) each world region (probably only hydrogen, methanol and ammonia).

8.4 HGV & LGV fleet and labour market models

Fleet models

Fleet models allow the make-up of the vehicle fleet in any future year to be estimated based on scrappage and new-build rates. In an era of fleets changing their make-up to reduce carbon emissions, this would be a useful tool.

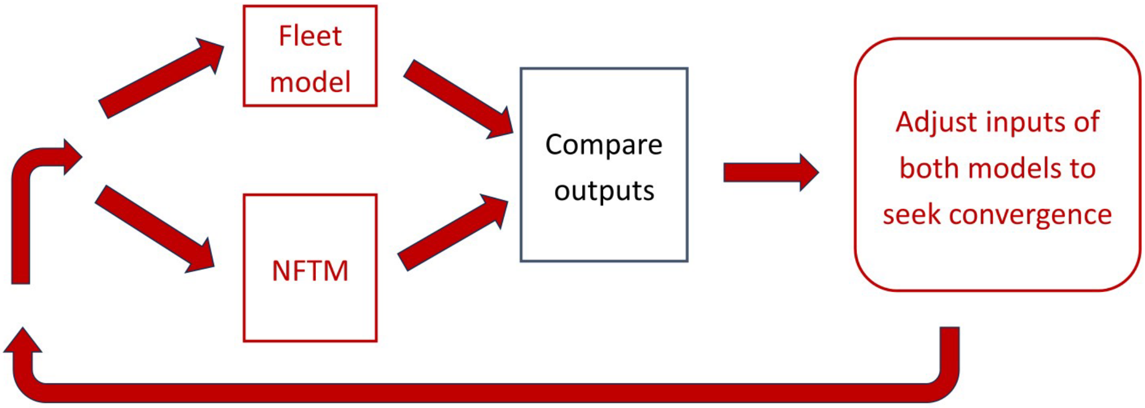
They would probably not be fully integrated into the NFTM and instead would provide an input into the main NFTM as a sub-model, but with a feedback loop. For example, the baseline fleet model is likely to suggest that there will not be many zero-emission HGVs in the fleet in the short term (1-2 years). But if an NFTM scenario included cost models without much difference between costs of different propulsion types, then the NFTM would output a similar volume of traffic for each propulsion type, despite there not being the fleet to carry out these forecast movements.

There should therefore be some feedback from the HGV/LGV Fleet Model whereby the NFTM cost models have to be changed to produce outputs more consistent with the fleet model. There could also be some feedback from the NFTM to the HGV/LGV Fleet Model whereby, if outputs were consistently showing zero-carbon vehicle demand to be significantly in excess of HGV availability, the fleet models could be adjusted to include a higher rate of scrappage and new-build penetration.

As the HGV/LGV Fleet Models are very different models conceptually to the NFTM, it is likely to be important for the model user to have oversight of the convergence of the Fleet Models with the NFTM. However this convergence could potentially be automated such that the models were fully integrated.

Fleet models could also be applied to rail locomotives and wagons, barges and ships of all types, which in the case of deep sea container ships would be modelling a global fleet. Similar "fleet" models could be applied to other replaceable assets that have a limited life such as warehouses. These fleet models could all be used to check that the NFTM is producing reasonable traffic outputs that could be realistically carried out by the available fleet. The fleet models could all be adjusted as required to allow the NFTM to produce acceptable results (Figure 2).

Figure 2: Interaction of fleet models with NFTM



Our normal modelling philosophy relies on modelling a scenario in an equilibrium state; making the implicit assumption that if scenarios are far enough into the future, and the market knows what the future scenario is going to be, that the market will provide the necessary assets. However in the real world it often takes time for a market to adjust to new conditions, and it can be prudent to assume a period of adjustment in behaviour after the scenario has changed. For an era of fast-changing propulsion technology, this is less valid and the use of a fleet model is beneficial.

It would be possible to use the NFTM without a fleet model for long term forecasts, or for a scenario that does not involve significant changes in asset types. If looking at a medium-to-long term forecast, it may be helpful to run the NFTM with the fleet model for several intermediate years so that the fleet model can be set up to reflect reasonable scrappage and new-build assumptions for the intermediate years.

There are various inputs for the fleet model that would need to be established.

- Scrappage rates (the percentage of vehicles lost to scrap per year) can be based on historical rates by age of vehicle, with adjustments made as required to reflect any expected changes in future.
- Levels of newbuilds entering the market can be based on historical levels. However these are likely to change in future for different propulsion types, with an influx of battery-electric or other zero-carbon means of propulsion being introduced.

To avoid over-supply, scrappage rates for diesels may need to be increased. This could be achieved through a “carrot and stick approach” by the public sector with:

- a government-led scrappage scheme whereby cash is paid to hauliers to scrap polluting vehicles;
- Higher taxes or restrictions on using polluting vehicles.

As these are policy interventions, they would need to be actively modelled.

Imports and exports of second-hand vehicles can to some extent also balance this, although the fact that vehicles drive on the opposite side of the road in Continental Europe limits the market to nearby left-hand-drive countries such as Ireland. Such other countries are likely to be going through similar decarbonisation efforts to those in the UK.

Results from the demand model should influence the fleet model’s input parameters. For example a forecast high *demand* for zero-carbon vehicles should be reflected in the fleet model’s assumptions such that they converge to produce consistent results.

Recommendation: A sub-model for the NFTM which models the fleet of HGVs and LGVs operating in the UK, with a focus on their fuel type should be developed. Similar models could also be developed for rail freight locomotives and wagons, barges and ships and even warehouses but this would increase the complexity of FAME and would draw resources away from the key issue which is the fleet of road freight vehicles.

Labour market model

Given the ageing of the British HGV driver workforce, the loss of market flexibility following the UK’s departure from the EU’s Single Market and the relative importance of HGV driver wages within total road haulage costs, an HGV driver labour market model would also be useful as an input to the NFTM.

This would include baseline data on the existing size and age of the workforce and then allow:

- Workers leaving the workforce, based on assumptions about retirement rates for older workers and younger workers leaving the industry;

- Workers entering the workforce, whether British citizens (most likely given current immigration rules) or imported labour from overseas.

Any resulting shortfall within the model could be accounted for either by a lack of resources to provide the supply of road freight services or through an increase in wages to attract more drivers into the industry.

The modelling principles are similar to the vehicle fleet model, with:

- an annual loss of supply with workers leaving or retiring being equivalent to vehicle scrappage; and
- an annual increase in supply with workers entering the workforce being equivalent to new vehicles being purchased.

As with the fleet, both the annual loss of, and increase in, the supply could be based on historical figures as a starting point. Higher wages would increase supply by reducing the annual loss of workers and encouraging more workers to enter the workforce. A separate economy-based model could be set up to represent this, whereby wages required could be an output based on comparing future demand to expected supply. This could feedback into the drivers' wages input into the demand model.

Recommendation: A sub-model for the NFTM which models the HGV Driver Labour Market should be developed as an input to the NFTM.

9 NATIONAL FREIGHT TRANSPORT MODEL: METHODOLOGY

9.1 Introduction

The objective of the methodology for the NFTM should be to replicate as accurately as possible the way the freight and logistics market works in reality and as described in outline in section 3 of this report.

9.2 Agent-based model of classic four stage model?

Agent-based Model (ABM)

A model could be built as an agent-based model (ABM) whereby various decision makers in the industry are modelled as agents, all seeking to maximise their success at achieving their defined goals, which would mainly revolve around being as profitable as possible. The way that freight is organised is that cargo owners contract with transport suppliers to move cargo for a period of time at agreed tariffs. Transport suppliers, in turn, both invest in their own staff and equipment and also contract with other suppliers to fulfil such contracts from cargo owners. Therefore it is these inter-company decisions and commercial deals that would be most sensibly modelled through ABM.

For example, a rail freight operating company (FOC) could be modelled as an agent, seeking to make best use of its assets to carry freight around the country in the most profitable way. This could be by comparing demand for non-bulk goods transport across the country with the available rail freight services, and introducing new services where they would appear to be profitable. The equivalent could be represented for shipping lines introducing new services and ships.

A road haulier agent could seek to buy the most profitable vehicles by forecasting the likely profit to be made by purchasing diesel or zero-carbon vehicles based on expected tax, incentives and restrictions, and make vehicle purchases accordingly.

Similarly, a port developer agent could choose where to invest in enhanced infrastructure based on where demand growth is likely to be seen. For example, if a port "agent" foresaw a switch from driver-accompanied ferries to unaccompanied services on the North Sea, they may invest in facilities to handle such traffic.

A warehouse developer agent could choose where to build new warehousing based on land, labour and transport costs to serve likely markets. If rail were to become cheaper, the incentives to locate at a rail-served site would increase.

However it is difficult to accurately represent agents in such an ABM, and each run produces a different result, such that there can be many outcomes for a given scenario. It is therefore difficult to represent small changes and observe any discernible responses in the model, because the small impact of a small change can be drowned out by the variability in model outcomes for a given scenario.

Classic four-stage model

As discussed in section 2 of this report, the backbone of the NFTM within FAME should be a classic four-stage model, with some adjustments. This is what the majority of large strategic transport models are based on, and it is a well-established technique for modelling long term stable scenarios.

This involves the following process:

1. The origin-to-destination (OD) of cargo is established in a base year.
2. A generalised-cost based method (normally Logit-based) is used to split between modes, vehicle types (with fuel types) and routes.
3. Assignment to the road and rail networks may be desired.
4. Calibration to known values is completed to ensure that outputs for the base year match observed reality. Validation using separate data will give further confidence in the outputs.
5. There may be some capacity constraint for road, rail and ports.
6. Forecasts can be run by changing the OD matrix of the cargo and by altering the costs, along with various other input changes.

However there is scope for blending this approach with other methods to achieve a better outcome, as discussed in the sub-sections below. Other sub-model components would feed into the main NFTM structure such as a fleet model to represent the transition from diesel to zero-emission vehicles. Equivalent “fleet models” could also be applied to other transport assets that need replacing over time.

Recommendation: The NFTM should be developed as a classic four-stage model, with some amendments to improve its functionality.

9.3 Establish Origin-Destination matrix for the base year

Domestic OD matrix

The ideal method for generating an OD domestic tonnage matrix would be to base it on an extensive detailed survey or actual movement data which matched the zone structure of the model. However the DfT’s Continuing Survey of Road Goods Traffic (CSRGT) is aggregated to ITL (NUTS) 3 zones for confidentiality reasons and to avoid “lumpy” data due to the small sample size. Even at the ITL 3 zone level, some origins and destination do not have sufficient coverage such that they need to be grouped

into ITL 2 or ITL 1 zones. Therefore there is a need to generate an OD commodity domestic tonnage matrix synthetically as an initial estimate. CSRGT uses the NST2 commodity classification (20 commodity groups), so this is the level of commodity that would be available for road freight.
This can then be constrained by region-to-region totals derived from CSRGT, Network Rail data and inland waterway data (from DfT's Waterborne Freight Statistics) to ensure that the OD matrix matches the best data available at a region to region level (see Figure 3 below).

The synthetic OD commodity domestic tonnage matrix could be produced using Supply and Use data (which link employment by Standard Industrial Classification (SIC) to commodities produced and consumed). Other methods of generating an initial synthetic matrix may include the use of input-output tables.

Warehousing

Lots of non-bulk cargo movements are to or from warehouses. There is good data on each warehouse's location and footprint area, but not on their traffic generation and attraction. Warehouses can be classified into different types and therefore cargo generation rates based on their role. For example National Distribution Centres (NDCs) for retailers typically have a slower turnover of cargo (and therefore low traffic generation) than Regional Distribution Centres (RDCs). Cold-chain distribution centres have a faster turnaround time. NDCs are typically located towards the middle of Great Britain to minimise transport costs.

Surveys could be carried out (or existing surveys used) to determine typical cargo generation rates for each type of warehousing. The distribution of cargo to and from a warehouse is dependent on its type. NDCs typically receive goods from around the country and overseas, while distributing to locations across the country. RDCs typically receive goods from NDCs and distribute within their regions.

These warehouse-based cargo generation estimates can be added to the original cargo origin-to-final cargo destination based estimates.

Interchanges such as rail terminals or ports are not cargo origins or destinations in themselves – they are just intermediate locations where the mode can be changed en route. The costs of using them need to be incorporated into cost models. For extra efficiency, they are often located on warehousing or other industrial sites to remove the need for a local road haul.

Gravity models

Gravity models are commonly used in transport models to estimate how cargo would be distributed from a cargo generator origin or received to a cargo consumer.

The concept parallels the gravitational force equation whereby the force of attraction between two objects is proportional to the mass of object 1 and the mass of object 2, and is inversely proportional to the square of the distance between their centres. For freight transport:

- traffic volume replaces the force;
- transport generalised cost replaces the separation distance;
- the masses are replaced by some means of quantifying traffic generated and consumed, such as warehouse floorspace or number of employees in a particular industrial sector.

Relationships can be established between employees, in particular producing and receiving industries based on “Supply” and “Use” tables such that for example, employees in the quarrying sector would generate cargo (aggregates) for distribution to the employees in the construction sector.

The results of the gravity model could be compared to origin, destination by commodity tonnage information from CSRGT and Network Rail. The power factors for each parameter (e.g. the amount that the transport cost is raised to, which could be varied from the factor 2 in the actual gravity equation) can be adjusted (calibrated) to better match CSRGT and Network Rail data, with a possible target being to match the average length of haul and the length of haul distribution for each commodity separately.

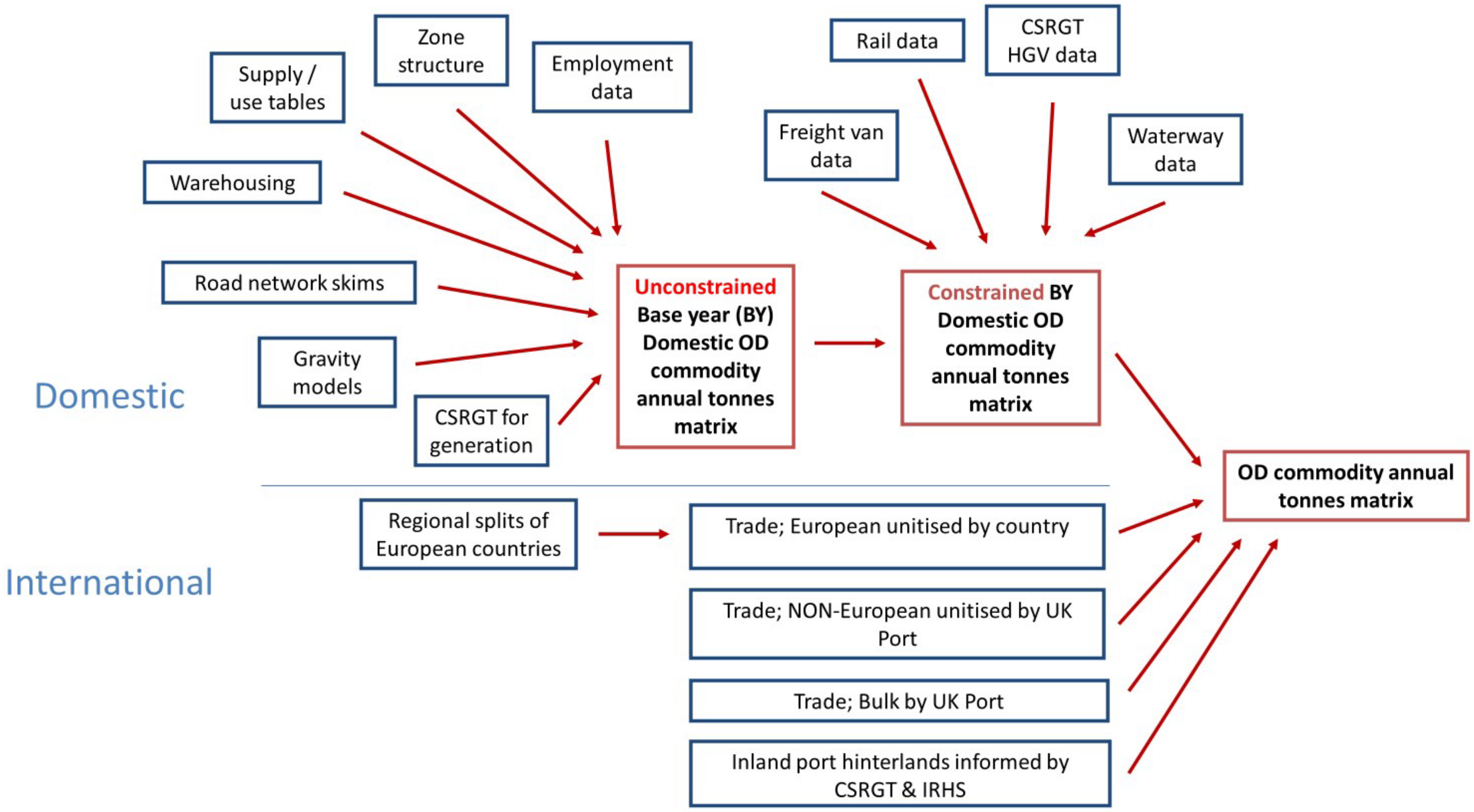
International OD matrix

For international traffic, the traffic at the ports is well defined through trade data and port freight data. Trade data also gives the other-end country. Given the commodity detail that is available by port from HM Customs and Revenue trade data, international traffic could be broken down to at least SITC2 digit level (80 separate commodities) for the base year, although each commodity would then have to be forecast for the future.

Inland hinterlands for each port can be estimated based on CSRGT and DfT’s International Road Hauge Survey (IRHS).

This is summarised in Figure 3 below.

Figure 3: Establishing the origin-destination matrix for the base year



9.4 Forecasting freight to a future year

Introduction

There are various levels of sophistication that forecasting demand can take. The overall market should be forecast first, and then that market can be assigned to various route and mode options based on generalised costs – to give rise to forecast demand by route and mode.

Market

Market forecasts at their simplest can be based on observing historic trends and assuming they will continue into the future, or with a manual adjustment. For example, historical figures for total inland tonne kms by road and rail could be found, and these could be projected forward into the future. For long term forecasts, it is normally better to take a long historic view as the basis for the projection. For a short-term forecast, recent history is typically more important, albeit specific events can skew trends.

If there is a logical justification for other parameters to be drivers of freight transport volumes, and there are exogenous forecasts for these parameters (or forecasts can be made), then it may be worth comparing historical changes in these parameters and relating them to freight transport through a series of multiple regression analyses. If a good correlation is found, suggesting that a particular parameter is a good driver of freight transport, forecasts of the parameter can be used in combination with the regression analysis results to forecast the freight market.

Potential explanatory-variable examples include population, GDP and exchange rates. There may be some explanatory variables for specific industries, relating for example to energy policy. These forecasts can be produced at a national level, or at a regionally disaggregated level.

It should be noted that sometimes there can be a lag effect, where an explanatory variable changes and then, some time later, the impact is felt on the freight transport volumes.

There is much more detailed data on trade (very detailed commodity, overseas partner country and port) than there is for domestic road movements. It may therefore be possible to conduct a more disaggregated forecast analysis for different components of trade. There may be a wish for this to take on board any expected changes in trading relationships with particular countries or for particular commodities. For example a comprehensive trade deal could be expected to boost trade with that country beyond its long term trend. Conversely leaving an existing trading block and introducing barriers to trade is likely to reduce trade below the long-term trend.

Cost

Forecasts of general cost components such as fuel and drivers' wages can be taken from the DfT's TAG and applied to all modes. Other cost changes may be considered relevant depending on what the scenario is to be used for. For example model runs focussing on forecasting rail traffic demand could consider different scenarios where cost components of particular relevance to the rail industry were varied, such as train length, wagon type, maximum axle loads and loading gauge (bridge heights).

The level of detail and sophistication in choosing which demand forecast method to use should be based on the focus of the scenario. For example, if the focus is road freight, then details about changes to rail services should be simplified to avoid distraction.

Changes in infrastructure can be included in demand forecasts if they change the cost of operating.

9.5 Split between modes, vehicle types and routes

Once an origin destination matrix is established, it can be split between modes, vehicle types and routes. Given the importance of shipping routes in determining which ports' traffic 'appears', it is important to incorporate the maritime mode, particularly as technical developments may lead to a radical reduction in emissions from shipping as the 'price' of emissions becomes part of future transport costs. Intermodal coastal shipping (i.e. shipping services transporting trailers and containers) may emerge more strongly in the future.

For rail, a series of services needs to be available to assign to, such that the model can determine the through cost incorporating legs:

- from cargo origin by road to origin rail terminal;
- by rail to destination rail terminal;
- by road to final cargo destination.

This service list can either be provided as an input, or the model could generate the list itself based on a knowledge of where terminals and the rail network are, combined with overall demand. There would even be the ambitious option of allowing the model to spontaneously generate terminal locations, but there are many other considerations when choosing where to build a terminal than the model would be able to represent and therefore we would not recommend this approach.

The simplest and quickest representation of the rail option is: for each origin to destination, to choose the lowest generalised cost service (incorporating road legs at either end) from origin to destination and allocate all rail traffic to this service. Alternatively for each origin to destination, all services could be considered, with most traffic allocated to the cheapest rail route. However this could generate a huge variety of options, and take a lot of computing power.

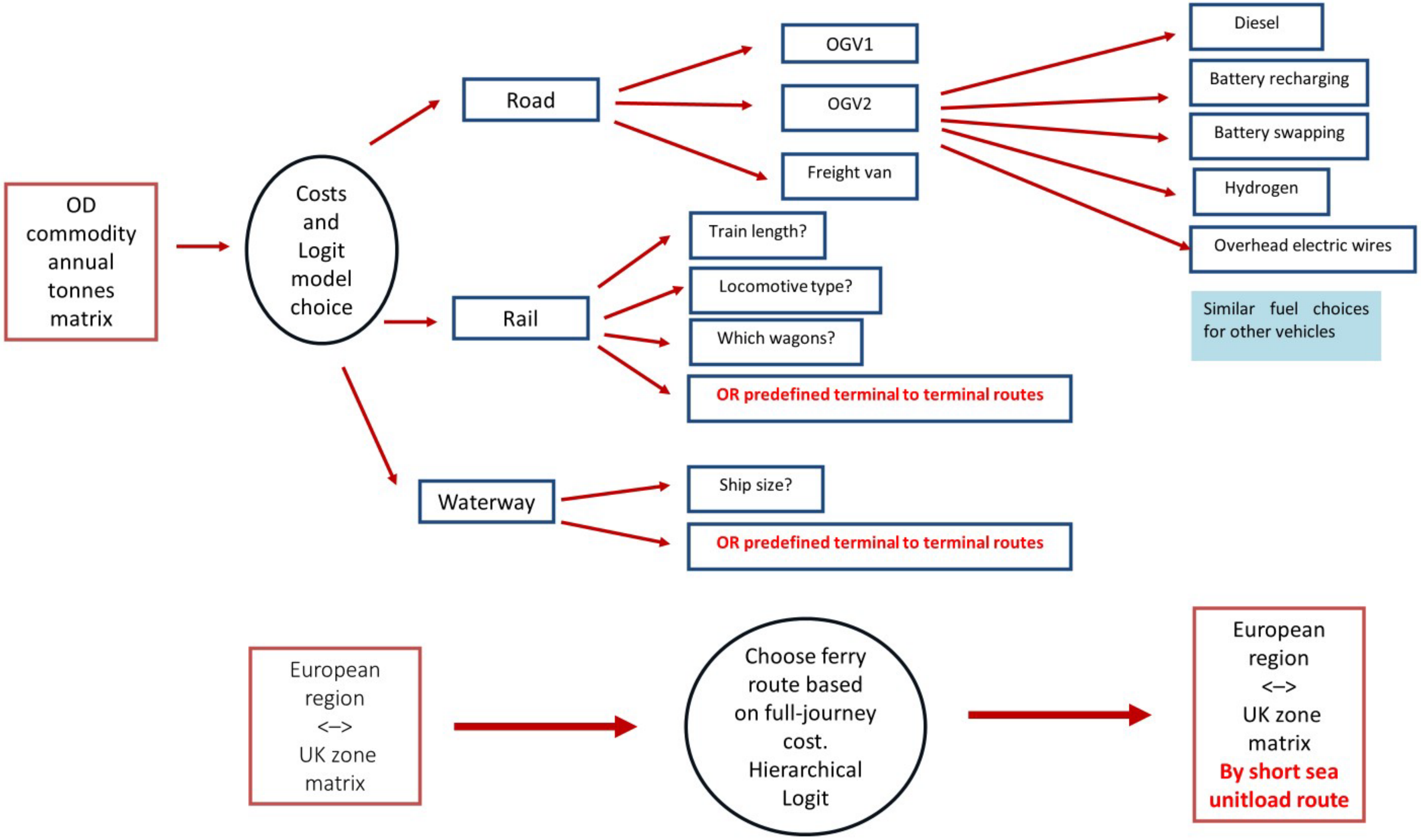
Waterway services are in principle similar to rail in their representation.

A Logit model is probably the most suitable method to consider competition between modes and competition between vehicle type within each mode, and then competition between propulsion types within each vehicle type.

For European unitised trade, the traffic is represented between European region and UK zone. Similarly, for each European region to UK zone, a Logit model can be used to choose between short sea unitload services.

This is represented in Figure 4 below.

Figure 4: Split between modes, vehicle types and routes



9.6 Assigning demand to the road and rail networks

There are options when assigning to a road network.

- If a quick simple output is required, a road OD matrix can be assigned along the lowest generalised cost route for each OD using the Dijkstra algorithm on an All Or Nothing (AON) basis. This calculation would have to be based on a network that included average speeds on each link to find the lowest generalised cost routes.
- A similar approach is to spread the traffic amongst several (parallel, competing) routes to avoid taking an AON approach.
- A more involved approach is to send the road OD matrix to another transport model such as the NTM for it to be assigned there. This can incorporate congestion caused by non-freight vehicles.

Traffic for each road vehicle type could be assigned separately or together.

In order to convert tonnages into vehicles, each vehicle type would have a carrying capacity in the cost models. However HGVs are often not fully loaded to the maximum tonnage. CSRGT records the tonnage carried in each movement and therefore gives a means of translating tonnes in each vehicle type to vehicles by commodity transported. For new vehicle or propulsion types, their tonnes per vehicle by commodity can be estimated based on how their carrying capacity compares to the carrying capacity of existing vehicles and their known tonnes per vehicle.

Empty returns can either be:

- *Included* in this conversion such that all vehicles are always in the same direction as the tonnage. This would mean that assignments are not reliable by direction. As vehicle counts on most main routes are reasonably well balanced by direction, the modelled traffic on a link can be summed over both directions and then halved to give a more realistic representation of the number of vehicles in each direction.
- OR *Excluded* such that this conversion represents loaded vehicles. If that is done, empty vehicles need to be calculated and added into the matrix. This would mean that the modelled vehicle output by direction should be more accurate without the need to sum traffic in both directions.

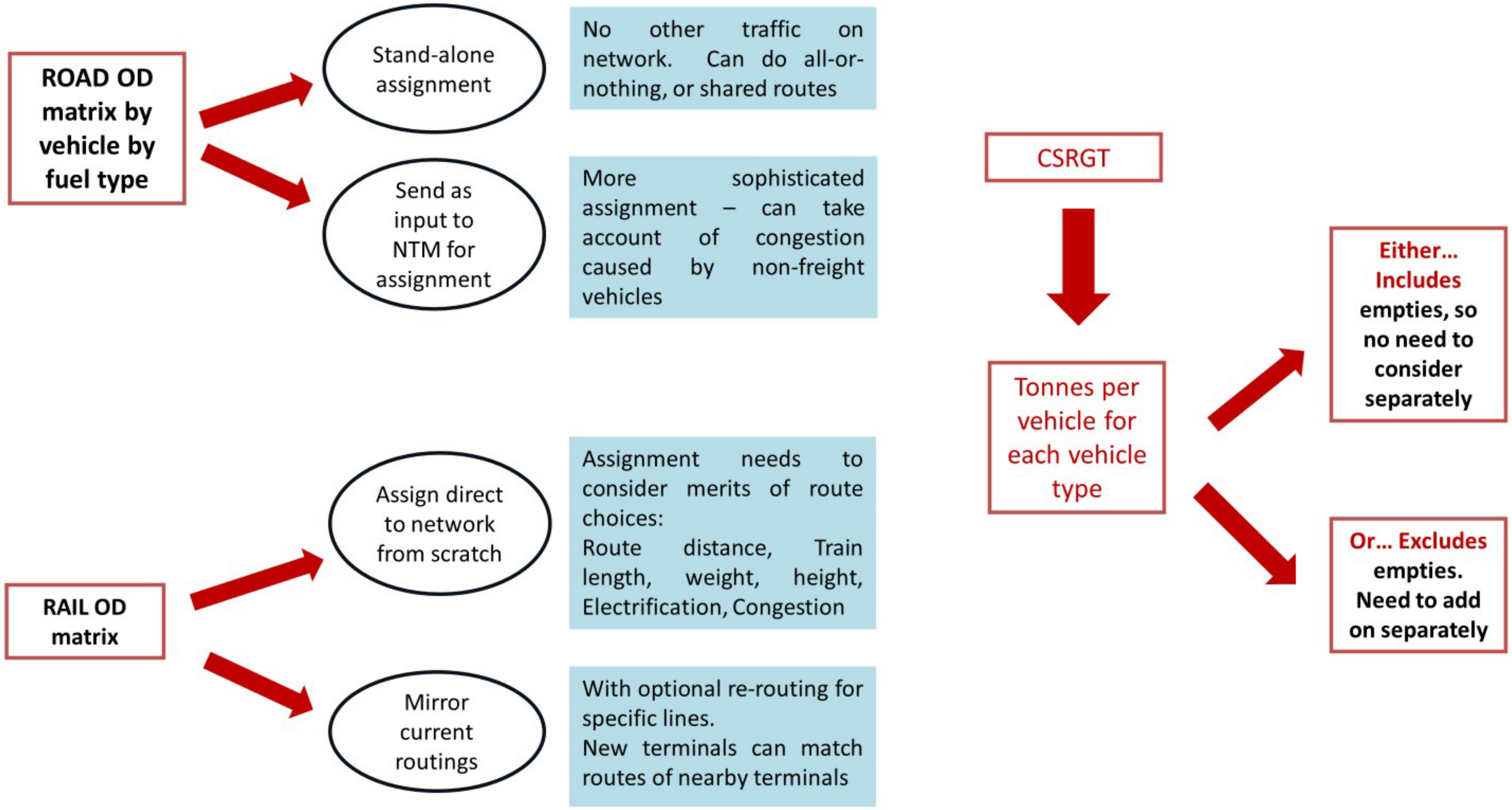
Recommendation: The NFTM should convert tonnes to loaded HGVs, and then generate balancing empty HGV movements to add to the OD matrix (Figure 5).

Assignments to the rail network are more challenging. Either OD traffic can:

- Follow similar principles to road freight assignment of assigning traffic along the lowest generalised cost route; or
- Mirror current routings where possible

Recommendation: **The NFTM should include the facility to match existing rail routings to maximise the realism of the route choices. However there should be the option to allow for routing to be established afresh with consideration of calculated generalised cost. Similarly new routes should have the facility to follow sections of routes of existing services where available, but should also be able to be routed independently of existing services based on generalised cost (Figure 5).**

Figure 5: Assignment to the road and rail networks



9.7 Calibration

Calibration to known values is conducted to ensure that outputs for the base year match observed reality.

Road

For road, outputs can be calibrated to CSRGT – by origin region to destination region by commodity and vehicle type. Such CSRGT-sourced traffics should only be considered valid if they are based on a sufficient number of survey records, otherwise the matrices may be lumpy if based on a very small sample.

Rail

The commodity-specific tonnage on each terminal-to-terminal service can be calibrated to the known tonnage in the base year (from Network rail data) by adding a service-specific cost.

Inland waterways

The commodity-specific tonnage on each terminal-to-terminal service can be calibrated to the known tonnage in the base year (from DfT Waterborne Freight data) by adding a service-specific cost.

European unitised shipping & deep sea container shipping

The number of HGV-equivalent units on each service can be calibrated to the known traffic in the base year (based on DfT Port Freight Statistics) by adding a service-specific cost. Economic rent (particularly at ports) would need to be taken into account in the calibration process.

9.8 Validation

Validation using separate data provides further confidence in the input to, and outputs from, the base year of the model.

Road traffic counts

After road assignment, the resultant traffic counts on each link on the network can be compared to observed traffic counts (DfT Traffic counts (AADF) or WebTRIS from National Highways), by vehicle type. As the NFTM would be a strategic model, the focus should be more on the strategic national network, rather than on roads through urban areas.

Rail traffic

The base year should be calibrated to actual terminal-to-terminal tonnages (Network Rail). However it is good to validate those targets against other data sources too and the Office of Rail and Road (ORR) publishes rail freight tonnes (Table 1315 – "Freight lifted") and rail freight tonne kms by commodity and quarter (Table 1310 – "Freight moved by commodity") which can be used for this purpose.

Busy rail junctions (capacity modelling)

Calculating how busy a rail junction is based on its design and passenger and freight traffic, and is difficult to do in a generic but also robust way. It is therefore important to sense-check which junctions are calculated to be busy with the experience of Network Rail and rail freight operating companies.

Port traffic

Within the NFTM port traffic is likely to be derived from HMRC trade data because trade data gives detailed information on commodity. DfT Port Freight Statistics provides an independent measurement of cargo through ports, by mode of appearance, which can be used for validation purposes. Similarly the "Road goods vehicles travelling to Europe (RORO)" survey gives another independent count of RORO movements.

Cost models

Private companies are often reluctant to reveal how much they actually pay for transport and the components that make up that cost (wages, assets etc). However validation of the cost models should be done where possible which could be achieved by describing cost model results to a small panel of transport company representatives, , such as road hauliers, rail freight operating companies and shipping lines.

Given that the results of any modelling using the NFTM could have a direct impact on the value of privately held assets (e.g. ports, strategic rail freight interchanges) and that a crucial element of the modelling validity will be based on transport costs it will be important that impacted private sector players will have confidence in the model and freight rates upon which behaviour is assumed to be based.

9.9 Capacity constraint

Road

Road capacity constraint could potentially be incorporated into FAME but it probably makes sense to make use of existing modelling frameworks such as the National Transport Model (NTM). Road capacity constraint relies on a knowledge of the road network's capacity and the total amount of traffic on each link. Such a model could return revised journey time skims back to FAME to enable the NFTM to be re-run as a feedback loop. For example, forecast congestion on routes between two zones should feedback to NFTM and cause a reduction in road traffic through a switch to alternative modes and a reduction in demand. There could potentially be several rounds of feedback until NFTM and the road assignment model converged.

Lorry parks & motorway service areas

Lorries park in a wide range of areas, including at designated lorry parks and motorway service areas. It would be possible to represent such areas within the model. However they tend to be located at places that do not require much deviation from the route the HGVs would be taking anyway. It is simpler therefore to just assume they are available as required, in a similar way to diesel refuelling opportunities.

It is possible that some scenarios might impact on the need for and location of lorry parking, such as:
- a large switch of long distance traffic to rail;
- a move towards autonomous HGVs;
- a switch away from the Dover Straits;

For such scenarios, the reduction in HGV traffic (particularly long-distance traffic) in an area could be taken as a proxy for reduced need for lorry parks.

Rail

The rail network operates a planned timetable system whereby timetabled paths through the network have to be agreed with the network operator. If there is no space in the timetable, such paths will be denied. Therefore instead of increased traffic resulting in increased costs through congestion, rail freight demand can be suppressed.

One approach to calculating capacity available to rail freight is to establish the network capability at each junction and the expected passenger timetable. Any remaining capacity at each junction can be considered available for freight. Freight demand can therefore be added until any junction enroute becomes full. Demand beyond that would be suppressed and forced to use road.

This approach implicitly assumes that all passenger trains should have higher priority than all freight trains. However the value of higher-value freight trains is higher than the value of lower-value passenger trains.

One policy option that might be tested would be to attach a value to every freight train in a freight demand forecast, and attach an equivalently calculated value to every passenger train, and then allocate capacity through each junction with the highest value trains being given greater priority.

The value of trains could be calculated by assuming the alternative is to go by road. The extra user cost (haulage cost) plus any extra non-user cost (net externalities of using road instead of rail) of going by road could be calculated. However each service should be investigated further because often the most rational economic response instead of directly switching to road, would be to change the origin or destination, or cease operating the traffic. Being able to change the origin or destination would mean the value of the train is lower. Ceasing operating the traffic could result in industrial closures which could mean the value of the train should be calculated as higher. This may not be possible within a model and may require exogenous calculations and manual intervention.

Ports

Constraints on shipping capacity in the long term are dependent on the capacity of ports, because if ships serving the port are full, larger or more ships can be chartered if the port can accommodate them. However acquiring such ships can take time so that, in the short term, capacity is restricted by both the ports and the shipping services.

A sub-model may be required that assesses port capacity by mode of appearance according to selected parameters (e.g. length of quay, number of cranes etc.) based upon an inventory of port capacities (this used to be maintained by the National Ports Council until 1980). This would need to be updated.

For any ports or services for which the model is representing competition, capacity limits can be represented by a process equivalent to calibration where the model is repeatedly run;

- Run the model
- Any ports or services with excess traffic have an extra cost attached to them;
- Re-run the model until no port or service is over-capacity.

It would also therefore be possible to assess the impact of increasing a port’s capacity by, say, 10%.

Recommendations:

- **Include the option to interact with the NTM to represent road capacity if that is practical;**
- **Incorporate a description of the rail network and details of passenger train services in order to be able to assess capacity available to freight under a variety of network and passenger train scenarios;**
- **Incorporate functionality to calculate port capacities by mode of appearance, and then limit throughput to these capacities.**

9.10 Alternative scenarios

Any of the inputs to a NFTM can be changed for an alternative scenario and the model should be designed to allow for anticipated scenarios, such as:

- Changing any element of the cost models (e.g. introducing road pricing or changing the assumed price of oil) for any mode, vehicle type or propulsion type. The Logit model would then re-share the traffic accordingly.
- Changing the time, distance and toll skims.
- Adjusting the OD matrix in various ways:
  - It can be adjusted to represent adding warehousing in specific locations or changes in employment.
  - In theory the base year matrix generation can be repeated for alternative assumptions. However because the initial matrix generation relies on scaling to CSRGT and other real base year data, there is a difficulty in replicating that same scaling in a consistent way for a forecast.

While many anticipated scenarios should be explicitly accounted for within the NFTM, it is inevitable that many scenarios require innovative approaches to ensuring that the model represents what is required. This would probably require specialist input from freight transport modellers and economists.

Any scenarios would be developed in the Scenario Studio, which would provide the ability to generate scenarios within certain pre-defined parameters and also provide access to assumptions and parameters from previous scenarios that have already been run.

9.11 Assessing the responses of the model

Backcasting

One means of assessing the responses of the NFTM would be through backcasting, whereby instead of running the model for a future year, the model is run with inputs representing a historic year. The model's response can then be tested by comparing against actual data for that year.

In principle this can be a good test of the functionality of a model, but in reality it is often rare to get large isolated changes in parameters for which responses are represented in the model. The effect of small changes in parameters are often "drowned out" by other unmodelled changes that are occurring in the background, so that it is difficult to isolate any real-world response. If significant real-world large, isolated changes in parameters for which responses are represented in the model can be identified, then they can be used to test responses.

For example, if a shipping line discontinues a ferry service, the vast majority of its traffic will find alternative routes to use. In 2013 the Ramsgate – Ostend ferry service closed. This closure could be represented in the model, and the modelled increase in traffics on parallel services could be compared to actual traffics.

A larger disruption came with the opening of the Channel Tunnel and the introduction of Eurotunnel Freight Shuttle services using rail technology for accompanied HGVs in the early 1990s, which could be similarly modelled. However the competing ferry operators via Dover also significantly reduced their freight rates in order to compete (an example of economic rent being severely reduced through a change in the competitive environment), so it is difficult to directly compare the market offering before and after. This illustrates the need for cost modelling to be applied to all relevant modes so that a competitive environment can be replicated.

For another example in late 2021 there was a shortage of HGV drivers. This pushed up the generalised cost to hauliers of operating services and encouraged a switch to rail for traffic for which the generalised cost of using rail was previously only slightly higher than using road. Such cost changes could be input into the cost models and the modelled response could be compared to the actual response. However, as with backcasting, there were a number of other things going on at the time that would have affected demand by mode when trying to quantify the real-world changes. Also, the rail industry may not have thought that this was a long-term change and therefore did not want to make significant changes to its service offerings, only to have to withdraw them if HGV driver availability increased.

Comparison to other models

Comparisons can be made to the responses of other trusted models. For example there is significant overlap between FAME's and GBFM's expected modelled responses and these could be compared to provide assurance.

Often "back-of-envelope" or simple spreadsheet models can represent a particular response well. Looking at the cost models to establish the cheapest propulsion type for different journey types and distances could be done to investigate how NFTM allocates traffic to vehicle and propulsion types.

There are many potential responses that the model can make to changing scenarios. As there are few similar models that attempt to replicate all the functionality aspired to in FAME, the scope for assessing the responses in the model is lower than for a typical generic transport model.

Recommendation: An assessment of the functionality of the NFTM should be carried out once it has been developed through a programme of backcasting (using the model to simulate the impact of past events for which there is reliable historic data, while taking account of other background factors) and comparing the results with reactively simple spreadsheet models which have been developed for specific purposes within the DfT. It would also be possible to compare outputs with the results from other trusted freight transport models with essentially the same geography and functionality, such as the GB Freight Model.

9.12 Relationship of NFTM to appraisal

The outputs of scenarios from the NFTM in terms of changes in user costs (the financial costs of providing freight transport services) and in non-user costs (the external costs to society) should be used to provide an estimate of the benefits of transport schemes with the appraisal of schemes using cost benefit analysis (CBA).

This requires that the values included in the NFTM and the DfT's Transport Appraisal Guidance (TAG) for its Core Scenario are both consistent with each other and reasonably accurate to reflect real-world costs in the base year. Similarly, the values included in the NFTM and the DfT's Common Analytical Scenarios (CAS) - which seek to reflect the uncertainty around the future economic and technological environment - need to be consistent with each other.

Within TAG the full market-based cost of road freight transport should be used, including:

- The salary of the driver(s);
- The cost of the fuel (excluding VAT, as it is a business and so there is no impact on decision-making); and
- The non-fuel vehicle operating costs

The costs should be expressed in terms of a variable cost per kilometre and a fixed cost per hour. The non-fuel vehicle operating costs should include the full capital cost of the vehicles and its financing, spread over its useful economic life and its annual operating hours.

A similar approach needs to be taken to all other modes, with a particular emphasis on rail freight as this is the main inland mode which competes with road freight transport.

Calculations of non-user costs should be based on standardised calculations of net external costs. Consideration should be given to whether Marginal Economic Costs (MECs) or Modal Shift Benefits (MSBs) are the most appropriate measure of net external costs to use, with a particular attention being placed on the value of carbon emitted.

10 SCENARIO STUDIO

10.1 Introduction

The Scenario Studio would provide access to assumptions and parameters from previous scenarios that have already been run (and therefore already subject to Quality Assurance processes) and provide the ability to generate further scenarios within certain pre-defined parameters. It would be the only way for non-expert freight transport modellers to run scenarios.

Some of the assumptions and parameters, such as macro-economic indicators and population size, are already included in DfT's Transport Appraisal Guidance (TAG) Databook and Common Analytical Scenarios (CAS) Databooks and so would be immediately available for use within the Scenario Studio. Making use of these Databooks within the Scenario Studio would ensure that the NFTM can be used on a consistent basis with TAG and CAS to develop both a core scenario and sensitivity analysis for the estimation of the benefits of transport infrastructure schemes and the impact of policy levers on the freight transport market.

Market-based factors affecting assumptions in the Scenario Studio, where market players (principally shippers/receivers and transport operators) determine behaviour, and their market-led response would be simulated in the NFTM. As the road freight transport market, in particular, is competitive, policy-makers can have a significant impact on these factors through a wide range of policy levers.

10.2 Variables for scenarios within the Scenario Studio

The available parameters and potential scenarios are informed by assumptions on a wide range of factors that can be changed and therefore allow new scenarios to be tested and a comparison made with the base case. These factors, which may include forecasts for future years, would be as follows:

- Macro-economic indicators: principally GDP for the UK, or GVA for other geographies within the UK, as the main established measure of economic growth. These are exogenous factors which are external to the freight transport market in its own right but have a significant impact on it. Assumptions are already available in the TAG and CAS Databooks.
- Demography (principally population size). Again, these are exogenous factors which are external to the freight transport market but have a significant impact on it and assumptions are already available in the TAG and CAS Databooks.
- Emergencies (e.g. severe congestion at a major port). This is an exogenous factor in that emergencies are one-off external events that affect the freight transport market. Assumptions would often not be directly available and there would be a need for the development of bespoke assumptions within the Scenario Studio. Parameters used in scenarios will depend on the nature of the emergency, but could be extreme in that (say) a port would need to be "closed" in the scenario by increasing the cost of using that port by

imposing a very high toll on all traffic through the port to force the traffic to move to another route/port.

- Freight transport costs by mode, type of vehicle and fuel type/technology (diesel, battery electric, hydrogen etc.): these market-based assumptions are fundamental to the functioning of the NFTM and should be included in the DfT's TAG and CAS Databooks (see section 9.12 above). Parameters would be available from the Databooks but could be changed as a result of the DfT pulling various policy levers. Some of these levers could be quite "strong", such as reducing taxation of some fuels to zero or banning certain vehicles from some geographic areas (implying increasing the cost of those vehicles to a very high level to deter all traffic).
- Land use: assumptions related to changes in the amount and location of different land uses such as warehousing would be most likely to be market-based (involving private sector investment), but would be strongly affected by policy levers such as planning policy. Assumptions would often not be directly available and there would be a need for the development of bespoke assumptions within the Scenario Studio. Parameters used in scenarios will depend on the nature of the emergency, but might need to be limited to growth or reduction of (say) 20% in the traffic associated with warehousing in any year in any given zone to reflect the practical realities of changing land use quickly within the planning system.
- Policy interventions or policy levers (e.g. road pricing, change in tax on diesel, carbon pricing): assumptions related to changes in the policy or regulatory environment within which the freight transport market is operating. Assumptions would often not be directly available and there would be a need for the development of bespoke assumptions within the Scenario Studio, which would be possible as long as they can be translated into generalised costs for use as an input to the NFTM cost sub-models. For example, the impact of an increase in fuel duty can be tested by increasing the taxation level in the HGV and LGV road costs models by the required amount and then running the NFTM and comparing the outputs against the base case. Parameters used in scenarios will depend on the nature of the policy lever but could be quite "strong" to strongly incentivise or disincentivise certain behaviour in the market, perhaps to pursue environmental objectives or radically change the taxation system for freight vehicles.
- Infrastructure developments (e.g. addition of new road link): assumptions related to the impact of changes in the road or rail freight network. Assumptions would often not be directly available because they would need to be geographically specific and therefore there would be a need for the development of bespoke assumptions within the Scenario Studio. Parameters used in scenarios will depend on the nature of infrastructure enhancement but could include reductions in journey times between origin-destination pairs, which would be possible as long as they can be translated into generalised costs for use as an input to the NFTM cost sub-models. For example, the impact of an increase in fuel duty can be tested by increasing the taxation level in the HGV and LGV road costs models by the required amount and then running the NFTM and comparing the outputs against the base case. Of particular interest for DfT policy makers would be the potential policy levers that could be modelled using the NFTM.

10.3 Managing scenarios

The Scenario Studio would therefore be the access point to using the NFTM within FAME and would ensure that only realistic scenarios can be run, given the wide range of DfT teams that might want to use the model. This ensures that:

- There is consistency in the development and running of scenarios;
- The NFTM takes account of basic freight transport economics and the functioning of the freight and logistics market in the UK, avoiding attempts to use the NFTM in inappropriate ways for which it has not been designed;
- There is an audit trail showing who has run what scenarios and with what assumptions;
- Users are able to set up a new scenario with little difficulty.

To make it easier for a user from different backgrounds within the DfT to use the NFTM, the Scenario Studio should:

- Have some pre-defined standard scenarios from which changes can be made. These could be based on the Common Analytical Scenarios (CAS) that have already been developed by the DfT, as applied to the freight market;
- Restrict the level of change that can be applied to specific variables to ensure values are kept within expected normal operating limits of the model;
- Keep a record of every scenario run, such that it can be recreated or adapted.

10.4 Definition of scenarios

In order to maintain this record of a scenario developed and run, each would need to have:

- A unique ID number;
- A short text name, defined by the user, which concisely describes the scenario’s nature or purpose;
- A date stamp for when the scenario was run;
- Values for all parameters that have been changed and the absolute change compared to the base case (with units, such as £GBP);
- No change specified against parameters/variables that have not been changed;
- Name and DfT team of user that ran the scenario, with contact details (email address and telephone number).

This would allow users to browse scenarios that have already been run so that the results can be re-used wherever possible rather than wasting resources on new runs. To promote the use of the results from new scenarios, the above information on each new scenario that has been run using the NFTM could be communicated to a list of DfT users with a particular interest in freight modelling.

The Scenario Studio should be designed with a web interface so it could be accessed and then scenarios run remotely by a wide range of users.

However there are often likely to be input files that need building for a new scenario (perhaps a more complex scenario), so having access to the model's input and output directories, with standard Windows software such as text editors, Excel and Access would also be beneficial for more skilled transport modellers and, where appropriate, with the assistance of freight transport economists. For example, adapting the base year OD matrix to represent a future scenario could involve scaling up the matrix in line with population or GDP or some other determinant of growth, while incorporating freight generators such as new warehousing.

10.5 Outputs of scenarios

Once a scenario had been developed and run, the results of the scenario would be available only to the DfT user/team that set up the scenario. This is because individual DfT teams have their own data storage and, although DfT TASM would host the NFTM, it would not be able to store outputs. The results of each scenario would be available by contacting the relevant DfT team and the contact details would be available in the Scenario Studio.

11 FREIGHT DATA WAREHOUSE

11.1 Introduction

The Freight Data Warehouse would be a repository of relevant freight data for use as inputs into the NFTM. It would therefore include all of DfT's official freight statistics, as well as any other relevant data from external sources, in a format that makes them accessible as inputs to the NFTM for the development of origin-destination matrices and traffic generation.

Data from the Freight Data Warehouse can be further disaggregated by means of Value Added Data Analysis, such as to break down data from the modelled scenarios by season, time of day and very detailed (local) geography.

Information on the recommended data inputs to the NFTM are set out in section 6.2 below.

11.2 Data inputs to the model

There is no point conceptualising the NFTM if the data needed to populate it is unavailable now and is unlikely to be available in future. Below we list and briefly describe the data sources that would be available to inform FAME, by main topic:

Data for road freight is provided in Table 4.

Table 4: Road freight data sources

Type of data required	Data source	Details
Road HGV OD	DfT Continuing Survey of Road Goods Freight Traffic (CSRGT)	A survey of road goods transport. The survey is designed to avoid bias. This provides origin-destination by commodity tonnage and vehicle data for the model at an aggregated-zone level.
Road LGV OD	DfT LGV surveys 2002-05 & 20219-20	The 2002-2005 survey is old but does provide traffic matrices by origin-to-destination by land-use-origin to land-use-destination and by purpose (freight, servicing or passenger). The 2019-2020 does not provide such origin-to-destination information, but includes more recent information on purpose.
HGV & LGV fleet	HGV & LGV vehicle registrations (DVLA)	Indicates the number of registered vehicles by type.
Traffic counts	Annual Average Daily Flows (AADF) – DfT WebTRIS, National Highways	Traffic counts for all major roads in Britain by vehicle type. This would be used for validation of the model's road assignments.
Highways network	Road network in National Transport Model v5 (DfT)	Road network for assignment or skims from the model.
	Ordnance Survey Highways Network	An alternative to the network in the NTM v5.
Routeing of HGVs & LGVs	Telematics/GPS data (INRIX & other providers)	Useful to determine typical routes between origins and destinations and their journey times.
International road freight demand	DfT Road Goods Vehicles Travelling to Europe	Survey which counts and categorises RORO vehicles travelling to Europe by overseas country and accompanied HGVs versus unaccompanied trailers.
Road cost model	Motor Transport Cost Tables/DVLA, HMRC, BEIS	Motor Transport is a trade publication for the road haulage sector, which provides typical cost being experienced in the market. Official Government publications and department websites provide information on taxes and duties payable to Government.

GPS data has been suggested above only as a means to determine typical routing and journey times. This is from a sample of road freight vehicles that are fitted with GPS technology to track their journeys and locations from ignition start to ignition off with an accuracy of around 5 metres and therefore, at first sight, appears to be a source of OD data. However, this does not necessarily represent the origin and destination of the cargo, or even the vehicle's journey if stops are made enroute and the data is from a small sample of around a few percent of the whole population. There is no attempt to avoid bias within the data, so that grossing up could result in a skewed matrix that is just based on those vehicles that happen to have the GPS technology fitted by the particular company that provides the data. It therefore should not be used for the development of an OD matrix.

The detailed costs to allow the development of a road freight cost model are available in the public domain because there are a large number of buyers and sellers of road haulage and there is high quality information available. However, there are no such sources of information for other modes because only road haulage is so uniform in terms of unit capacity and so highly competitive. Freight rates for other modes often include economic rent and for this reason the development of cost models for non-road modes requires market experience and an understanding of the commercial mechanisms involved.

Public domain data sources for rail freight are set out in Table 5.

Table 5: Rail freight data sources

Type of data required	Details	Source
International rail freight demand	Eurotunnel shuttle: HGVs with accompanying drivers between Folkestone and Calais.	Eurotunnel[17]
Rail network[18]	A coherent network would need to be developed data by joining mapped links together so that origin to destination demand data can be assigned along the shortest or lowest generalised-cost route. Coded location information (e.g. Stanox codes) would need to be attached to the network to reference origins and destinations on the network.	Ordnance Survey

Public domain data for maritime and waterborne freight transport is provided in Table 6.

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[17] Eurotunnel publishes its freight shuttle traffic every month and so the annual total is available on its website in January each year.

[18] MDS Transmodal has developed its own rail network for use with GBFM, but this could be duplicated by DfT in the way described.

Table 6: Maritime, waterborne & air freight data sources

Type of data required	Details	Source
UK trade data	Tade data in tonnes provides a measure of the demand for international freight transport movements by port of entry including airports and the Channel Tunnel. It complements, or can be used as an alternative to using port freight statistics. Since leaving the EU, trade data specifies the tonnage, detailed commodity and UK port/airport of entry and exit.	HMRC trade Data
Trade data by European region	For road freight only, data is available on trade by ITL (NUTS) 1 overseas region as well as country for short sea trade.	Eurostat
Port freight demand	Published data shows tonnage and units data by UK port, mode of appearance and the other-end country. In the published data, the port is the statistical port (for example "London" is one statistical port, rather than being broken down by terminal).	DfT Port Freight Statistics
Inland waterway demand	Details the amount of traffic on specified inland waterways, including the detailed wharves of origin and destination by commodity.	DfT Waterborne Freight Statistics
Air freight demand	Traffic in tonnes transported by airport, with a split between international and domestic and between bellyhold and cargo aircraft	Civil Aviation Authority
Maritime service capacity	AIS data showing the location and movements of ships can be linked to ship databases to identify ship characteristics, including their capacity. This can then also be linked to shipping services to estimate the parameters and therefore costs for shipping services as well as their capacity.	Automatic Identification System (AIS) data providers e.g. Marine Traffic
Port capacity[19]	Estimates of port capacity would require the development of a database on the parameters (e.g. depth of water alongside, terminal space for storage) of individual terminals by mode of appearance at each relevant port and the use of generic calculations of port capacity.	Individual port websites, satellite photos

The last official survey of the inland origins and destination of cargo was carried out by the DfT in 1996, following a more comprehensive survey in 1992. This is now an old data source and, although some ports carry out their own unofficial surveys, there is no consistent source of rent reliable data available.

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[19] MDS Transmodal has developed a proprietary database of terminal parameters in the past for use with clients; this could be replicated if the DfT wanted to provide a measure of terminal capacity.

Table 7: Macro-economic & land use data

Type of data required	Details	Source
Size & location of warehouses	Data useful as key origins and destinations of freight movements. The data shows the precise location and area with shapefiles covering the site area, and the surrounding parking areas together. Having the precise location and area means that the warehousing site can be accurately attributed to the relevant model zone. Most warehousing in the OS data is covered by "Distribution and Storage" and "Industry and Business" categories, although some significant warehousing sites are missing from the whole database, such as Asda's large Magna Park warehouse.	Ordnance Survey
Employment data by industrial category	Number of employees by Standard Industrial Classification (SIC) by any zone structure. HSL derived this from the Inter-Departmental Business Register (IDBR) which provides information on 2.1 million businesses in the UK. Similar data is publicly available at the MSOA level from the Business Register and Employment Survey (BRES) and Nomis (a service provided by Office for National Statistics) also publishes statistics related to population, society and the labour market at national, regional and local levels.	Health and Safety Laboratory (HSL)
Population data	Population for base year and forecast years are included within the DfT's National Trip End National Trip End Model (NTEM)	DfT NTEM
Supply and Use Tables	A "Supply" table is a matrix that shows the total monetary value across the country that each Standard Industrial Classification (SIC) generates, split by the type of product (commodity or service) produced. Similarly a "Use" table shows the monetary value that each SIC consumes, split by the type of product (commodity or service) consumed linking producing industries to produced commodities, and consuming industries to consumed commodities.	Eurostat

11.3 Filling data gaps

There are several data gaps that could potentially be filled or partially filled, which would facilitate more accurate representation of freight movements, or could enable further modelling capabilities to be developed within the NFTM.

However when designing a model, the availability of existing data and the challenges associated with filling any data gaps should always be balanced against how much the model's functionality would be improved by that extra data.

Enhancing CSRGT

CSRGT could be enhanced by asking respondents to provide information on the stage in the logistics chain that each movement is in, as this would enable the separation of movements into and out of warehouses for scenarios involving different warehouse locations. This could be achieved by introducing a question on land use. However, judgements have to be made regarding surveys as the more information is sought, the less patient the respondent will be and the reliability of the responses often deteriorates. It may also be difficult to unambiguously define the question on land use so that the respondent could easily understand the question and know how to answer it.

Some estimates of logistics stage can be made without additional data, on the basis of the vehicle type, mode of appearance, commodity, origin and destination. For example a maritime container from Felixstowe port to the Northampton area is likely to be arriving at a National Distribution Centre.

Knowing the departure and arrival times of each HGV movement would mean that dwell times at origins, destinations and depots could be determined. This would help in understanding how feasible recharging at those locations could be. However this would add a significant burden to survey respondents, and the resultant data may not be reliable.

Rough estimates could be made of dwell times using the existing survey, based on the origin, destination and journey distance of each movement to estimate the journey time. Adding up the estimated journey times for a day could indicate the likely stationary time during that 24 hour period. However this would be the total, rather than the stationary time at each delivery / pickup point.

GPS data for road freight vehicles

More data could be purchased by DfT from a variety of providers to increase the sample size in the coverage of road freight vehicles. This would reduce the risk of bias in the sample population so that the data could be grossed up to represent all freight vehicles. An attempt could be made to better reflect vehicle movements from origin through to destination, by removing engine-switch-offs for refuelling, or service station or depot stops to assess vehicle utilization. This could lead to a better understanding of HGV dwell times at origins, destinations, depots and truck stops, to improve understanding of opportunities for re-charging batteries.

CSRGT data does not provide detailed data for multi-stop journeys. However GPS data would treat every stop in a multi-stop journey as the end of one journey and the start of a new journey. That would give a much more complete representation of movements and would allow the daily movements of each HGV to be built up to compare to likely charging regimes for electric vehicles.

DfT LGV Survey

The last survey that collected origin-destination movement information was in 2002-2005, but the movement of freight in vans has changed significantly since 2005, so an update to the survey results would provide a more robust basis for understanding LGV movements for freight purposes. However it is difficult to carry out a robust van survey due to respondents not providing reliable data and the very high frequency of individual deliveries. It may be worth the DfT considering using transponders to record the behaviour of a representative sample of vans from major distribution companies over periods of time.

The OD information from 2002-2005 surveys could be combined with more recent surveys. For example, journey purpose proportions from the 2020 van survey could be used as control totals for the 2002-2005 survey.

Mobile phone data

Mobile phones of HGV drivers can be tracked as they move, with the data then being sold on an anonymised basis by the network operators. There are efforts to filter just the movement data from mobile phones belonging to users when they are actually driving HGVs and this would potentially generate a much larger sample size than the current GPS data. However location precision is lower and there do not appear to be validated results to confirm the robustness of the filtering of HGV drivers. There may be some instances where these limitations could be overcome such as for isolated ports where there is little ambiguity that a mobile phone in an area must belong to an HGV driver in the port.

Automatic Number Plate Recognition (ANPR)

If enough ANPR cameras were placed around the country, a reasonably complete OD matrix could be generated, with the zone size dependent on the number and placing of cameras. When combined with registrations data from DVLA, this could associate each number plate with a vehicle type and various other information. However, this relies on accurate reading of number plates and whether it is sufficiently reliable to produce a robust data set. Overseas-registered vehicles could not be so readily identified unless agreements were reached for vehicle registration databases from other countries, or details could be gathered as those vehicles entered the UK. In addition, this data source does not provide any data on the commodities being transported.

There is the potential to integrate data from CSRGT, GPS, mobile phone and ANPR data to take advantage of the strengths of each source together.

CSRGT benefits from being a representative sample, but has a small sample size and lacks geographical precision. Large-zone to large-zone summaries by commodity from CSRGT could be used as control totals for OD matrices generated from the other sources if they have limited coverage or are not a representative sample.

GPS data is geographically precise and could provide the detail within CSRGT's large-zone to large-zone summaries. Mobile phone data could offer the equivalent.

ANPR could refine the CSRGT OD matrix, with a near-complete coverage of vehicles crossing the cordons with cameras.

Survey of the inland origins and destinations of port traffic

No official survey of this type has been carried out since 1996 and would be useful to validate the modelled data in the NFTM for the inland distribution of freight to and from ports by mode of appearance at the port and by inland mode. This could be carried out by the DfT using a survey of import and export consignments based on a sample of customs returns completed by importers and exporters. Following the UK's departure from the EU Customs Union, these are available for all trade through all ports, airports and the Channel Tunnel.

Recommendation: The priorities for additional data collection to improve the functionality of the NFTM should focus on collecting additional data on the origins and destinations of freight movements by:

a. enhancing the CSRGT to include some information on the land use of origins and destinations of journeys,
b. collecting additional data on the origins and destinations of LGVs and
c. carrying out a survey of the inland origins and destinations of port traffic by mode of appearance at the port and inland mode.

11.4 Data outputs from scenarios

Introduction

Detailed results from the scenarios would only be available to the relevant user and DfT team, with most outputs being database-style text files. The main themes for the data outputs, which would be provided in absolute values and accompanied by the equivalent values for the base case to allow meaningful comparisons, are described in more detail below.

Road traffic

The data for freight transported by road between an origin zone and a destination zone would be as follows:

- Origin zone and aggregated areas;
- Destination zone and aggregated areas;
- Port (if relevant);
- Import / Export / Domestic;
- Commodity;
- Mode (OGV1, OGV2, LGV);
- Vehicle type (diesel, battery electric, hydrogen fuel cell)
- Tonnes of freight transported
- Number of vehicles (by mode and by Passenger Car Units, PCUs)

As well as the number of vehicles by road mode, PCUs is a useful measure as an output so that it can used directly alongside passenger traffic in a highways model.

Rail traffic

The data for freight transported by rail between an origin zone and a destination zone would be as follows:

- Origin rail terminal;
- Destination rail terminal;
- Commodity;
- Tonnes;
- Number of HGV-equivalents;
- Trains (split between intermodal and bulk);
- Original cargo origin zone;
- Final cargo destination zone.

As many intermodal rail freight services are not between rail-connected locations such as Strategic Rail Freight Interchanges (SRFIs), a distinction needs to be made between OD terminals and OD zones. This allows for the simulation of the economics of intermodal transport chains.

Inland waterway traffic

The data for freight transported by inland waterway between an origin zone and a destination zone is similar to rail freight and would be as follows:

- Origin terminal/wharf;
- Destination terminal/wharf;
- Commodity;

- Tonnes;
- Number of HGV-equivalents;
- Barges (split between intermodal and bulk);
- Original cargo origin zone;
- Final cargo destination zone.

Short sea unitised shipping traffic

The data for freight transported by short sea unitised shipping between an origin zone and a destination zone would be as follows:

- Origin port terminal (UK and continental mainland or Ireland);
- Destination port terminal (UK and continental mainland or Ireland);
- Commodity;
- Tonnes;
- Number of HGV-equivalents; (split bet;
- Mode of appearance at the ports (accompanied HGVs, unaccompanied trailers, shipborne port-to-port trailers, short sea LOLO);
- Original cargo origin zone (UK and continental or Ireland);
- Final cargo destination zone (UK and continental or Ireland).

The data is similar to rail freight, but also includes data on the mode of appearance at the port (which is also how the traffic was transported on the short sea unitised shipping services), as this affects the generalised cost of the zone-to-zone transport cost and the routeing by service.

Deep sea container shipping traffic

The data for freight transported by deep sea container shipping between an origin zone and a destination zone would be as follows:

- Origin port terminal (UK and world region);
- Destination port terminal (UK and world region);
- Commodity;
- Tonnes;
- Number of HGV-equivalents and Twenty Foot Equivalent Units (TEUs);
- Inland mode in UK (road, intermodal rail, inland waterway);
- Original cargo origin zone (UK and world region);
- Final cargo destination zone (UK and world region).

The data is similar to short sea unitised international freight, but the overseas zones are larger (world regions) and it also includes data on the inland mode of transport to/from the UK port as this affects the generalised cost of the zone-to-zone transport cost and the routeing by service. As well as HGV equivalents, this would be translated into TEUs (as the standard unit of capacity in the container shipping industry).

Assignments to networks

Network assignment maps are an effective way of conveying how much traffic there is on specific routes (showing traffic counts on links) and then used to highlight change between scenarios. These can be filtered to show specific vehicle types.

Other maps

As well as network assignments, maps can convey traffic information for regions or ports etc.

User & non-user costs and appraisal

User costs (or the financial costs experienced by the transport operators/customers) would be provided by multiplying the traffic outputs by the cost model values. These could be disaggregated by the same variables as the traffic.

Non-user costs net of taxation - or the external costs experienced by society which have not been included in the price paid by the transport operators, such as the cost of emissions (including the cost of carbon), accidents and traffic congestion - would be added up by multiplying the traffic outputs by the external costs for each mode and vehicle type.

User costs and non-user costs would provide the main building blocks for an appraisal of a transport infrastructure project for freight traffic by means of a comparison between a “WITH” the infrastructure and a “WITHOUT” the infrastructure scenarios to produce the benefits for freight.

Emissions

Related to non-user costs, emission factors for various pollutants including carbon dioxide would be applied to the traffic outputs by mode and vehicle type, with the factors being provided as inputs.

The calculations should consider the emissions related to shipping and overseas inland transport as well as inland transport in the UK. For example, if comparing scenarios for a movement of freight between Brussels and Leeds, travelling via a Dover ferry would involve a long road journey and high carbon emissions if no other emissions were considered. The alternative shipping option of using a ferry from Rotterdam to the Humber would involve a short inland road journey, but a longer shipping route, for which the carbon emissions should be included in any comparative calculation.

Ideally there would be a similar representation for deepsea cargo, although it is much harder to come up with realistic alternative scenarios to make a like-for-like comparison. For example we could investigate cargo from China to Manchester. Using a deep-sea ship calling at Southampton on its way to Northern Continental ports would involve a long inland UK haul. If the ship called at Liverpool instead, that would involve a shorter inland haul. However for the deep sea ship to call at Liverpool would involve travelling further at sea, and if it were to retain the same schedule, it would have to travel faster, thus using more fuel. The shipping industry is constantly seeking to optimise its schedules, making comparative scenario analysis challenging and complex.

11.5 Value-added data analysis/non-modelling tools

Data from the Freight Data Warehouse (or the results of scenarios that have been run using the NFTM) can be further disaggregated by means of Value Added Data Analysis, such as to break down data from the modelled scenarios by season, time of day and very detailed (local) geography. Specific tools would be required and we understand that such as tool has been developed by Transport for North (TfN) called the Local Freight Tool. MDST has not been involved in its development, but we understand that in general terms the Local Freight Tool takes outputs from the Great Britain Freight Model and then disaggregates the annual data by MSOA zone into smaller zones and shorter time periods for use in local highways models. A similar tool could be developed for the FAME..

Active modes (cargo-bikes and portering) and drones are considered to be too focused on last mile movements in urban areas to be actively modelled within the NFTM itself. However, modelling approaches could be developed as Value Added Data or non-modelling tools, particularly as they are most appropriately analysed or modelled at a local level.

Similarly, while they are too specialised to be included actively modelled within the NFTM, non-modelling tools could be developed to consider the specific economics of air freight and pipelines to assist in the work of specialised teams with the DfT.

Apart from this functionality, it is generally not practical to pre-empt all analyses and have a model ready whose functionality matches the scenario to be analysed. There are also situations where a rapid and approximate result is required, and a full model run may take too long to set up, run and analyse.

Such situations need some analytical capability independent from the NFTM. These methods can either be developed in advance of their need, or they can be spontaneously decided upon or adapted when the situation arises.

Analysing the NFTM outputs will also require queries and analytical tools to best summarise the outputs in a way that can be easily understood by the audience. For example, if local air quality was a topic of interest, all NFTM traffic should be assigned to the relevant networks, translated into emissions and mapped. Outputs could be provided to the UK's National Atmospheric Emissions Inventory model and the emissions expected at any location could then be estimated.

If HGV driver demands were of interest, the total HGV traffic time could be added up in HGV hours, plus an assumption on loading, unloading, repositioning, and breaks to estimate the total HGV driver hours required. Alternative scenarios could be run with the same post-model analysis to estimate the percentage change in total HGV driver hours required. For example, a very pro-rail scenario may result in less demand for HGV drivers.

If there was an urgency for a model result for which the scenario was part way between two already-run scenarios, then the outputs of each existing model run could be taken, with the appropriate proportion of the results taken from each pre-run scenario. For example, if a model run was required for diesel prices of £1.70 per litre, when there was already an identical run (A) but with prices of £1.69 and another identical run (B) but with diesel prices of £1.73, then the output for diesel prices of £1.70 per litre could be approximated by taking:

- Output from (A) multiplied by 75%
- Plus output from (B) multiplied by 25%

Prior to running a proposed model run, to try to avoid errors, it is good practice to broadly estimate what the expected output should be. This can either be done through market experience of the user, or through simple calculations.

Given the way DfT wishes to manage the storage of data from scenarios, with data being dispersed among various teams with a particular but also often specialised interest in freight transport, many of these value added tools are likely to be developed (or may have already been developed) by DfT teams outside FAME itself. However, metadata for the value added tools that make use of data from the NFTM should be developed by DfT to facilitate working across teams and avoid duplication of effort in the development of other value added models.

Recommendation: The most likely Value Added Data tool that would be needed would be a tool which takes annual outputs from the NFTM and disaggregates it to a more detailed geography and by time of day and therefore this should be the priority. Other value added models could be developed on an ad hoc basis.

12 NFTM DASHBOARD

While detailed results in the form of data would only be available to the relevant user and DfT team, the NFTM Dashboard would automatically provide visual summaries of the results of scenarios compared to the base case which could be used as a sense check of results by modellers, analysts, policy specialists and economists and could also be shown to senior civil servants and ministers as high-level summaries of results.

The results presented would include at a glance summaries of the data set out in section 6.4 above, but with a focus on change between a scenario and the base case, another counterfactual scenario and would include changes in freight transport required (tonnes lifted and moved by mode, type of vehicle and fuel type) and in terms of user and non-user costs (including the cost of carbon), as well as carbon emitted and other environmental emissions.

The NFTM Dashboard would also include assignment maps to help visualise changes in flows on transport networks at varying levels of geographic detail so that change can be seen at both the UK level and at more regional and local levels.

The NFTM Dashboard would also, where a scenario was testing the impact of a new infrastructure scheme, provide the results of appraisal in terms of the net present value of benefits based on the relevant official discount rate.

The outputs on the NFTM Dashboard for a particular scenario should be clearly associated with the relevant scenario ID and name and then retained within the Scenario Studio as a clear visual record of the main outputs from the running of the scenario.

13 CONCLUSIONS ON FEASIBILITY

13.1 Introduction

The Freight Analysis and Modelling Environment (FAME) as described in this report may, given sufficient time and resources, be feasible to develop from a technical point of view. It would, however, be complex and highly ambitious and there would therefore be significant risks. This concluding section of the feasibility report provides a summary of the key issues in relation to technical feasibility and highlights some of the key risks.

13.2 The National Freight Demand Model (NFTM)

The core of FAME would be the National Freight Demand Model (NFTM), which would allow the DfT to test the impact on the freight transport market of changes in policy and carry out appraisal of the potential benefits for freight transport and wider society from transport projects. This freight transport model should be developed as a “classic” four stage transport model, which would therefore be based on established techniques used in Europe and beyond, and which has been used successfully in Great Britain since 2001 in the form of the MDS Transmodal Great Britain Freight Model (GBFM).

The geographic scope of the NFTM would be able to incorporate all four countries of the UK, with about 9,000 “internal” zones of a reasonably consistent size and larger “external” zones for intra-European trade with Ireland and the European continental mainland and various world regions for intercontinental trade.

The NFTM would be a useful tool for the appraisal of the benefits to freight transport operators and wider society as a result of the development of new transport services and infrastructure and for the analysis of impacts of policy scenarios. This means that the assumptions included in TAG (for the DfT’s Core Scenario) and CAS (for sensitivity analyses) need to be consistent with the cost models used in the NFTM. At present the Non-Fuel Operating Costs included in TAG do not appear to reflect the full user costs for operators and do not allow for the introduction of zero emission HGVs up to 2040, despite it being Government policy that all HGVs purchased from 2040 onwards must be zero emission. User costs included in the NFTM and TAG/CAS should be based on the full costs experienced by industry as it is these costs which mainly determine decision-making in the market.

13.3 NFTM sub-models

The demand-side elements of the NFTM would therefore need to accommodate a variety of modes (at least road, rail, short sea and deep sea unitised maritime and inland waterways) as well as different technologies for propulsion because of the increasingly urgent need to reduce carbon emissions from freight transport. They would also need to be developed for different sizes of vehicle, train and vessel and take account of the economies of scale that are available in the global freight transport market.

This will mean that a large number of cost models (as sub-models of the NFTM) will need to be developed, which should be based on the financial costs (user costs) experienced by the operators as they are the key decision-makers between modes and propulsion technologies. Generalisations will need to be made for the representative size/capacity of vehicles, trains and vessels that are relevant to different types of local, regional, national, short sea and deep-sea logistics chains. As the development of technologies and their costs up to (say) 2050 are inherently uncertain, a degree of expertise in freight transport economics will be required, while also needing to accept that there is an inherent risk of inaccuracy when forecasting costs 20 to 30 years into the future.

Due to the need to decarbonise freight transport, the composition of the national fleet of LGVs and HGVs will change up to 2050 but there is some uncertainty about which technology will be most appropriate and many operators are seeking greater certainty before investing in vehicles that would operate in a highly competitive environment. In this context there is likely to be a difference in any future year between what is likely to be the theoretical demand for particular technologies on any given origin-destination flow (based on user costs) and the supply of vehicles of the relevant technology within the fleet. During this transition there is therefore a need for further sub-models for the HGV and LGV fleets so that a feedback loop in the NFTM can constrain the demand for any given type of vehicle for which there is an insufficient supply of vehicles. In theory, a similar approach might be needed for all other modes of freight transport.

The loss of a supply of younger HGV drivers from the European Union after Brexit also means that an HGV labour sub-model would be needed. This would allow the supply of HGV drivers to be modelled, with any apparent shortages met through an increase in average driver salaries to attract more (younger, UK-resident) labour into the market.

13.4 Supply-side analysis

One of the more ambitious elements of the NFTM would relate to the requirement to include network capacity constraints. Iterations of road freight demand and highways capacity - perhaps using the NTM - would be possible and there are well-understood techniques for carrying this out; it would, however, lead to longer run times and mean that FAME would not be self-contained.

Constraining rail and maritime network capacity is not usually required within freight transport models and would make FAME more complex and may even be controversial. MDS Transmodal has developed a proprietary and generic modelling technique to estimate the available capacity on any link on the British rail network, which has been used in projects for both the DfT and Network Rail; however, this is an innovative technique and has not been widely used within the railway industry, which usually assesses capacity on short sections of what is a highly regulated network at a very detailed level. We are not aware on any other attempts to innovate in this way in the British rail sector.

Similarly, MDS Transmodal developed a proprietary and generic modelling technique to estimate the available capacity of different types of port terminal for all British ports for the Royal Society for the Protection of Birds (RSPB). Assessments of the capacity of a port and its individual terminals would normally be carried out at very detailed level by engineers or port master planners in order to secure funding for investment or to increase port productivity. "Official" estimates of port capacity by the DfT within FAME for the purposes of policy development or national planning purposes could lead to concerns in the ports industry, which is mainly privately owned and not usually funded by the state.

These supply-side considerations would, in any event increase the complexity of the NFTM very significantly and lead to long run times. There is likely therefore to be some "development risk" involved in the development of the NFTM and a strong likelihood that run times would be long.

13.5 Run-times for the NFTM

The DfT has an aspiration to have run times for the NFTM of up to 3 hours, but it is likely that this will not be possible given the number of zones, the number of modes, vehicle/train/vessel sizes, the propulsion technology permutations and the iterations that would be required between demand for freight transport and the supply of freight transport services and network capacity.

The most practical workaround that is suggested in this study is to run the NFTM at two different levels, with "Tier 1" involving runs of the full model (including capacity constraints) and "Tier 2" involving a smaller number of zones and without capacity constraints. The latter might be able to provide the DfT with reasonably rapid answers to policy makers' most urgent questions in relation to freight transport, but there is a risk that the Tier 1 and Tier 2 answers might be quite different depending on the nature of the input assumptions.

13.6 Scenario Studio, NFTM Dashboard and the Freight Data Warehouse

The concept of the Scenario Studio should be feasible as a means to provide a user-friendly input interface to the NFTM and allow a wider group of users within the DfT to have access to the model. It would perform a useful role in managing scenarios and avoiding erroneous input assumptions to be made.

The NFTM Dashboard would provide a user-friendly summary of the outputs from the NFTM which would allow sense-checks on outputs to be carried out and provide useful summaries of results for key decision-makers within the DfT.

The Freight Data Warehouse would provide a repository of input data for the origin-destination matrices, with the data available for use with non-modelling tools for further disaggregation

13.7 Freight transport economics

A potential significant difficulty in relation to the potential development of the FAME is that freight transport modelling requires an understanding of how the freight transport market works. This market understanding is required not only to develop a model that simulates its mechanisms reasonably accurately, but is also required to develop realistic assumptions for future scenarios and to understand whether the responses from the model are realistic. In order to be able to operate the model and reduce the risk of modelling results being unreliable, unrealistic or even erroneous, the DfT would therefore need to employ transport modellers and economists with multimodal freight transport expertise.