The GB Freight Model

Methodology

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MDS transmodal

The GB Freight Model Documentation Project

Document 1: Methodology

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1   Executive Summary

MDS Transmodal were retained by the Department for Transport (DfT), Integrated Transport and Environmental Appraisal (ITEA) Division, in April 2003 to provide technical documentation for the GB Freight Model (GBFM). The objective is to make public the methodology contained within GBFM, and to provide information for subsequent audit work.

GBFM is a software system designed to model strategic domestic freight flows across Great Britain and international flows between Great Britain and trading partners, focusing on the Cross-Channel corridor.

The software has evolved from a set of single mode ferry models (early 1990s, Kent County Council), to a multimodal Cross-Channel model (mid 1990s, DG-TREN, STEMM Project), to a domestic multimodal model (2000, SRA) into its current form. It is now used as the freight module for the DfT's National Transport Model (NTM).

The model:

- Covers international and domestic freight flows, concentrating on average to long distance shipments.

- Has three levels (or geographical scales): international (NUTS2/3), domestic multimodal (NUTS3), and domestic road (2700 zones, based on postcode boundaries).

- Is based upon an OD matrix derived from existing datasets, including UK trade statistics, the Continuing Survey of Road Goods Traffic, and Network Rail's database of rail freight flows.

- Uses trends to forecast trip generation. Some land use impacts (limited to the development of inland freight facilities, i.e. trans-shipment points with local storage) can also be modelled.

- Simulates trends in trip generation by feeding commodity specific changes in trip length into the trip matrix.

- Cascades results are from higher to lower levels.

- Uses the DfT's NTM road network, and produces outputs compatible with other NTM modules, e.g. FORGE.

- Generates multi-modal paths by combining network and freight service data.

- Employs "accounting" models of transport costs, designed to reproduce realistic freight rates for given trip chains.

- Attributes utilities (or negatively, generalised costs) to multimodal network paths, adding time-based and reliability-based costs to the calculated freight rates.

- Assigns traffic, using the F-Logit algorithm developed by the Institute of Transport Studies, Leeds University for DG-TREN's STEMM project.

- Allows trend-based and scenario-based forecasting techniques to be used, by attaching policy levers to the cost models and network databases.

The 1999 SACTRA report[1] criticised the "usual approach to forecasting [goods vehicle travel demand]", Para. 10.49, referring to the conventional methods used within local and regional highways models, in which there is often little emphasis on the structure of the freight market.

GBFM can be seen as one alternative to that approach, i.e. the tendency to over-simplify the freight sector in order to fit freight flows into models which are primarily concerned with passenger vehicle journeys. The emphasis on freight allows the methodology, the data sources, the structure of the supply side and the sectoral and international dimensions to be constructed to reflect the variables most relevant for the freight market.

It is one of relatively few dedicated strategic freight models being used in the UK, and the methodology has been developed for this specific objective, given current available freight data.

This document describes why and how it was done.

2   GBFM Introduction

The GBFM project started in August 2000. The objective was to combine a group of existing software components and data sources into a single entity, and develop them into a comprehensive model of international and domestic freight flows within Great Britain.

GBFM now forms part of the Department for Transport (DfT) National Transport Model (NTM). It has been applied within the DfT's Ten-Year Plan, the Strategic Rail Authority's (SRA) Freight Strategy, a number of Multimodal Studies, the DfT's analysis of road user charging, and a series of local, regional, and commercial studies.

The model design and the development route chosen has been directly influenced by the immediate needs of these studies and the limitations of the data sources rather than an initial concept or design. However, with a blueprint for modelling freight transport in Great Britain now established[2] by the DfT, the challenge is to review the validity of the evolutionary approach embodied by GBFM. This documentation, is one element of the recommendations set out by the DfT review.

Given that GBFM was developed to be what MDS Transmodal's clients needed: an evolutionary, working model, making use of existing data, it is first necessary to understand the model's origins.

2.1   Origins

There are possibly three fundamental influences on the resulting model, all related to MDS Transmodal's role as economists working in the transport field:

•   Analysis of traffic flows – and the development of databases and forecasting tools,

•   Cost Models,

•   Competition/Market Share Models.

The need to understand and analyse these three components underlies the need to combine them into a consistent framework. It is also evident that the erosion of data availability in certain areas, such as that resulting from the creation of the Single European Market in 1992, has also focused attention away from database-driven analysis towards behavioural models. So, as the reliability of

flow data has declined, the importance of cost models, and the use of synthetic techniques has increased.

Fundamentally, GBFM exists to replace data that is no longer available or which would be expensive to collect. As a theoretical exercise it is no more complex than a means of representing simple micro-economic forces.

The primary influences upon the structure of the model are outlined in the following sections.

2.1.1 Kent Ports Strategy

One of the first applications of this methodology was carried out within the Kent Port Strategy[3] (KPS) for Kent County Council in 1994. The objective was to predict Eurotunnel's traffic, in order to inform local transport, land use, and economic development activities within the county. It was necessary to do so in a way that was acceptable to the ferry industry, as well as to the new entrant, Eurotunnel.

A set of models was built, one each for

• passengers with cars,

• short haul air passengers and Eurostar

• accompanied ro-ro, and

• unaccompanied ro-ro.

They used the (then) recent ODIT91[4] survey for the freight elements to build 100 UK by 100 Continental zone trip matrices. Journey times and distances based on Automobile Association (AA) software were combined with simple transport cost multiples to predict costs via competing cross-Channel routes.

A simple assignment algorithm that allocated traffic according to the degree of "premium" compared to the lowest cost route completed the model.

The published forecasts estimated that Eurotunnel would take 28.04% of the accompanied ro-ro market, and 34.91% of the passenger car market, based on a corridor defined as being all Continental services, excluding the Nordic countries, including all GB ports from Teesport to Plymouth. The model predicted that these shares would only be achieved if Eurotunnel priced their services in line with the incumbent operators, a forecast that contrasted with the levels predicted by Eurotunnel's Traffic and Revenue Consultants.

In 1999, Eurotunnel achieved 838,776 accompanied road goods vehicles (ARGVs) out of a market of 2,907,400 ARGVs[5], a market share of 28.85%. In the car market, Eurotunnel achieved a 1999 annual volume of 3,260,166 units, from a market of 8,383,241, a share of 38.89%.

Technically these KPS models were simple programs, running in MS-DOS. Trip generation and distribution were treated as givens, with the market size set by the ODIT91 data. Mode split was also treated as a constant with each of the four models (vehicle-accompanied passengers, walk-on passengers, driver accompanied HGVs and unaccompanied HGVs) operating independently. The main functions of the models were path enumeration, path cost calculation and assignment, with the emphasis on the cross-channel network, rather than the hinterland network.

Figure 1: KPS Model Structure

```
        ┌────────────────────────┐
        │ Trip Matrix: Given      │
        │ Mode (e.g. ARGV)        │
        └────────────────────────┘
                   │
                   ▼
        ┌────────────────────────┐
        │ Path Enumeration:       │
        │ Path Cost               │
        └────────────────────────┘
                   │
                   ▼
        ┌────────────────────────┐
        │ Assignment: Cross       │
        │ Channel Network         │
        └────────────────────────┘
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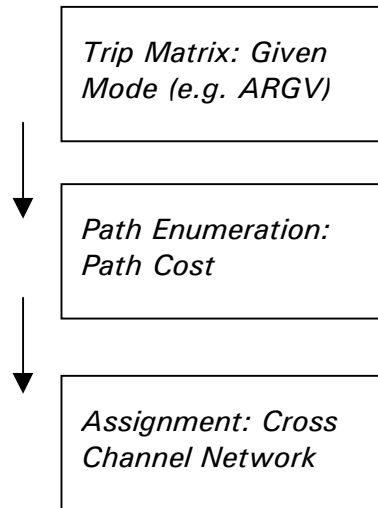
They relied on a set of rules that reflected our interpretation of the way that marketing departments in the ferry industry at that time viewed their market:

• Demand for freight transport services is 'derived' i.e. dependent upon the underlying demand for the goods being transported: metals, foodstuffs, chemicals, consumer goods etc.

• Total levels of demand were inelastic with respect to price i.e. reducing the cost of transport does not induce demand for metals, foodstuffs, chemicals etc. It is therefore difficult for a transport company to "create" or induce traffic to make the total market larger.

- Differentiation between individual service providers on competing routes (ferry companies) is difficult to achieve, so for any given service, elasticity of demand with respect to price is high.

- In competitive industries with relatively low barriers to entry, prices tend to reflect costs in the long run.

- In a network, where links are competing businesses, increased demand does not produce the speed-flow trade-off typically assumed for networks with no rationing mechanism (e.g. urban roads). Instead, successful ferry services benefit from higher levels of utilisation.

- The concept of transport mode split is vague within the freight market. Service providers may invest in a specific mode (road vehicles, rail terminals, container ships), but competition is not limited by these technical definitions. Consequently, a ferry on wheels (a Eurotunnel Shuttle) should be treated as a direct competitor for a maritime ferry.

These guidelines for the way in which the freight market operates are still present within the assumptions built into GBFM.

2.1.2 STEMM

The STEMM project, (Strategic European Multimodal Modelling)[6] funded by the European Commission (DG-TREN), provided the second stage of development for the KPS freight models. Whereas the KPS project had focused on a specific market segment, i.e. cross-channel ferries, and had sought to model strategic market behaviour, STEMM was concerned with modelling methodology, data collection, model building, and applications within policy-making.

STEMM looked at both passenger and freight models on a number of corridors, but as far as GBFM and freight are concerned, the principal work-packages were:

- WP2 – Freight Modelling Methodology, led by the Institute for Transport Studies (ITS), Leeds University

- WP3 – Cross-channel Data Collection, led by the Department of Transport

- WP4B – Freight Model, led by MDS Transmodal

- WP5 – Channel Tunnel Effects, led by CERTE, University of Kent

- WP6 – Trans Alpine Transport, led by IWW (Karlsrühe) and ECOPLAN (Berne)

One of the outcomes of these work-packages was the STEMM Freight Model, incorporating data, and methodology developed within the project, and applied to case studies also analysed within the project.

The main advances over the KPS models were:

- The simultaneous treatment of different unitised Cross-Channel modes, i.e. accompanied and unaccompanied ro-ro, maritime container services, and Channel tunnel services, requiring a multimodal approach.

- The use of stated preference models to estimate parameters for value of time and value of service reliability.

- The use of a flat logit model for traffic assignment.

- The development of new Cross-Channel freight matrices.

- The development of a framework for building policy-oriented scenarios.

In fact, two model applications were built; one each for the Cross-Channel and Trans-Alpine[7] corridors. However, they shared the same underlying structure. The Cross-Channel implementation of the STEMM freight model forms the basis for the international components of GBFM.

2.1.3 DETR Studies

Between October 1999 and May 2000, MDS Transmodal were involved in two studies for the DfT ITEA division, formally the HETA division of the Department for the Environment Transport and Regions:

- Assessing the Effects of Transport White Paper Policies (AETWPP) on National Traffic[8]

- Freight Model Structure for the Road Traffic Reduction Act (RTRA)[9]

Both studies required models of domestic freight and the domestic leg of international freight flows. For the AETWPP study, the STEMM freight model was used for international flows, and a new model for domestic traffic was constructed. The two models were separate entities, requiring each scenario to be run on each model.

The base matrix for the domestic freight component originated from the CSRGT[10], a road-only survey, so the model could only divert traffic from road to rail. There was no representation of existing rail flows which could divert back

to road. Forecasts had to be made externally, by extrapolating from a base year set of estimated variations.

The RTRA model, subsequently referred to as the 10YP model was a spreadsheet application (MS Excel and Visual Basic), built by WS Atkins with input from MDS Transmodal. It contained mode-switching elasticities based on results from the AETWPP models. The model was designed to represent policy levers, and it used extensive time series of CSRGT data from which forecasts could be produced.

2.1.4 SRA Freight Strategy

The establishment of the Shadow Strategic Rail Authority (sSRA), the publication of the Ten Year Plan[11] (July 2000) and the SRA Freight Strategy[12] (May 2001), focused attention on the need to set medium term targets for rail freight. At this point there were no models capable of forecasting both road and rail. MDST had the RTRA and AETWPP models, and Railtrack had a spreadsheet based rail forecasting model written by McKinsey & Company. There was no mechanism for linking the Department's road freight models with Railtrack's rail model.

The SRA commissioned MDS Transmodal to add a rail component to their existing AETWPP models, and they simultaneously developed two new models:

• The Additional Freight Model, written by Sinclair Knight Merz (SKM) with AEA Technology and ITS Leeds, and,

• The Interchange Model, based upon the CAST-dpm strategic supply chain model, by Radical Ltd and Excel Logistics.

Reviews of these methodologies can be found in the 2002 Freight Model review (section B1)[2].

The SRA's need to examine the potential for new rail markets brought about the first version of the GB Freight Model (GBFM). It was built by combining the STEMM Cross Channel Freight Model, the AETWPP model of domestic road freight, the RTRA model's forecasting ability, and a new rail component, using data from Railtrack plc.

The economic foundation for both road and rail was improved by developing new cost models. The new approach was based on the outcome of the October 1999 Merseyside Freight Study[13] and the analysis of the UK rail freight market[14] carried out for GB Railways in April 1999.

The GBFM project started in August 2000. The May 2001 SRA Freight Strategy published a target of 80% growth in rail freight by 2010, estimated using this software.

2.1.5 GBFM Development

Version 1:

The first version of GBFM, created in September 2000, was designed to address the problems encountered previously. The model:

• Incorporated domestic and international flows into a hierarchical system whereby the domestic legs of international journeys could be modelled from origin to overseas destination, allowing port choice to change according to the network costs.

• Used the UK HMC&E (Customs and Excise) data to a greater extent to include flows of bulk cargo into GB ports, and to extend the set of overseas destinations beyond Europe.

• Used Railtrack's sample database of freight flows to add existing rail traffic to the base matrix, to calibrate the base case for rail, and to set up a realistic set of rail services.

• Allowed the base matrices to be forecast, using trend-based estimation for the domestic flows, and a link to the MDS Transmodal trade forecasts for the international flows.

Version 2:

Created in January 2001, produced the forecasts used within the SRA's Freight Strategy. The main addition was a method for automating the process of adding new rail connected freight facilities. The process "morphed" the trip matrix by attracting traffic into the zones where there would be new rail freight facilities, and set the degree of direct rail connectivity.

Version 3:

Created in April 2001 incorporated a number of basic enhancements, by bringing many of the input data sources up to date for the end-of-year 2000, and refining the calibration process. Two new functions were added:

• A method for calculating the level of subsidy applied to rail flows under the SRA's proposed Company Neutral Grant scheme was included. The model could calculate the subsidies for specific journeys under specific subsidy levels, and then apply these within the model to calculate the diversion of traffic.

• A method for creating a detailed output OD matrix for rail flows, defined by Railtrack's STANOX code system was added for the East Midlands Multimodal Study.

Meanwhile, a new project, GBAM, or GB Assignment Model was created, in response to the need to analyse flows of road traffic at a finer level of detail, and to assign the traffic flows to specific links in the road network. This ran in parallel to GBFM, and used GBFM's outputs as its inputs.

Version 4:

Created in January 2002, this version addressed the need to combine the main GBFM routines with the network improvements created within GBAM. This would enable link specific costs, such as road user charges to be modelled.
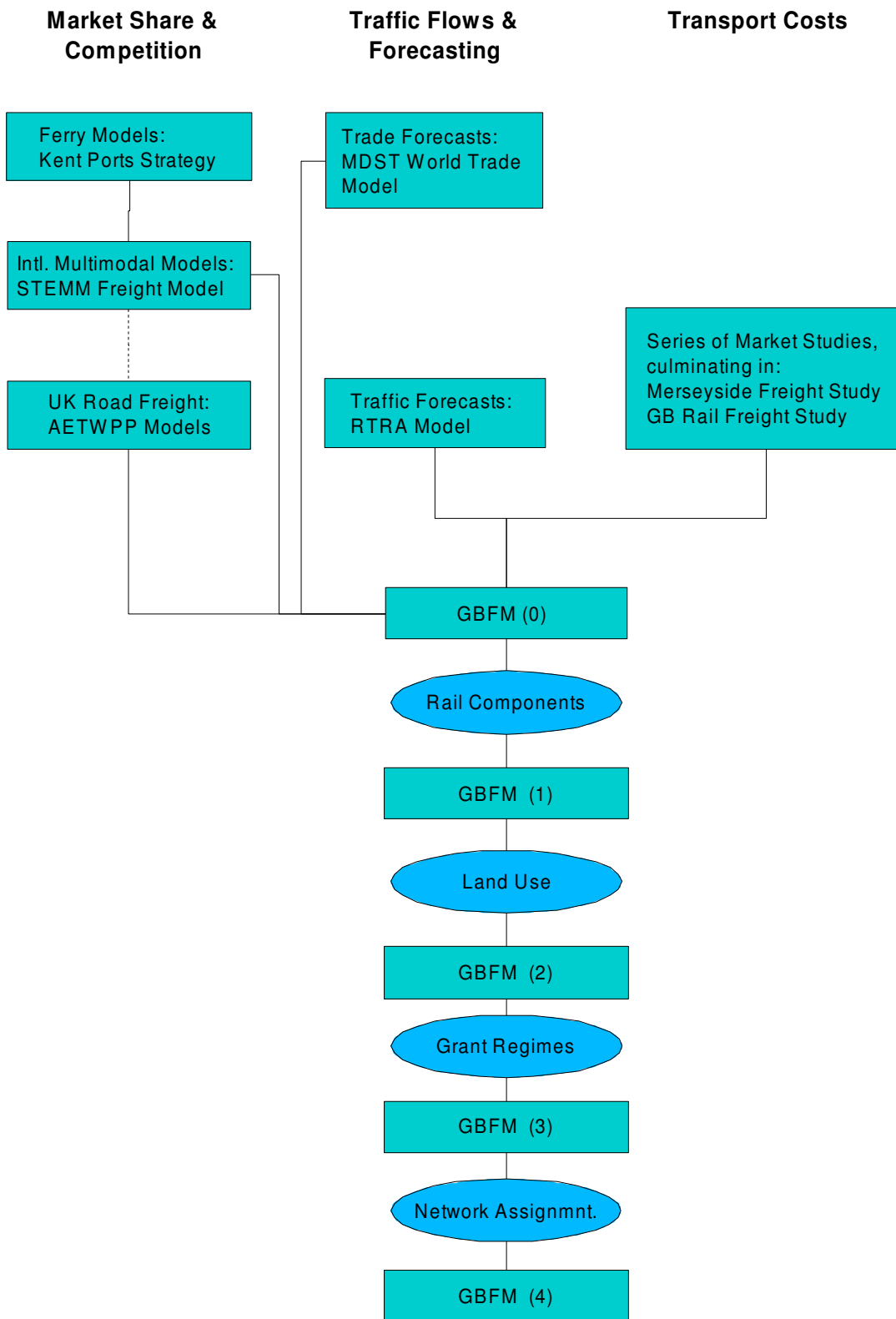
The impetus for Version 4 came from the work of the TET (Transport, Environment & Taxation) Division of the DfT, who identified the potential for using the model to analyse the impact of road tolling.

At the time of writing (April 2003), the current version of the model is v4.12.

Figure 1 summarises the evolution of GBFM.

2.2   GBFM "Evolution"

Figure 2: GBFM Evolution

2.3 GBFM Uses

To complete the introduction, we should consider the function of the GB Freight Model. What does it do, and what are its typical applications?

From the preceding sections, it can be concluded that the design of the model has evolved from user needs and practical application. Unlike many transport modelling systems, the software has been constructed to bridge the gap between existing data availability and actual user needs for a *single* problem set. The approach has been to adapt the inexpensive component (program code) to the expensive component (data), and not the other way round. The result is a system that only works for a single implementation, GB freight flows. This is a limitation on the wider application of the software, but within this geographical limitation, many applications are possible. Some straightforward examples are shown below.

Macro Forecasting

| GDP (Year) | → | TKms by Mode |
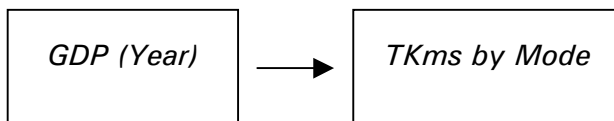
The system allows national transport indicators such as tonne kilometres or vehicle kilometres to be forecast by mode, commodity and regional impact. It is possible to demonstrate the impact of macro economic indicators such as GDP and sectoral output on these values.

National Policy Impacts

| Taxation | → | TKms by Mode, User Benefits |
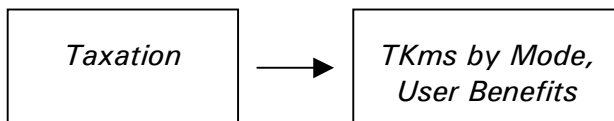
Policy instruments such as vehicle taxation, road user charging, freight grants and revenue support, fuel taxation, and legislation covering drivers' hours can be represented as part of a forecast scenario. Outputs can be analysed in terms of mode split, regional impacts, and changes in demand for infrastructure. These can also be translated into values suitable for transport appraisal, such as changes in external costs and user benefits.

Regional Analysis

National Rail Policy	→	Road Vehicle Trips by Zone
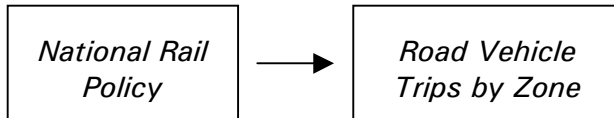
National or region-specific policy changes analysed can also be examined at a regional level. Typically it is useful to create forecast vehicle trip matrices, containing the impact of market or policy changes. These can be used as inputs for local or regional road transport models.

Ports and Port Hinterlands

Changes in Port Demand	↔	Changes in Inland Patterns
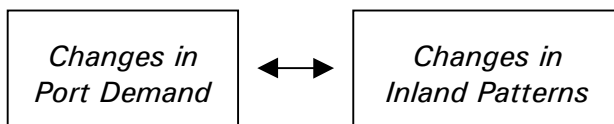
The components for the software dealing with international freight flows can be isolated from the other processes allowing these to be examined in detail. As well as modelling the demand for shipping services (ferries and short-sea container services), the software can represent the linkages between sea mode, inland mode and inland origin/destination. The inter-dependence between port traffic and the supporting inland networks can therefore be examined.

Inland Rail Freight Terminals

New Rail Terminal	→	Impact on Traffic Distribution and Mode Split

Inland rail freight terminals are essentially treated the same way as ports. However, their impacts tend to be analysed from a different perspective. One element to be considered is the extent to which inland terminals can replace existing warehousing facilities, and therefore increase the population of freight trips for which there is a direct rail connection to the Channel Tunnel, a container port, or another similar facility in another UK region. The ability of an inland facility to change mode shares can be analysed within GBFM.

Road and Rail Network Impacts

Policy Change	→	*Impact on Network Links*	→	*Impact on Mode Share*
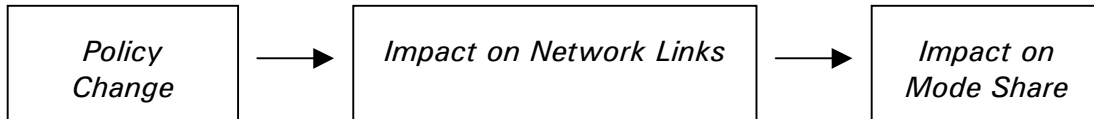
In order to be able to analyse regional and local impacts, it has been necessary to use a detailed road network within the model. It follows therefore that the software can reflect impacts upon the network, as well as impacts caused by changes to the network. Typical applications have included the impacts of new links, the impacts of changes to existing links (e.g. lower or higher congestion), and the measurement of HGV flows on specific links. In practice it means that the model is capable of looking at local impacts (postcode zones and individual road links) of national changes.

The technical development process has been to start from the aggregate view, looking at long distance HGV and rail freight movements between large zones (counties), and then to add spatial detail in subsequent stages. This is now a potential source of consistency problems, and it is one of the major changes expected in future model versions.

3 Overview of Methodology

The purpose of this section is to provide a high level understanding of GBFM's methodology. Following sections (4,5,6 and 7) fill in the detail that has been omitted here.

Section 2 (Introduction to GBFM) stated that the model has been an evolutionary process, adapting to the data, the user requirements, computer software and hardware specifications, and the availability of technical advice.

The software has been regarded as a "black box", but in many ways the methodology is conventional.

In "Modelling Transport", Ortúzar and Willumsen[15] set out a flow chart for the classic four stage transport model. They argue that this provides a useful point of reference against which a given model can be contrasted. The familiar four stages are:

- Trip generation, trips (tonnes lifted or vehicle trips) generated or attracted by zone.

- Trip distribution, the relationship between trip origins and destinations, or spatial distribution.

- Mode split, the segmentation of demand according to transport mode, and

- Assignment, the assignment of traffic to a transport network structure.

3.1 A Simple Transport Model

At the most basic level, a four-stage model could be constructed for a system with two zones (e.g. Britain and France), and two links (e.g. road plus ferry, and through rail).

Stage one (generation) would set out generations and attractions e.g.

```
TrafficGenerated[Britain] = TG_B

TrafficGenerated[France] = TG_F

TrafficAttracted[Britain] = TA_B

TrafficAttracted[France] = TA_F
```

(i.e. four numbers)

Where, $TG_B + TG_F = TA_B + TA_F$

so that the system is closed.

Stage two (distribution) would construct an origin destination matrix, e.g.

Origin / Destination	*Britain*	*France*	*Total*
Britain	*T(B,B)*	*T(B,F)*	*TG$_B$*
France	*T(F,B)*	*T(F,F)*	*TG$_F$*
Total	*TA$_B$*	*TA$_F$*	*T*

Stage three (mode split) would calculate mode shares, e.g.

Origin / Destination	*Britain*	*France*
Britain	*P$_{road}$(B,B)*	*P$_{road}$ (B,F)*
France	*P$_{road}$ (F,B)*	*P$_{road}$ (F,F)*

Where P_{road}(B,B), means the probability of a trip in this cell of the origin destination matrix using the road + sea option, and where:

$$P_{rail}(B,B) = 1 - P_{road}(B,B)$$

since there are only two modes in this example.

Stage four (assignment) would then perform the assignment to the two assumed network links, Link[road] and Link[rail]:

```
For ( all origins, 'o')

      For ( all destinations, 'd' )

            Link[road] += T( o, d ) * P_road( o, d)

            Link[rail] += T( o, d ) * P_rail( o, d )
```

These routines produce a very simple transport model, containing all of the principal requirements:

• How many trips happened

• Which modes were used, and,

• Who won the traffic.

This structure could be used to test the impact of a new transport link, or a change in the patterns of trade, or a change in the probability that a specific mode is selected.

3.2 GBFM Compared to the Four Stage Model

In principle, GBFM follows the previous example, although it would be more accurate to see it as three sets of two-stage models. In each two-stage model, generation and distribution are grouped together into a composite matrix-building stage, and by using a multimodal network, the assignment stage takes over the mode-split function. So although the four stages cannot be observed within the software in the familiar sequence, their roles have not been discarded.

Four Stage Model   **GBFM**

| Generation | → | Matrix Building |
| Distribution |

| Mode Split | → | Assignment |
| Assignment |
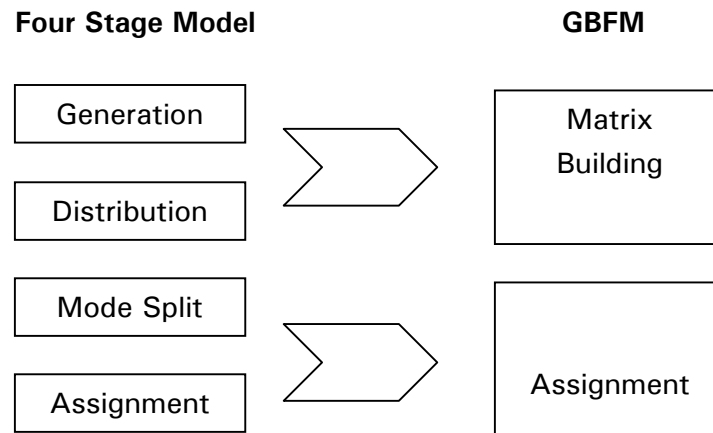
However, whereas the simple example (previous section) is defined by a single zoning system and a single network, GBFM can be seen as three implementations, each defined by different zoning systems and networks. These can be termed 'levels'. They are:

• Level 1: International traffic, modelled against county zones in the UK and approximately 150 zones on the Continent, using a multimodal network covering this region.

• Level 2: Domestic GB traffic, modelled against county zones, using a multimodal (road and rail) network.

• Level 3: Domestic GB road traffic, modelled against 2,700 postcode districts and a single mode (road) network.

The model is run in this *top-down* sequence, with results from one level being passed down the hierarchy. Thus, a change in level one, such as the creation of a new container shipping service, would cause traffic to divert from existing competing services. This would affect the distribution of domestic traffic: here domestic traffic includes the domestic leg of international trips. In level two, the redistribution could affect the demand for rail services, and therefore divert inland traffic from road to rail. Level three would then start from a new initial setting.

Figure 3: GBFM Comparison with Four Stage Model

Generation		1.International
Distribution	Matrix Building	*Flow Data*
Mode Split		2. Domestic Multimodal
Assignment	Multimodal Assignment	*Flow Data*
		3. Domestic Road
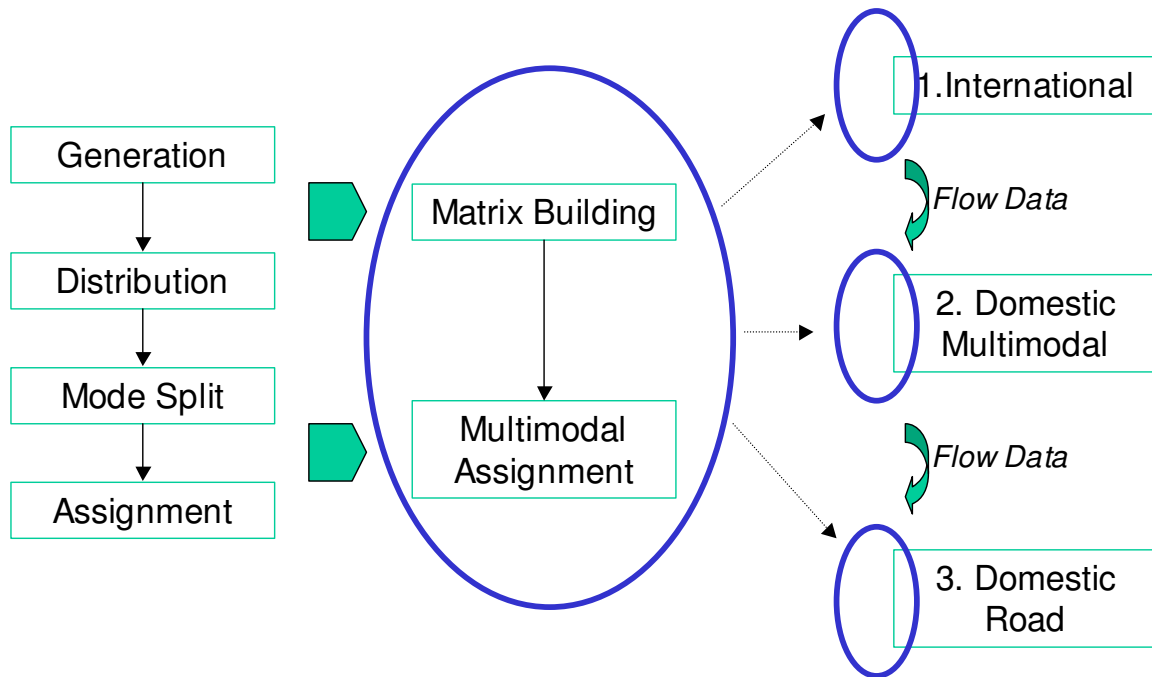
In this form, GBFM can be seen as a top-down model in which the four-stage procedure has been simplified and executed as a sub-routine in the top-down sequence. It is therefore probable that GBFM inherits the strengths and weaknesses of the four stage model. The main strength has proved to be the way in which the structure can be arranged around existing data.

The main weakness is the encapsulation of the transport process; optimisation of a complete production\distribution process in which transport is simply one element, is not dealt with. Furthermore, there is ambiguity in the direction of this sequence. We are limited to a view in which the transport industry responds to shippers. There should be an intermediate level in this problem i.e. warehousing which responds to both the OD matrix building and the transport-routing problem, through a higher-level, but more slowly evolving optimisation problem. A more detailed summary of the model stages is shown in Figure 4.

Figure 4: Overview of GBFM Stages

Level 1: International

```
                    ┌─────────────────────────┐
                    │   Matrix Building -      │
                    │   Continental            │
                    └─────────────────────────┘
                                 ⬇
                    ┌─────────────────────────┐
                    │   Assignment –           │
                    │   Intl. Multimodal       │
                    └─────────────────────────┘
```

Level 2: Domestic Multimodal

⬇   ┌ Domestic Legs of International Journeys ┐

```
                    ┌─────────────────────────┐
                    │   Matrix Building –      │
                    │   GB Counties            │
                    └─────────────────────────┘
                                 ⬇
                    ┌─────────────────────────┐
                    │   Assignment - GB        │
                    │   Multimodal             │
                    └─────────────────────────┘
```

Level 3: Domestic Road

⬇   ┌ County-based Road Trip Matrix ┐

```
                    ┌─────────────────────────┐
                    │   Matrix Building –      │
                    │   Postcode Districts     │
                    └─────────────────────────┘
                                 ⬇
                    ┌─────────────────────────┐
                    │   Assignment – GB        │
                    │   Road Network           │
                    └─────────────────────────┘
```
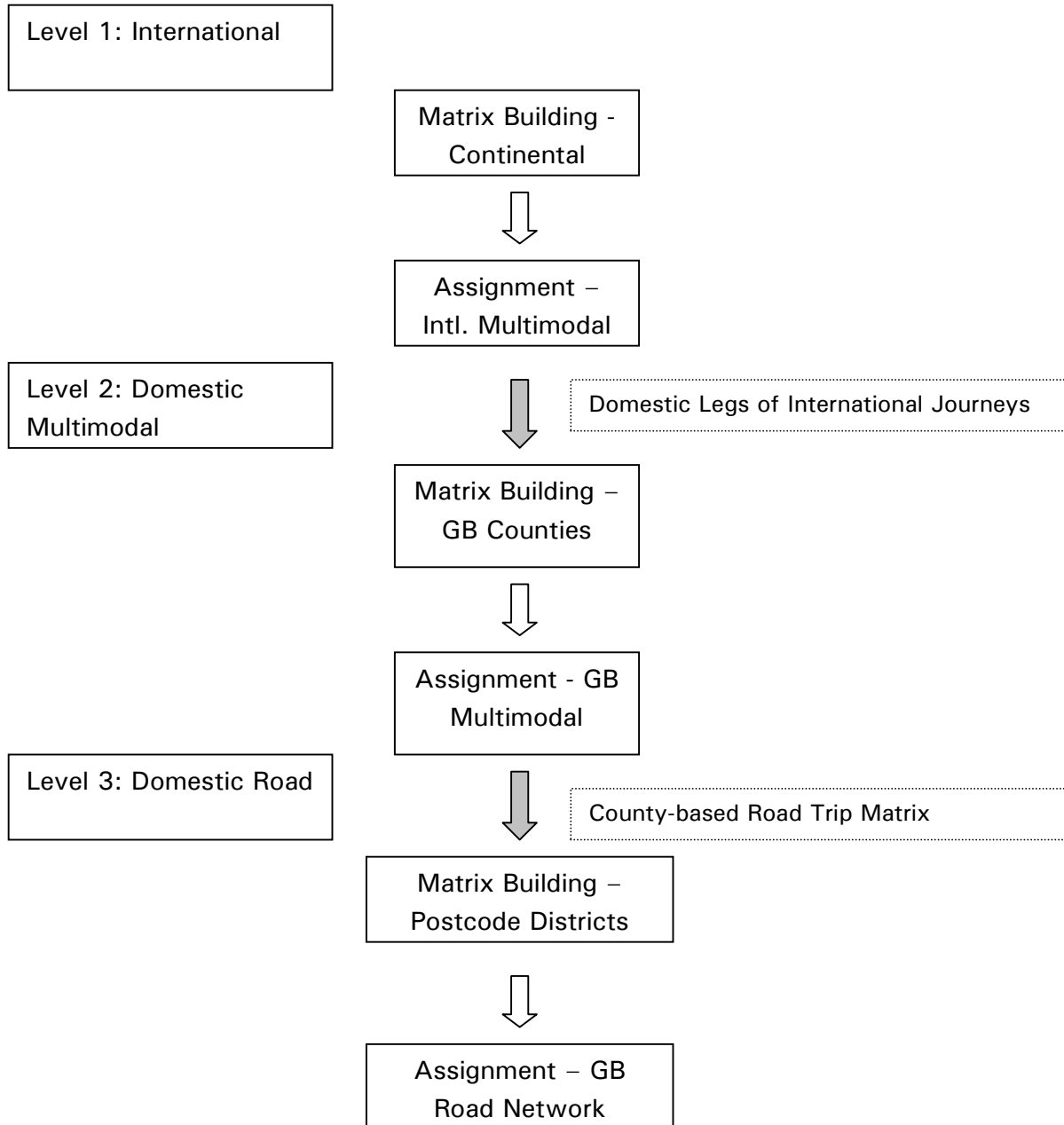
The structure has developed in this form not because it represents an ideal, but because it has been necessary to use different levels of data precision for

dealing with different parts of the problem. For example, if the origin of the traffic is Moscow, it is probably irrelevant whether the destination is Liverpool or Birkenhead; it is enough to specify the UK zone as Merseyside. Increasing zone detail is required as the trip lengths become shorter, but commodity details and factors affecting choice of mode become less important. The cascading structure presented here allows different dimensions of market segmentation to be expanded or collapsed depending on their relevance to the transport choices available for a specific flow type.

3.3 Key Components

Behind the four-stage (or two-stage) process, there are a number of key components worth mentioning at this point.

3.3.1 Forecasting

A classic four-stage model does not require a forecasting component. However, it is almost inevitable that forecasts will be made from transport model results, so it makes sense to integrate forecasting into the modelling system. In practice, forecasts can be trend-based or scenario-based or a combination of the two. GBFM allows these approaches to be combined. Scenario-based forecasts must be designed by the user, but trend-based forecasts are built-in.

For International Trade (Level 1), GBFM uses results derived from an external trade-forecasting model, constructed by MDS Transmodal in the early 1990s. It provides growth rates by country of origin/destination and commodity, based on an econometric model relating trade flows to macro-economic indicators such as GDP, exchange rates, and price levels for the trading countries.

The trade model is updated quarterly with trade data and annually with changes in the macro-economic variables. At any moment, due to delays in reporting, the trade data is approximately six months old.

Within Great Britain (Level 2), trend-based forecasting is applied to the underlying traffic matrix. Again, an external model relates freight tonnes lifted (broken down by NST commodity) to GDP or sectoral output. Growth rates derived from this model are fed into the model. However, this process of grossing up a base matrix is not sufficient, as on its own it tends to underestimate changes in the distribution of cargo, resulting in an overall increase in the average length of haul. Therefore, an extra step has been added,

effectively grossing up the average length of haul for those commodity flows where a trend is visible.

The growth rates used are based on historical trends visible within the CSRGT database, and are applied as a linear trend forecast. The current rates are shown below for the commodity groups used within the freight model. They are coded directly into the software and are therefore independent of any scenario variables.

Table 1: Growth in Average Length of Haul by Commodity

Code	Commodity	Growth Rate
1	Agricultural Products	0.987%
2	Foodstuffs	0.987%
3	Beverages	1.378%
4	Construction Materials	0.425%
5	China Clay	0.425%
6	Ore	-0.108%
7	Coal	-0.537%
8	Petroleum	1.441%
9	Chemicals	-0.709%
10	Nuclear	-0.709%
11	Forest Products	1.165%
13	Metals	-0.118%
14	Misc. Manufactures	2.475%
15	Cars	1.042%
16	Mail	2.475%
17	Waste	0.425%
18	Intermodal	2.475%

| 19 | *Own Haul* | *0.425%* |
| 20 | *Channel Tunnel* | *2.475%* |

3.3.2 Cost Models

The treatment of transport costs determines the flexibility a model has for testing a wide range of policy instruments, as this is one of the most obvious ways in which policy-makers can influence demand in the transportation system. At the heart of any conventional four-stage model is a mode-choice component. This relates any given mode's share of total traffic to the "attractiveness" of this mode relative to other options.

A large amount of effort has been directed towards understanding the underlying choice behaviour. The emphasis is on distinguishing between the financial or out-of-pocket cost, and the generalised cost which also includes all the factors such as time taken and reliability that affect the attractiveness of a given alternative.

One example of a generalised cost function quoted by Ortúzar and Willumsen[15], and attributed to Kresge and Roberts (1971) is:

$$C_{ij} = f_{ij} + b_1 s_{ij} + b_2 \sigma s_{ij} + b_3 w_{ij} + b_4 p_{ij}$$

Where:

C_{ij} is the generalised cost between zones i and j,

f_{ij} is the out-of-pocket charge for this trip,

s_{ir} is the door-to-door travel time,

σs_{ij} is the variability of travel time

w_{ij} is the waiting time,

p_{ij} is the probability of loss or damage,

$b_1..b_4$ are coefficients.

(all expressed in monetary units)

Two sets of problems arise here. One is the question of formulating generalised cost functions, estimating parameters (for example, $b_1..b_4$), and the choice models using them. The second is predicting the values of the independent

variables for any given trip. The first set of problems (functional form and parameter estimation) have received a large amount of attention in the technical literature. However, it is surprising that relatively little attention has been placed upon calculating the values of the explanatory variables, particularly f_{ij}, the out-of-pocket cost. In the freight market, it is the second problem set, i.e. the extent to which rivals can achieve competitive advantage, through strategies such as cost leadership[16] that dominate the agenda, and not the question of consumer behaviour.   Consumers are simply expected to know a good deal when they see one.

GBFM therefore attempts to balance these problem sets. The emphasis is placed on building detailed cost models to predict the out-of-pocket costs for given network paths. Generalised cost values are constructed as functions of out-of-pocket costs, door-to-door travel time, and the variability of travel time (otherwise referred to as reliability). The function parameters, such as value of time, and value of reliability have not been estimated within GBFM, but have been drawn from the results of Stated Preference interviews carried out by Leeds University.

Stated preference techniques in this context attempt to derive individual weightings for the components of a cost function. During STEMM, Leeds University applied the LASP (Leeds Adaptive Stated Preference model) within the freight industry to arrive at valuations of time, reliability and the use of rail.

The values used are not commodity specific, although the ITS work did consider different industries. They are:

- Value of time: 1.04167% Of Freight Rate Per Hour

- Value of reliability: 5.0% Of Freight Rate Per 1% Late

- Value of rail: 0.0% Of Freight Rate – a positive result was suggested by the LASP work, but a value of zero has produced more accurate market shares. Thus although interviewees may attach a penalty to rail options, it does not appear to translate into revealed preferences.

3.3.3 Choice Modelling

The central task of a transport model is to make rational choices on behalf of the virtual actors it represents. The term 'discrete choice' is used because the alternatives within the choice set are usually presented as a countable, mutually exclusive set. Alternatives can be ranked according to their generalised cost, so

the purpose of the choice model is to calculate the probability that a given alternative, i, is chosen.

In a simple choice structure it could be proposed that the alternative with the lowest generalised cost wins all the traffic:

"i"	*Generalised Cost(i)*	*Probability(i)*
Alternative 1	*100*	*1.0*
Alternative 2	*110*	*0.0*
Alternative 3	*120*	*0.0*

In practice, this degree of rational decision making cannot be observed. This is either because decisions are being made without perfect knowledge, or because decision-makers are affected by apparently random factors, or because the model is looking at an aggregated set of decisions made by a group of individuals, with similar but not identical characteristics. These effectively converge to the same argument, i.e. that the generalised cost for a given alternative is itself a random variable. The variance surrounding the estimation of generalised cost falls as information about the trip or the decision-maker or the set of choices improves.

A more readily observable result might be:

"i"	*Mean Generalised Cost(i)*	*Probability(i)*
Alternative 1	*100*	*0.7*
Alternative 2	*110*	*0.25*
Alternative 3	*120*	*0.05*

Apparently inferior options may be chosen.

In principle, this choice model, expressed as a mapping from Generalised Cost(i) to Probability(i) is a straightforward process to simulate within a computer model. However it is virtually impossible to prove that any particular combination of an out-of-pocket cost function, a generalised cost function, and a choice model is "correct".

The approach taken has been to follow the F-Logit method established by Fowkes and Toner (1996) within the STEMM[6] project, itself influenced by Cascetta's C-Logit[17] Model (1995). The attraction of this approach has been the ability to represent similarities between alternatives, without having to add a further subjective construct such as a hierarchy based on a definition of transport mode. Cascetta's model deals primarily with overlapping paths in a road network through an additional cost attribute, referred to as a Commonality Factor. However, Fowkes and Toner emphasised that this concept could be extended to other path attributes, such as the combination of modes, the requirement for a specific freight unit (e.g. trailer, container), the identity of the company offering the slot, the combination of terminals used, and so on.

In this context of a freight market, commonality can be considered analogous to the idea of strategic positioning, a much broader concept than a technical attribute such as transport mode.

Again this can be seen as a defensive approach within GBFM. With a high degree of uncertainty regarding actual costs and the formulation of generalised costs, an elaborate or computationally intensive choice method cannot be justified. The C-Logit/F-Logit approach is intuitive and logical, suggesting that a route can win traffic if it is attractive (in terms of generalised cost) but not dominated by a similar, better alternative. It is flexible in the way that commonality can be defined, and it is transparent enough to allow any underlying weaknesses in the cost structures to be revealed.

3.3.4 Path Choice and Networks

Having defined a method for choosing between alternative transport options, it follows that the model needs to be able to enumerate a set of alternatives, and to calculate a set of attributes for each. The conventional although not universal approach, and that adopted by GBFM is to use a network.

However, within any conventional approach in this sphere, there is a considerable degree of latitude concerning the exact implementation. Within GBFM, different implementations are used within the three levels (international, domestic multimodal, and domestic road), but they can all be seen as variations on a single general case:

Figure 5: Network Example
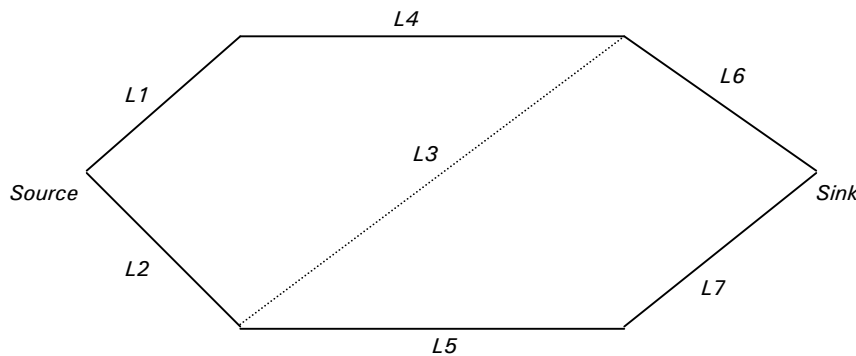
A network consists of a set of links (or arcs), shown here as L1.. L7. In the simple example presented here, the links form a connected network, creating a set of nodes where the links join, such that any pair combination of nodes are connected by at least one path.[18]

Link L3 is shown as a dotted line to indicate that it has different attributes. It might for example be a rail link. The lengths of the links are not limited to physical distance. They can, for example, be defined in generalised cost space.

In a transport application, it is normal to define a source (origin) and a sink (destination). Path enumeration is the process of defining sequences of links connecting the source to the sink, e.g.:

Path	Sequence	Cost
1	L1,L4,L6	GC(L1,road) + GC(L4,road) + GC(L6,road)
2	L2,L5,L7	GC(L2,road) + GC(L5,road) + GC(L7,road)
3	L2,L3,L6	GC(L2,road) + GC(L3,rail) + GC(L6,road)
..	..	..

Thus, by using a multimodal network, paths involving combinations of mode can be enumerated, and evaluated in terms of their generalised cost. They can therefore be compared and used within a choice model.

By attaching the trip matrix to the choice model, traffic can be assigned back to the underlying network, so that the assigned traffic volumes for a given link can be recorded.

3.3.5 Services

For a freight network, the basic concept of a network path can be simplified to that of a 'service'. A service can simply be regarded as a wrapper for a path, where only the customer-oriented information (cost, time taken, reliability, access terminal, egress terminal) are known.

One example could be a parcel service. The customer (the sender) needs to know the cost, the expected delivery date, the various service quality attributes they perceive about the service provider's brand, the location of the nearest post office and the address of the recipient. The actual path that the parcel follows, the combination of transport modes it uses, the speeds of the vehicles, and the road types involved are not usually relevant to the user.

Within GBFM, it is possible to define services that can be added directly to the paths within the choice set, or as hyper-links within the multimodal network. This is typically implemented for rail and maritime services. In the previous example (Figure 5) link L3 could be a service representing a simplified hyper-link from one railhead to another, without describing the details of the rail network.

3.3.6 GIS Elements

The last of the key components outlined in this section are the Geographical Information Systems (GIS) elements. GBFM has been designed to read data created by GIS software[19], and to generate results that can be re-interpreted as maps.

It has been evident, during the development process that there is a need to be able to link the primitive objects within the model such as zones, network links, and nodes, within the spatial dimension. This arises, partly, because of the need to translate from one set of definitions (e.g. counties) to another (e.g. countries or postcode districts), and partly to be able to deal with a wide variety of data sources. Creating "map-able" results is another probable user requirement.

Representing data in a geo-coded form (with latitude and longitude co-ordinates) is a simple way of imposing a degree of referential integrity between the components of a transport model. Simple algorithms can be built to test the distance between objects, and whether one object contains or intersects with another.

3.4 Overview Flow Chart

Therefore, revisiting Figure 4, and expanding the two stage matrix-building and assignment processes would reveal:

Figure 6: Flow Chart of Two Stage Process Within GBFM
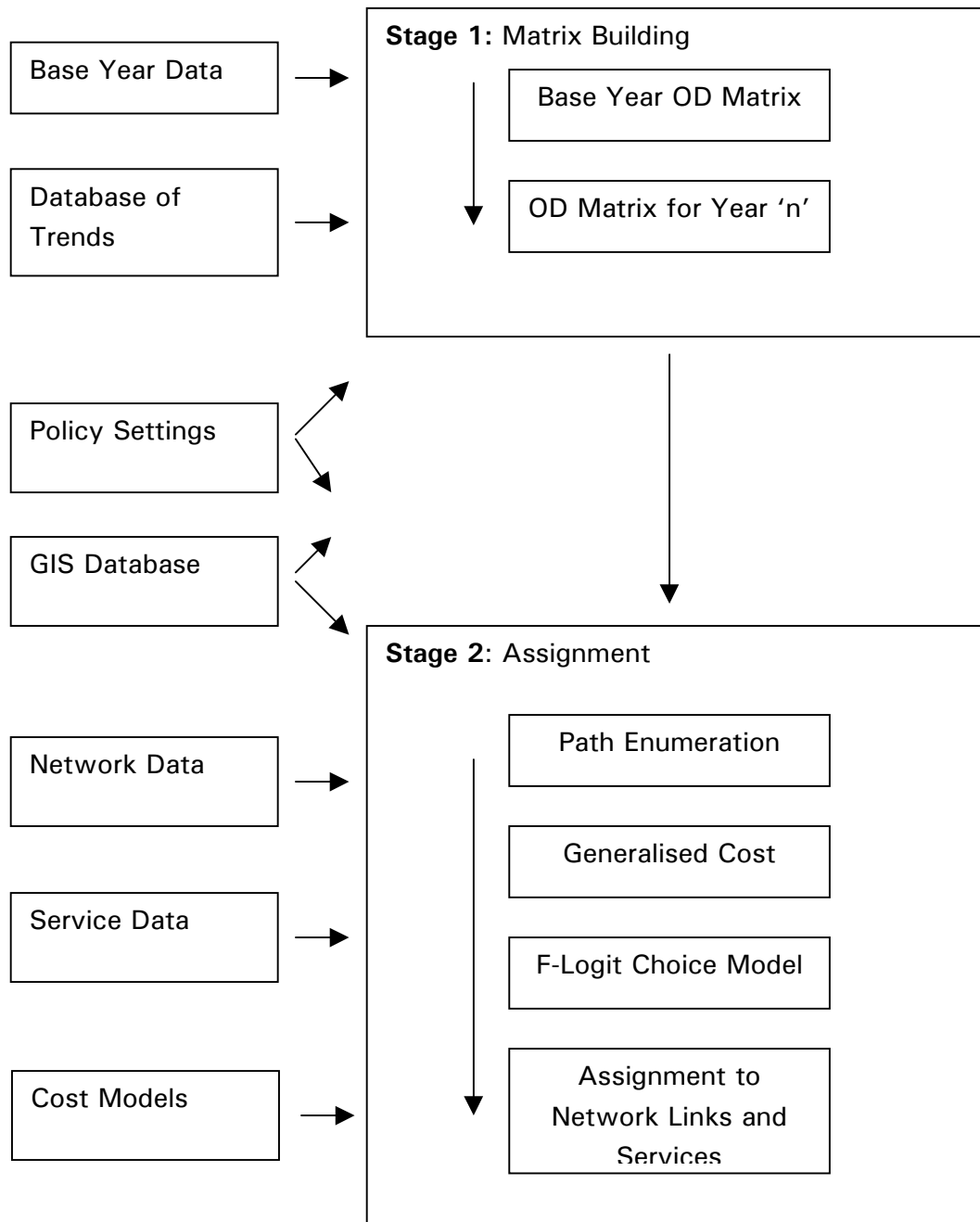
The following sections will explore the methodology in greater depth.

4 Fundamentals

This section outlines some of the fundamental influences on the structure of the GB Freight Model. It is not intended as a full discussion of transport modelling techniques, but rather as a summary of the influences and specific techniques adopted within the software. We will consider:

• The Role of the GB Freight Model

• Buyer Behaviour in the Freight Market

• The C-Logit and F-Logit Discrete Choice Models

• The Network Assignment Algorithm

• Land Use Effects

4.1 The Role of a Freight Model[20]

The consensus within the freight sector suggests that a freight model needs to represent what is essentially a private sector, business-to-business market, regulated by competition and by Government. Perhaps, unlike personal transport, the market for freight is necessarily rational, (motorists do not go out of business if they persistently make inefficient choices) and therefore likely to be predictable. It is therefore logical to base a model design on a traditional micro-economic structure.

One possible visualisation, is offered in Figure 7.
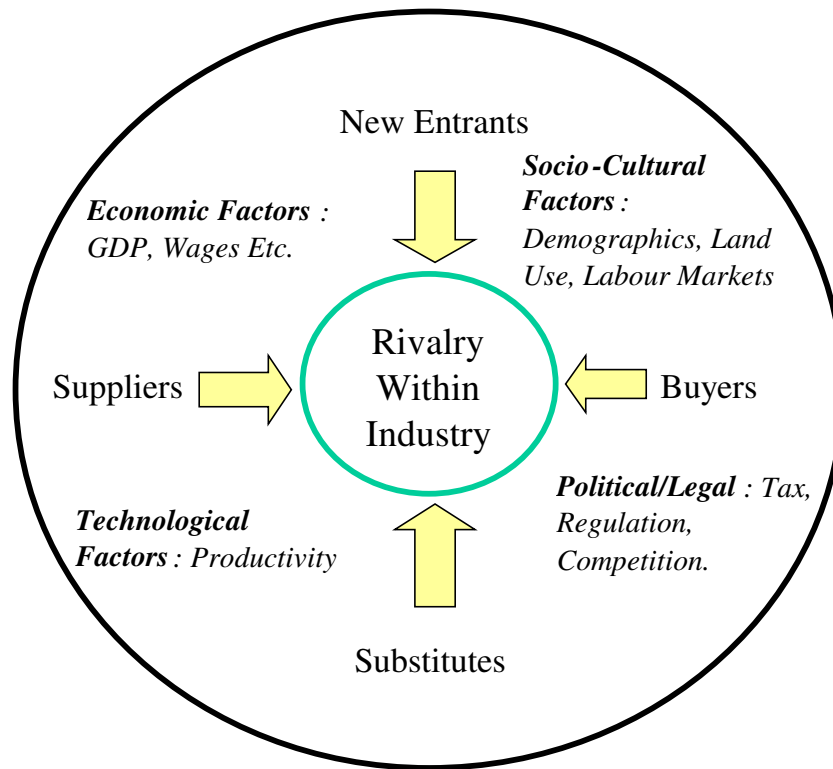
Figure 7: The Industry and Its Environment

Adapted From: M.E. Porter, Competitive Strategy, and Johnson & Scholes, Exploring Corporate Strategy

This diagram considers the freight transport industry within a simplified, general framework designed for applications within the field of corporate strategy. However, the concept of understanding the interaction between the fundamental micro-economics of an industry and its wider context, also serves as a useful first step towards understanding the role of a freight model.

Figure 7 presents a simple micro-economic model, in which an industry's characteristics can be described by the competitive forces acting upon it.

New entrants and the availability of substitutes limit the degree to which profit levels can grow, and the extent to which inefficient companies can survive. Road haulage is a typical example of a successful industry that generates high efficiency and low profits due to ease of entry. The rail infrastructure industry has high barriers to entry, but must compete with substitutes such as the motorway network.

Buyers and suppliers position the industry within a value chain, and also raise the issue of vertical integration within the industry. Many freight businesses are integrated across transport mode and in many cases into other related industries such as warehousing.

Four groups of factors representing the industry's wider context or environment are superimposed onto the micro-economic model. These can be seen as pressures from outside the industry which actors within the industry must respond to.

- Economic Factors - could include changes in quantities such as the business cycle, interest rates, and exchange rates, which can alter costs or impact demand.

- Technological Factors - may affect productivity, fuel consumption, or in the case of transport businesses improve scheduling and reliability, and reduce damage for example.

- Political/Legal Factors - represent the regulatory environment, as well as tax considerations, measures to protect the natural environment, and competition rules.

- Finally, Socio-Cultural Factors - possibly less important in business to business markets such as freight, can affect issues such as land use, and labour markets.

The framework was developed as a means for analysing industries, but it also provides a general framework for the design of a freight model. A typical freight model design is presented below, Figure 8, in the form of a flow-chart.

It is customary for freight transport models to be used to predict how market structures will react to changes in their environment, typically meaning changes in policy. Mechanisms need to be created for translating these external changes into low level market impacts such as cost structures, and the impacts of these are subsequently described in physical terms such as changes in traffic volumes, CO_2 emissions, congestion, or monetary terms such as external benefits or tax revenue.

Exogenous Trends	Government Action	Industry Action

Environment Changes

Road Haulage   Rail Freight   Shipping   Distribution

Industry Changes

Impacts on Mode Shift, Congestion, Natural Environment, Tax Revenue, Regions, Specific Roads, Land Use .. Etc..
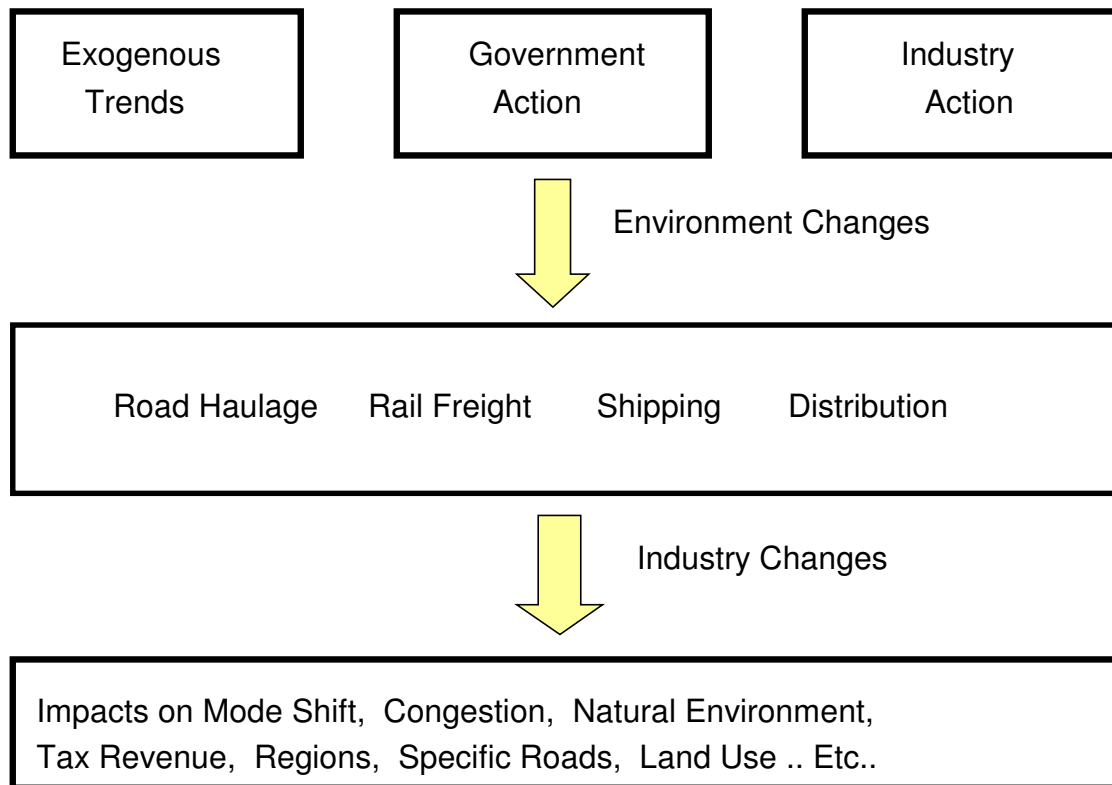
Figure 8: The Role of a Freight Transport Model

These simple diagrams provide useful design criteria. They indicate which market mechanisms should be replicated within the model, and which elements should be treated as external forces (data) or results (outputs).

They also focus attention on a single decisive mechanism, assignment, in which the forces external to the industry (influencing demand, and the composition of demand) are matched to the industry's supply side.

The role of a freight model is therefore to provide a simplified representation of the interactions between the businesses within the freight industry, and their strategic environment. A freight model should predict the impact of exogenous forces within the strategic environment upon the industry and translate these into commercial and policy-oriented quantities.

4.2 Buyer Behaviour

The design of choice algorithms within a transport model is based either consciously or sub-consciously on a theory of buyer behaviour. Ben-Akiva and Lerman (1985)[21] identify four elements comprising a theory of choice:

- The unit of decision making

- A non-empty set of alternatives

- The attributes of the alternatives

- The decision rule, e.g. dominance, satisfaction, lexicographic rules, and utility.

GBFM is based on perhaps the most conventional choice theory. Alternatives within the choice set are treated as discrete and mutually exclusive. Each alternative is described in terms of a vector of quantifiable attributes, which reduces to a scalar value of utility, treated as a random variable. Consumers are assumed to maximize their expected utility.

Within the freight market, the question of identifying a single decision maker is likely to be unsatisfactory, and this is possibly one of the fundamental contrasts between passenger and freight markets. When considering the freight market, Willumsen (2001)[22] addresses this issue directly by stating that nobody decides the choice of mode. GBFM implicitly endorses this view.

This conclusion is neither alarming nor particularly surprising, given that freight is an industrial or business to business (B2B) market. The alternatives within the choice set are paths, implying a sequence of transactions, which the demand model is attempting to encapsulate. Even if a single business is sufficiently vertically integrated to control the entire supply chain, it is likely that each component, (e.g. haulage, storage, terminal operations, equipment ownership), will be treated as a profit centre, and therefore analogous to the disintegrated example. It is also likely that a number of departments within the business (i.e. not just the transport manager) will contribute to the purchase of transport services.

In practice it simply means that attributes such as cost, speed, and reliability which are passed along the path from actor to actor are more likely to be important than those (e.g. mode) that can be "hidden" from the remote consumer, such as transport mode.

Inherited attributes matter, encapsulated attributes do not.

Given these important distinctions between freight (B2B) and passenger markets (B2C), it is helpful to examine other possible contrasts.

Kotler[23] identifies the characteristics of B2B markets which contrast with B2C markets. They include:

- Fewer Buyers.

- Larger Buyers.

- Close Supplier-Customer Relationship – it is increasingly likely that transport contractors will customise their service so that they are effectively an integrated part of their customer's production process or supply chain.

- Geographically Concentrated Buyers.

- Derived Demand – the demand for freight services is derived from household consumption.

- Inelastic Demand – changes in the price of transport services are unlikely to have a great effect upon the total quantity of goods transported in a given time period. The cost of transport is often a relatively small fraction of the price charged to the ultimate consumer of the goods being transported. Therefore, total demand is likely to be inelastic with respect to price.

- Fluctuating Demand – changes in levels of household consumption tend to be magnified within the supply chain.

- Professional Purchasing – freight transport services are purchased by companies seeking to make money in their own markets, and not to satisfy personal aspirations. Buyers are constantly attempting to balance cost and service quality and decisions are more likely to be scrutinised for inefficiency. There should therefore be a strong inclination towards rational choice.

All of these B2B/B2C contrasts can be found in the transport market. There are two further distinctions to make:

- Utility-Direct and Derived - In the market for personal travel, the purchaser experiences the journey, as well as the utility derived from the completion of the trip. In the freight market, the purchaser is only concerned about the end result; the implementation may be hidden.

- Gross Market Size - Passenger and Freight markets often share and compete for network capacity. In a typical national network, passenger vehicle kilometres are likely to be significantly higher than freight vehicle kilometres. In many circumstances, the provision of freight capacity is a by-product of the need to provide passenger capacity.

Freight and passenger market contrasts can therefore be summarised as:

Table 2 : B2B vs. B2C

Stage	*B2C*	*B2B*
Generation	*Influenced by economic activity and by price in certain sectors, e.g. Air travel.*	*Influenced by economic activity.*
Distribution	*For a given set of socio-economic indicators, likely to be consistent from zone to zone.*	*Pairs of zones with similar socio-economic conditions may generate significantly different quantities and types of freight.*
Mode	*Likely to be significant, with consumers showing strong preferences for specific modes.*	*Largely irrelevant, except in circumstances where the use of a specific mode is strongly correlated with a technical constraint or a specific service attribute e.g. Reliability.*
Assignment	*High degree of feedback from assigned demand to network performance, as demand approaches link capacity.*	*Network performance can be treated as exogenous, for a given level of passenger demand.*

4.3 Discrete Choice Models

4.3.1 MNL and C-Logit

One of the guidelines for the GBFM project has been to focus on the *application* of existing methods, rather than to develop or critique the theoretical foundation. A full discussion of discrete choice techniques is not warranted in this document, but a few points of reference are required. For a thorough review of this subject, see Ben-Akiva and Lerman (1985)[21]. It is important to recognise

that the study of choice models is an extensive field, for which only a short history can be justified here.

Quoting Gaudry and Tran (1998)[24],

> "Since the behaviour of an individual faced with the choice of travel mode between two or more alternatives is by nature a discrete event, i.e. the dependent variable is a dummy variable (0 if there is no choice for a given mode, and 1 if there is a choice), discrete choice analysis must be used to explain this particular decision-making process in the disaggregate demand models."

> "Early applications of discrete choice models to disaggregate transportation demand include only two alternatives of travel mode. The extension of mode choice models to more than two alternatives was made during the early 1970's. The major contributions to economic and statistical ideas from which a new area of research, called 'behavioural demand modelling', emerged are due to McFadden[25] who established the theoretical grounding of discrete choice models in random utility maximisation and the use of disaggregate small-sample data in the estimation of choice models via the maximum likelihood method."

> "Among the available discrete choice models, the most computationally tractable and widely used is the Multinomial Logit (MNL) model which explains the behaviour of an individual in terms of a probability associated with each choice of travel mode among the different alternatives."

Following a textbook example[26] in the simple (binary) case where there are two mutually exclusive choices, it is possible to model the probability, P_m that the dependent variable (which can be 1 or 0) takes the value 1, using the logistic cumulative distribution function.

$$P_m = \frac{1}{1 + e^{-x_m'\beta}}$$

This has desirable properties. The probability, P_m is constrained to lie between 0 and 1, it increases according to the level of $x_m'\beta$, and it equals 0.5 when $x_m'\beta = 0$.

The logarithm of the odds ratio or *logit* is a linear function,

$$\ln\left(\frac{P_m}{1-P_m}\right) = x_m^{'}\beta$$

making the estimation of the beta parameters relatively straightforward.

The multinomial logit model is an extension of the binary model, allowing two or more choices to be considered.

The probability that individual i chooses option m, from M possible options in a choice set, is given by:

$$P_{im} = \frac{e^{(\beta' x_{im})}}{\sum^{M} e^{(\beta' x_{im})}}$$

Equation 1 : MNL Function

Here, the term $\beta' x_{im}$ represents a linear utility function, or negatively, a generalised cost function. A MNL function generating choice probabilities for a choice set containing four options, with utility values 1.0, 0.95, 0.90, and 0.80 respectively, would produce:

	Utility	$e^{(utility)}$	P_m
Option 1	1.00	2.718	27%
Option 2	0.95	2.586	26%
Option 3	0.90	2.460	25%
Option 4	0.80	2.226	22%
Total		9.990	100%

The shape of the distribution is controlled by the vector of coefficients, labelled β. The coefficients can be estimated through the maximization of the log likelihood function.

One of the well established problems with MNL arises when there is a high degree of correlation between elements of the choice set. In the above example, if a fifth option were added, effectively the same as option 1, and with the same utility of 1.0, options 1 and 5 would win 21% each, with options 2,3, and 4

falling to 20%, 19% and 18% respectively. This is unrealistic because the implication is that consumers will buy less of options 2,3, and 4, when in practice they have simply been offered more of option 1. This is known as the red-bus, blue-bus problem.

A number of methods for solving the problem have been suggested, adjusting the choice probabilities to take account of correlation between alternatives. One of the most influential, regarding the methodology adopted by STEMM and GBFM has been Cascetta's C-Logit[17]. It is of interest, partly because it retains the practical benefits of MNL, partly because it has a high degree of flexibility in determining the extent of any correlation, and also because it has been applied within a freight context, i.e. to truck movements on inter-urban networks.

Restating the MNL function for readability as:

$$P_{im} = \frac{\exp(V_{im})}{\sum^{M}\exp(V_{im})}$$

where the systematic utility function is given by:

$$V_{im} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ...$$

C-Logit can be represented as:

$$P_{im} = \frac{\exp(V_{im} - CF_m)}{\sum^{M}\exp(V_{im} - CF_m)}$$

where CF_m is the commonality factor, applied as a disutility. Within STEMM, this approach was rejected primarily because the commonality factor was taken to mean the number of links in a path shared by other paths within the choice set, measured in distance. Fowkes and Toner[28] pointed out that within multimodal networks, it was often not the length of the overlap,

> "but the existence of common components which might form bottlenecks or be subject to some other disruption".

It is this distinction that led to the F-Logit approach in which similarities between paths can be described in as many dimensions as the path generator can distinguish.

However, it should be added that Cascetta's framework allows the commonality factor to be calculated in units other than physical space, for example, generalised cost space. It also allows links to be weighted. Thus, a ferry crossing, which may only represent a small part of a path's total distance, could be weighted to reflect the fact that a consumer may regard two paths sharing the same crossing as more similar than two paths sharing the same road journeys, but different crossings. The relative merit of this approach versus the adopted approach has not been explored, but it appears to offer benefits.

4.3.2 F-Logit

GBFM uses the first draft of the F-Logit specification, written by Fowkes and Toner for WP2A of the STEMM project.[27] Note that the method used, differs from the version[28] published as the final deliverable for WP2A.

F-Logit calculates the probability that an alternative 'm' is chosen from a choice set containing 'M' elements, given an ordered vector of generalised costs C[M].

Within the C[M] vector, a single value, representing the minimum can be defined as C_{min}.

The central idea is that a number of criteria can be defined, against which pairs of alternatives can be compared for similarity. The model implementation must define what they are.

An similarity matrix S[i][j] is defined, representing the similarity between option 'i' and option 'j', where $1 \leq i \leq M$, and $1 \leq j \leq M$. The values within S[i][j] show relative similarities, such that $0 \leq S[i][j] \leq 1$. The similarity matrix is ranked in the same order (lowest cost to highest) as the C[M] vector.

A value of zero indicates independence, and a value of unity indicates that the options are identical. When $i = j$, S[i][j] $= 0$.

The probability of choosing option 'm' from a set of 'M' alternatives is given by the formula:

$$P_m = \frac{\sigma_m \exp(-\lambda C_m)}{\sum_{m=1}^{M} \sigma_m \exp(-\lambda C_m)}$$

Equation 2 : F-Logit Formula

where:

$$\sigma_m = \prod_{i \leq m} \left(1 - s_{im}\right)$$

Equation 3: Sigma-m Vector

and:

$$\lambda = \frac{\ln\left(\sum_{m=1}^{M} \sigma_m\right)}{C_{\min}\left(1 - k^{(M-1)}\right)}$$

Equation 4: Lambda

For parameter 'k', Fowkes and Toner suggested a value of 0.95

4.3.3 Worked Example

There are four options in a choice set. Their generalised costs are: 100, 105, 110, and 120 respectively. They form a similarity matrix:

'S' Matrix	Option 1	Option 2	Option 3	Option 4
Option 1	0	0.6	0.2	0.8
Option 2	0.6	0	0.6	0.6
Option 3	0.2	0.6	0	0.2
Option 4	0.8	0.6	0.2	0

The σ_m vector follows from Equation 3.

	$\prod (1-s_{im})$, for $1 \le i \le m$, and $1 \le m \le 4$	σ_m
Option 1	(1-0)	1.000
Option 2	(1-0.6)*(1-0)	0.400
Option 3	(1-0.2)*(1-0.6)*(1-0)	0.320
Option 4	(1-0.8)*(1-0.6)*(1-0.2)*(1-0)	0.064

$$\sum_{m=1}^{M} \sigma_m = 1.784$$

From Equation 4:

$$\lambda = \frac{\ln(1.784)}{100 * \left(1 - 0.95^3\right)}$$

so, $\lambda = 0.0406$

(note, there is an error in the original paper, resulting in a value of 0.125 for lambda)

Finally, the probabilities are:

	Numerator Expression	*Numerator Value*	*P_m*
Option 1	*1.0 * exp(-0.0406*100)*	*0.017249*	*64%*
Option 2	*0.4 * exp(-0.0406*105)*	*0.005632*	*21%*
Option 3	*0.32 * exp(-0.0406*110)*	*0.003678*	*14%*
Option 4	*0.064 * exp(-0.0406*120)*	*0.000490*	*2%*
Total		*0.027049*	*100%*

The similarity matrix has the effect of reducing the share allocated to options with a higher degree of similarity. If all options are considered to be independent, the shares would be 47%, 29%, 18% and 7%. This would be equivalent to the multinomial logit model with a β value of 0.097.

The impact of eliminating the similarity is shown in the following charts.

Figure 9: Market Shares With Correlation Between Alternatives
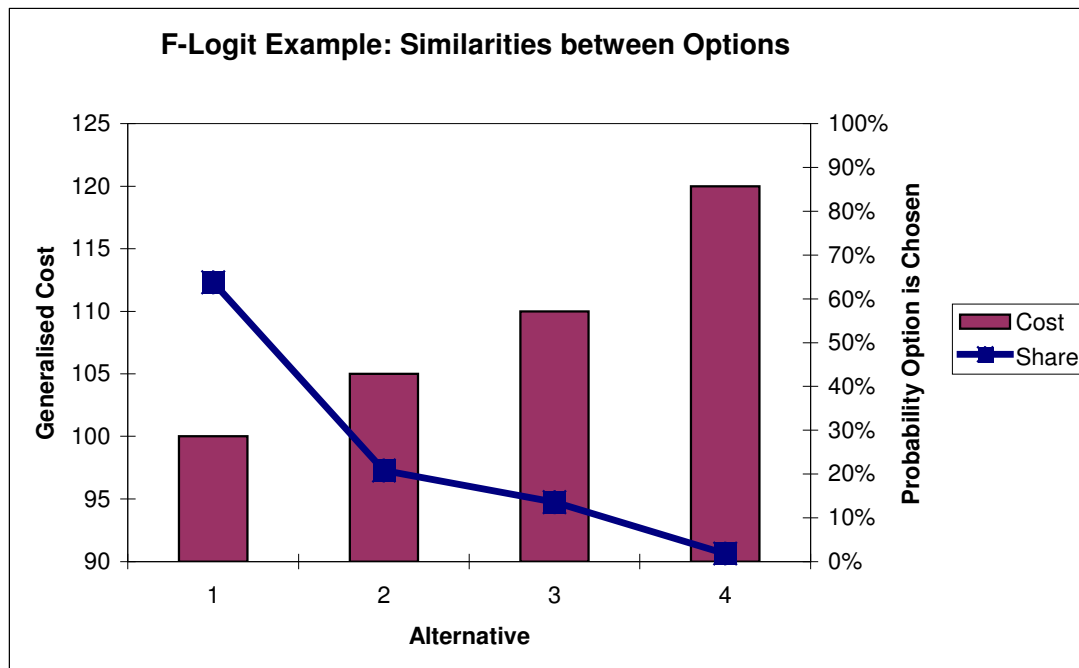
Figure 10: Market Shares with No Similarity Between Options
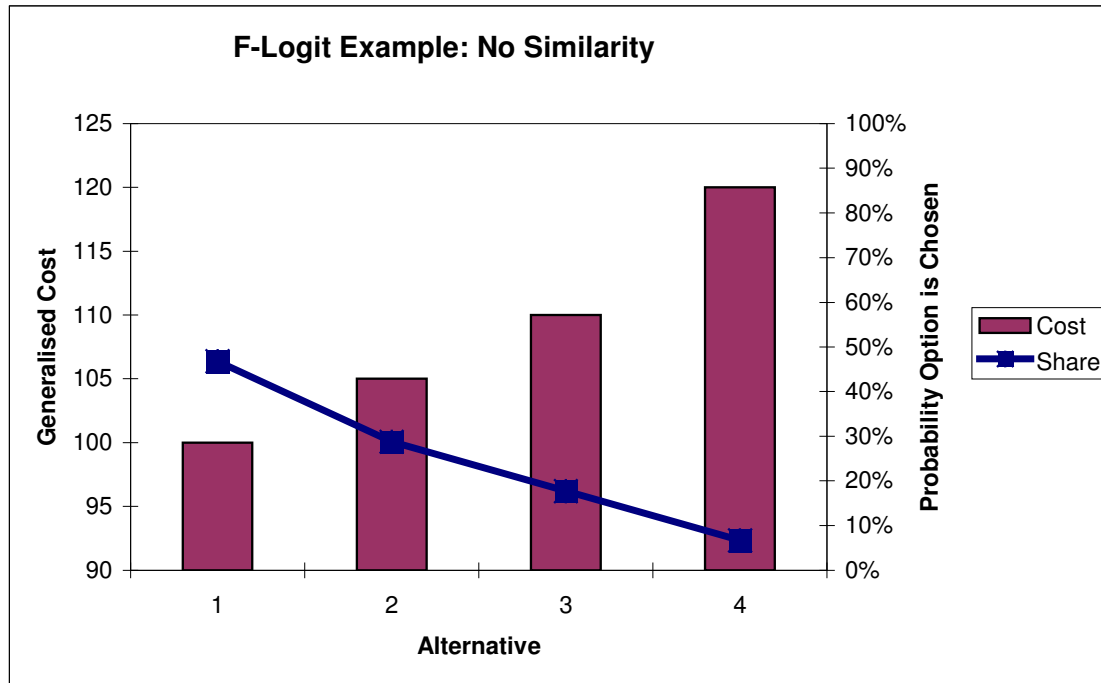
The impact of the 'k' parameter is also worth considering.

	k = 0.90	k = 0.95	k = 0.99
Option 1	60%	64%	83%
Option 2	22%	21%	13%
Option 3	16%	14%	4%
Option 4	3%	2%	0%

Increasing 'k' has the effect of concentrating the traffic onto the lowest generalised cost alternative, all things being equal.

Changing the σ_m vector to {1,1,1,1}, i.e. removing any similarity, and reducing 'k' to a very low value (0.1), results in shares of 28%, 26%, 24%, 21%. This

is the flattest distribution that the model can produce for the given set of generalised cost values.

Changing the units in which the generalised costs are expressed (e.g. from Euros to Yen) has no impact upon the distribution.

An example of the shares predicted by F-Logit, for a real example, using calibrated settings is shown in Figure 11. The routes are summarised by their cross-channel links. The generalised costs are presented as indexed values, with the 'best' value equal to 100. The resulting market shares are shown on the vertical axis.

Figure 11: Example of F-Logit Predictions

Route Shares: Greater Manchester - Koln (Primary Plastics)
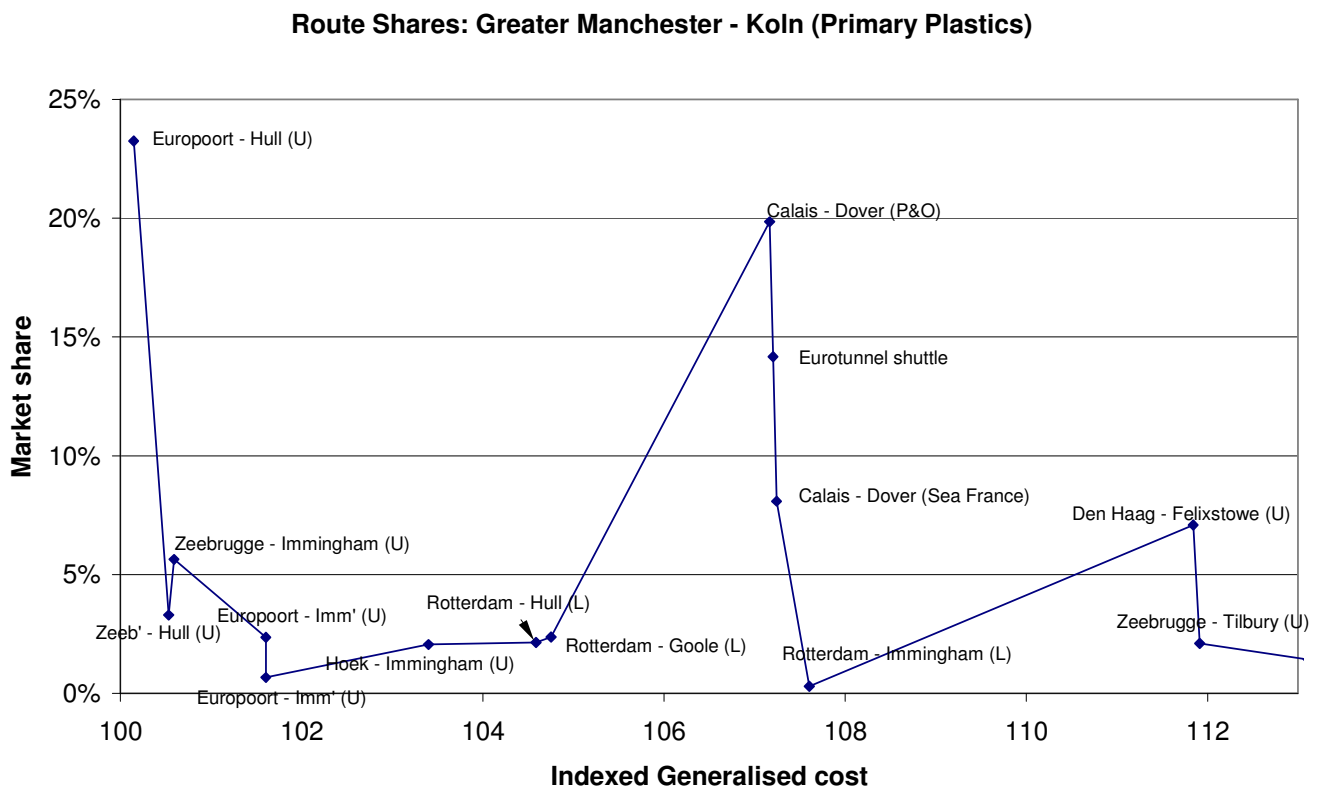
The example here is of a shipment of plastic between Manchester and Köln, a fairly typical market sector for international freight. The best option has been identified as an unaccompanied (U) ferry service between Europoort and Hull. Similar services on that corridor receive some traffic, but the Calais Dover

accompanied ferry service, which has a higher generalised cost captures more traffic as a result of being "different", and therefore able to offer value that the model cannot discern.

4.4 Assignment

One of the external political influences upon the STEMM project, permeating GBFM has been the concept of *intermodality*. Policy makers during the 1990's have sought to introduce or improve transport options containing transfers from one modal network to another. Where this can be achieved, it is possible for *complementarity* to exist between transport modes, as well as the expected *substitutability*. The improvement of a road link to a port may result in more road traffic and more sea traffic.

Within a four-stage transport model, i.e. one with sequential and distinct mode choice and assignment stages, it is implied that modes are competing and mutually exclusive options in a choice set. The results of a mode choice stage are passed to a set of unimodal networks, and assigned to the links.

Within STEMM WP1, Eberhard, Heinitz, Last, Mandel, Rothengatter and Schoch[29] argue convincingly for combining unimodal networks into a single multimodal network, and modelling route choice between multimodal paths. In this way, mode complementarity can be addressed, and the issue of breaking networks into potentially arbitrary modal subsets is avoided.

The difficulty with this approach is the computational overhead, when applied to a large-scale network. The approach adopted by the IWW/MKm/BETA team, who were considering a Continental scale, was to treat the multimodal network as a set of unimodal layers, connected by mode transfer points. Paths between transfer points in the unimodal layers were first optimised. Then, multimodal paths were constructed from these transfer to transfer connections.

Within the STEMM freight model, the approach was less elegant, but broadly similar. The UK and Continental road networks were reduced to a set of matrices, containing zone to transfer journey times and distances. These were calculated outside the model using AA Milemaster[30], a commercial route planner. The model generated a set of non-road 'services', such as a ferry or a rail connection, and a single path was generated for each service:
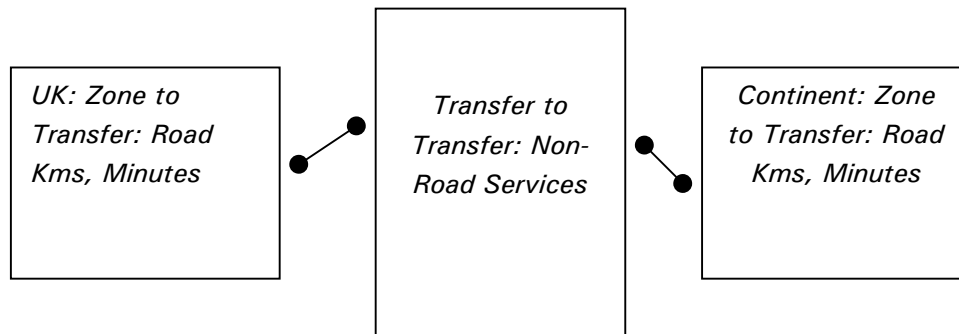
| UK: Zone to Transfer: Road Kms, Minutes | Transfer to Transfer: Non-Road Services | Continent: Zone to Transfer: Road Kms, Minutes |

Figure 12: Path: Zone – Transfer – Service – Transfer - Zone

The approach was suitable for analysing corridor flows within STEMM because there are only a limited number of Cross-Channel or Trans-Alpine services. It was also very fast, as it did not require any interactive path searching, and it avoided the issues raised by overlapping paths.

The focus changed within GBFM, from analysing multimodal Cross-Channel networks towards shorter distance domestic trips. There was a requirement for a greater interaction between the road network and the model, and a need to assign road freight to specific network links. Previously it was only possible to assign traffic to non-road services.

The first use of an interactive road network and a finer zone structure within GBFM was the 2001 MDS-Transmodal analysis of freight facility grants (FFG) in Scotland, for the Scottish Executive[31]. The FFG scheme provides capital grants for non-road transport schemes, based on the quantity of lorry miles saved. The level of grant awarded can be sensitive to the specific road route assumed to be relieved of freight traffic. Therefore, in order to evaluate the scheme it was necessary to use a standard, verifiable path choice algorithm, capable of relating a specific sequence of network links to a road trip.

A similar set of circumstances, resulted in similar requirements for the design of the SRA's Company Neutral Revenue Support (CNRS) scheme[32]. The adoption of CNRS, like FFG, depends upon the agreement of a set of rates for Sensitive Lorry Miles (SLM). Therefore in order to calculate the cost of the scheme it has been necessary to use transparent methods for applying SLMs to trips diverted from road to rail.

The solution adopted within GBFM has been to use Dijkstra's algorithm[33]. Many textbook examples of Dijkstra can be found. It is sufficient in this context to note that it is a relatively efficient algorithm (both in execution and storage) for

finding the shortest path, expressed as a sequence of nodes, from a single source to all other nodes in the network.

Within GBFM, Dijkstra is applied to a database of 27,518 road links to generate the table of distances and journey times between zones and transfer points. It is also used as the basis for assigning traffic to the network. The option exists to simulate sub-optimal path choice by allowing the links to become congested as the volume assigned to them increases. However, a thorough treatment of congestion within a freight-only model is outside the current scope.

4.5 Land Use

One of the policy variables that GBFM has had to incorporate is the impact of road to rail and rail to rail transhipment centres: the rail connected distribution/ storage centre. The proposition for the model to test is whether increasing rail-side activity promotes rail use. There is a need to show the impact of new rail services from new terminals and also a need to allow for a redistribution of traffic towards zones containing these centres.

Building large distribution sheds is likely to have an impact on local traffic. Traffic is likely to be transferred from neighbouring zones to those containing the new facilities. Within GBFM, there is a (standalone, spreadsheet) module that aims to replicate this transfer. The inputs are:

Inputs:
New sheds: *the estimated square metres of new distribution sheds in each county and the proportion of it that is rail connected. The likely associated annual traffic is calculated at 30 tonnes despatched and 30 tonnes received for each square metre of new distribution shed.*

Distances:
 	
    A matrix of distances from every county to county. Within county distances are defined to be 15km.
 	
    The extent of the transfer from a particular neighbouring county will depend on how far away it is from the new shed: the further away, the less effect. The formula we have used is based on a modified gravity model: proportional to 1 / (100 + distance(km)2).

It is expected that the distribution centres will cater for Fast Moving Consumer Goods (FMCG), so the transfer between zones will also be related to the amount of FMCG traffic there originally was in any particular zone.

There are various steps in the methodology to arrive at a sensible quantity to transfer. The transfer process applies to origins and destinations but in this description, we just focus on the transfer of the originating traffic.

1: Calculate a matrix where the cells are the total forecast originating traffic out of the column county / (100 + distance(km)^2). Consider the rows that have been generated: Each row represents a relative measure of the effect on the different counties of putting a new shed in that particular row's county.

2: Each row is then scaled so that the total effect on any county (row totals) = the tonnage capacity generated by the addition of the proposed sheds to that county (@ 30 tonnes despatched and received per year per square metre). Each cell is the tonnage transferred from the column county to the row county due to morphing before any control totals have been applied.

3: Adding up the total increases for each county (row totals) minus the total decreases for each county (column totals) gives the change in tonnage for that county due to the new distribution sheds. This is before any control totals are applied.

Control Totals

Normally the above methodology will result in acceptable values. However if several large new sheds have been built close to a particular county, under the above method there may be more traffic transferred than there is available. If so, there has to be some re-distribution:

1. Consider the county that has the highest ratio (above 1.0) of donations (available traffic). The donations from this county to all recipient counties are scaled down by [available traffic / donations] so that the total donations from that county equal the available traffic in that county.

2. The recipient counties then need to be compensated to re-balance the transfer: all other counties have their donations scaled up such that the total donated *to* each county remains the same as it was.

3. This process can send other counties over the [donations / available traffic = 1] barrier and the same re-distribution process needs to be repeated but without taking any further traffic from the original excessive donor.

4. After this process, the value for each county of the amount received minus the amount donated is calculated. The proportional increase that this represents over the original forecast county traffic is calculated and stored.

5. This whole re-distribution process is done separately for total traffic originating in the counties and total traffic destined for the counties.

6. The proportion of traffic that is potentially rail connected is also calculated: New shed tonnes in and out (@ 30t per sq m per year) * proportion of these sheds that are rail connected / (forecast traffic in and out + new morph generated traffic).

Morphing the OD data

7. The original forecast OD matrix for the FMCG commodities is scaled according to each county's proportional increases. In order for the matrix to match the required totals, the Furness method is applied.

8. The total tonnes transported in the country should remain the same after this whole county transfer process so the whole final matrix is factored to match the original forecast of total tonnes transported.

International Traffics

All the above refers to traffic where there is an OD matrix where all origins and destinations can be morphed. Domestic traffic fits this model. However for international traffic, there isn't the data available to add or subtract traffic from the foreign regions so the only morphing is done on the UK regions.

The process is effectively the same although the original forecast OD data has to be generated in a specific way as shown in the example below:

Table 3 : "Morphing" Process

	Destination UK					_Destination Overseas_			
Origin	0	0	0	0	0	531	534	537	540
_UK_	0	0	0	0	0	537	540	543	546
	0	0	0	0	0	543	546	549	552
	0	0	0	0	0	549	552	555	558
	0	0	0	0	0	555	558	561	564
Origin	381	387	393	399	405	0	0	0	0
Overseas	384	390	396	402	408	0	0	0	0
	387	393	399	405	411	0	0	0	0
	390	396	402	408	414	0	0	0	0

This is only for international traffic with the UK so there are zeros for UK to/from UK and International to/from International traffic. The proportional increase values for the International origins and destinations are set to 1 (= no change).

The proportional increases are applied in a similar way as for the Domestic morphing but to the Origin UK totals (first 5 row totals) and the Destination UK totals (first 5 column totals).

These new Origin UK totals are all scaled back down by the same factor so that the sum of the new Origin UK totals returns to the original sum.

The same factoring is applied to the sum of the new Destination UK totals.

The Furness method can then be applied as in the domestic case.

5 Data Sources

Transport data can be classified into two areas: demand and supply. The demand side deals with flows of goods; the creation of origin-destination matrices, and the supply side deals with networks and costs.

5.1 Demand Data

The construction of origin-destination matrices is a key task for the model. It determines the total volume of traffic moving through the network, (trip generation) and it describes the geographical dispersal (distribution). This establishes the distribution of traffic by distance band, and the nature of the hinterland for any mode interchange.

The derivation of OD matrices within GBFM has been complex due to the lack of a single data source. This has been an influential constraint within the final design of the software.

The decision to base the model upon published databases of freight flows, without constructing a model of trip generation means that the specification of GBFM differs significantly from the recommendations of the 2001/2 Freight Model Review[2]. However, recent developments within the West Midlands Transportation Surveys[34] (CEPOG, Advantage West Midlands, Mott MacDonald, and MDS Transmodal) have established survey and modelling methodologies for using land-use data to model trip generation at a finer level of spatial detail than can be achieved using national or international flow data.

International Traffic

The size of the international traffic sector is derived from HM Customs and Excise data (1999). See link for details of published data[35]. Trade data is an essential resource as it is published regularly by all of the major economies, using standard formats and definitions. It is highly detailed in terms of commodity definition, and it normally contains volume and value information. Since 1992, the UK has compiled trade statistics under two regimes.

Trade between the UK and EU countries is compiled under the *Intrastat* system, whereas extra EU trade remains within the original pre-1992 methodology. In practice, the two sets of statistics are published at different times, and their content differs. Extra-EU trade is generally more detailed, recording transport indicators such as mode and port of entry/exit. Intra-EU trade has been reduced to country of origin/destination, commodity, and quantity.

Within GBFM, the two sets of trade data are aggregated according to the following specification. The translation from the original databases, which are monthly, and broken down by 9 digit Harmonised System (HS) commodity, takes place outside the GBFM software.

• For non-EU Countries: Partner Country, 2 digit SITC Commodity, sea mode, UK port, and tonnes traded.

• For EU Countries: Partner Country, 2 digit SITC Commodity, and tonnes traded.

The key differences are the presence or absence of port and mode. For Extra-EU data, the model does not have to estimate the mode by which the trade arrives in the UK or consider the network structures that cause (for example) a container containing Korean televisions to arrive at Felixstowe. It is simply a matter of record, and the model can proceed to the second level; the inland trip to the GB destination.

For Intra-EU trade flows, this simplification is not feasible. The commodity information must be used to split the trade into two groups (unitised and non-unitised). Then the model must generate paths across the Continent and Ireland in order to determine the UK ports of entry or exit.

In neither case is it possible to determine the regional (i.e. sub-national) distribution. This has been achieved by marrying the trade data to the DfT's ODIT 1991 database[4], which is used to relate ports to their hinterland.

For Extra-EU flows, the ODIT survey is used simply to generate patterns of distribution by GB zones. Extra EU origins/destinations are not subdivided, as it is normally sufficient to know the country of origin, and in any case, ODIT was not designed to provide this.

For Intra-EU flows, regions of origin and destination on both sides of the Channel are generated, using NUTS 3 definitions (counties) for GB, and NUTS 2 (e.g. French Regions, German Länder) on the Continent. When considering port choice, it is clearly necessary to be able to distinguish between Bretagne-Cornwall flows and Normandie-Kent flows.

The process of linking national flows to regions is generally carried out outside GBFM, although there are exceptions (e.g. Ireland), where ODIT does not provide any information, and so, a simple gravity model is used.

A summary of the usage of international data is shown in Table 4.

Table 4: Demand Data Source Analysis

Level 1: International Demand Data

Trade Data:	
• UK Imports and Exports by Country and Commodity	
• Tonnes (unitised/non-unitised split can be estimated)	
• Forecasts - world trade model (GDP, exchange rates etc)	
Intra EU Trade Data: • No Port or Mode Data	Extra EU Trade Data: • UK Port • Mode (ro-ro, lo-lo etc)
Origin Destination Survey ('91): • Adds UK and EU Region	Origin Destination Survey ('91): • Adds UK Region (given port and commodity)
Model: • Adds Ports and Modes	

Level 2: Domestic Multimodal demand Data

Road Traffic • CSRGT Survey • Counties, NST Commodities	Network Rail Data • BIFS System • Sidings, TOPS Commodities
Domestic Freight Matrix • Merges Road and Rail Flows • 62 Counties and 20 Commodities • Domestic leg of international trips can be subtracted • External macro model of freight volumes by commodity	
Pure Domestic Freight	Domestic Part of International
Model estimates: • Mode, route, vehicle, cost	Model estimates: • Mode, route, vehicle, cost • Different procedures

Domestic Traffic: Road

The domestic road freight sector is derived from the Continuing Survey of Road Goods Transport (CSRGT[10]), collected by the DfT.

CSRGT shows:

• Counties of origin and destination

• Product types (2 digit NST)

• Tonnes lifted

• Vehicle type

The CSRGT databases are updated annually, and obtained as ASCII databases, formatted for printing. They are processed outside GBFM, and converted into a single flat file, containing revised zone codes. Data for Northern Ireland is not used.

The principal weakness of the CSRGT, as a record of road traffic, is that it is drawn from a survey, rather than a full record. However, this has not proved to be an obstacle.

Domestic Traffic: Rail

One of the breakthroughs for the initial versions of GBFM was the acquisition of rail freight data by the SRA from Network Rail (formerly Railtrack plc). Earlier MDST domestic freight models constructed freight matrices from road traffic. They could divert from road to rail, but they could not explain current rail flows.

In July 2000, the SRA supplied a database of rail freight flows and a rail freight model designed by McKinsey & Company for Railtrack. The raw data (produced by Railtrack) was extracted from the model, and used within GBFM. In 2002, this original rail database was replaced with a larger sample of rail freight data, acquired with SRA support from Network Rail's Paladin mainframe.

The database contains a full record of rail freight movements for a two-month period in May and June 2001; a sample designed to avoid instances of network disruption. It contains over 540,000 records, each relating to a train movement on the network. The records contain:

- Wagon Number

- Origin Date

- Origin Time

- Head Code

- Originating Station Stanox (the code identifying the network node)

- Terminating Station Stanox

- Stanox where Wagon was Attached

- Stanox where Wagon was Detached

- The Wagon Origin Stanox

- The Wagon Destination Stanox

- The Wagon's Tare Weight – in Tonnes

- The Wagon's Gross Weight – in Tonnes

- The Wagon's Chargeable Weight – in KGs

- The Commodity Code

- The "Euro" Commodity Code

The raw data is broken down so that individual train loads are identifiable. Where a rail journey spans a series of hauls, each section of the journey is visible.

Therefore, a wagon loaded with a forty-foot container at Felixstowe may be hauled to Ipswich, and then detached and re-attached to a different service from Ipswich to Birmingham. There are several immediately useful pieces of information to extract, including:

- The end points of the journey: Felixstowe to Birmingham,

- The route, and its distance,

- The extent to which any of the train loads are at full capacity,

- The relevant rail business, e.g. Freightliner, Enterprise, RES etc,

- The commodity (here, intermodal units are treated as a commodity type)

Thus, the records need to be viewed in context, and decoded.

The first stage involved sorting the file by wagon code, date and time so that the software could rapidly scan the history of each individual wagon in turn. Like this, it became immediately obvious whether wagons were shuttling between fixed loading and unloading points, or whether they were being relayed between connecting services. In either case it is possible to reconstruct the itineraries.

The software processing the data could then reduce the total number of records by saving only the initial loading and final unloading points of a particular consignment. Note that it was not possible to tell whether any consignments were subsequently relayed by another mode (e.g. road) to a different final destination, so it is still not possible to provide an analysis of the terminal hinterlands, and the complementarity that exists for road and rail within multi-modal chains.

The result of this analysis is a database that can provide county by county origin destination matrices by identifiable rail sectors. The software developed in this process can now be used to convert raw data from Paladin into a useable form, suitable for use within a transport model.

5.2 Supply Data

Supply side data can be subdivided by mode and into two broad headings; networks and costs. The objective is to describe which options exist within the transport network, and how much resistance they impose upon consignments of freight. This is perhaps the least readily synthesised data component, and the least readily forecast.

Road Network

The road network is based upon the DfT's NTM 2000 road network. A sample of this (Merseyside and Deeside) is shown in Figure 13. The version used within the current model (mainroads011), contains approximately 27,500 links. Each link has attributes for:

- FORGE area type

- Sub-region code

- Road Type (motorway, trunk dual, trunk single, principal dual, principal single, B roads, and C & unclassified)

- Speed

- SLM category

- Toll

Figure 13: Sample of GBFM Road Network

The network has been processed within Manifold 5.50[19] to delete links outside the British mainland, to 'snap' the nodes to integer co-ordinates, and reduce the total number of links. For example, where two links with identical attributes connect at a one-to-one node, they can be replaced by a single link.

Road Costs

The cost of road haulage has been based upon a series of studies carried out by MDS Transmodal since the 1980s. See the Modal Economics report by Garratt M. and Hatfield M.[13] produced for the 1999 Merseyside Freight Study. Also see the Motor Transport Cost Tables[36].

An example of the cost structure is shown below in Table 5. The figures represent the cost of operating a 6x2 tractor unit and a tri-axle trailer plated at 41 tonnes GVW.

Table 5 : Road Costs

Fixed Costs (£'s per annum)		
Interest		6,000
Depreciation		10,150
Maintenance		6,300
Insurance		5,500
VED		2,500
Wages		43,104
NIC,Pensions		6,466
Office Overheads		12,000
Profit		8,975
Miscellaneous		2,380
	Total Fixed Cost (£/Yr.)	103,375
Driver Productivity		
Weeks Per Year		50.4
Days per Working Week		5
Hours Worked Per Shift		12
Driver's Hours		100%
Number of Shifts		2
Total Hours		6,048
Total Minutes		362,880
	Fixed Cost/Hr	17.09
	Fixed Cost/Min	0.28
Running Costs		
UK Fuel Cost (£/Litre)		0.63
Continental Fuel Cost (£/Litre)		0.40
Fuel Consumption (km/l)		2.50
UK Fuel		0.2520
Continental Fuel		0.1600
Oil		0.0037
Tyres		0.0382
Maintenance		0.0235
UK	Total Running Costs (£/Km)	0.3174
Continent	Total Running Costs (£/Km)	0.2254

Source: MDS Transmodal Estimates

The key numbers are the rates for distance related costs (31.74 pence per kilometre) and fixed costs (28 pence per minute for the vehicle and the driver).

Rail Network

The latest version of GBFM (4.12) has access to a link based rail network, but it is not fully implemented within the software, and therefore not actually used. This situation will be rectified shortly.

The network was obtained from Kingswood Map Mechanics (http://www.mapmechanics.com), originally published by the AA. It has been enhanced by the inclusion of a loading gauge attribute, indicating the height and width constraints for rolling stock.
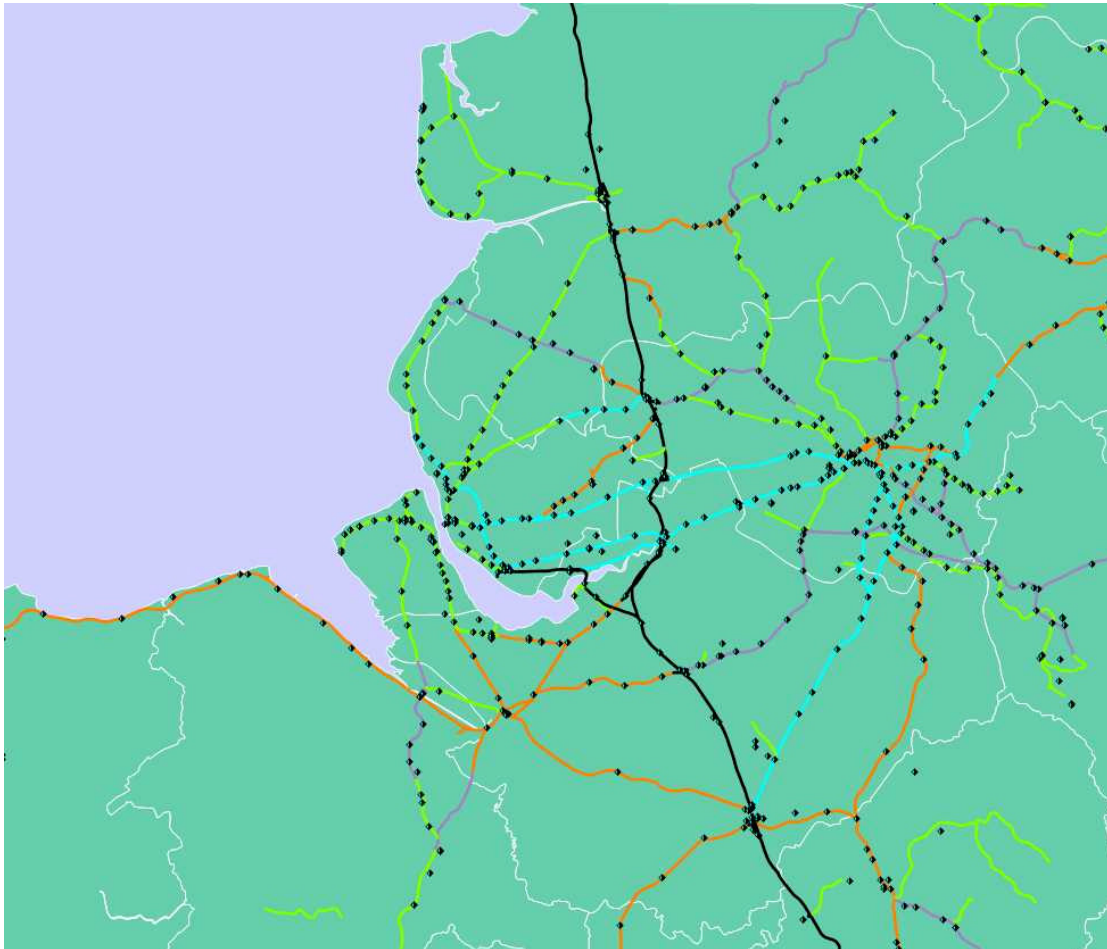

Figure 14: Rail Network

The network has 5,500 links. The 'dot' markers in the figure indicate STANOX locations, which can be related to the rail demand databases. Therefore,

although county-based OD matrices have been constructed for GBFM, it is possible to generate accurate matrices against a much finer zoning scale.

In practice, the network has been simplified to a database of 'services', i.e. hyperlinks from loading terminal to unloading terminal. They are defined for specific rail businesses, using the classification adopted by the Freightmaster publication[37], e.g. Freightliner, EWS Intermodal, EWS Metals, EWS Rail Express Systems. Commodity flows are therefore matched to suitable rail services.

The database of services has been extracted from the Railtrack OD database, using known train movements and wagon details to match the records to a set of rail businesses. Thus frequent, ad-hoc services can be treated as though they were time-tabled. Infrequent ad-hoc services can be excluded.

Rail Costs

(adapted from the Freight Model Review[38])

In order to understand the economics of rail freight it is necessary to view the industry as the sum of its parts, namely, track, traction, wagons, and terminals. In the current industry structure these are separate markets, operated by separate, private sector companies. It is also helpful as a means of indicating Government, the SRA, and the Office for the Rail Regulator (ORR) involvement in the value chain, as the provision of grants and revenue support are an important part of the price formation process.
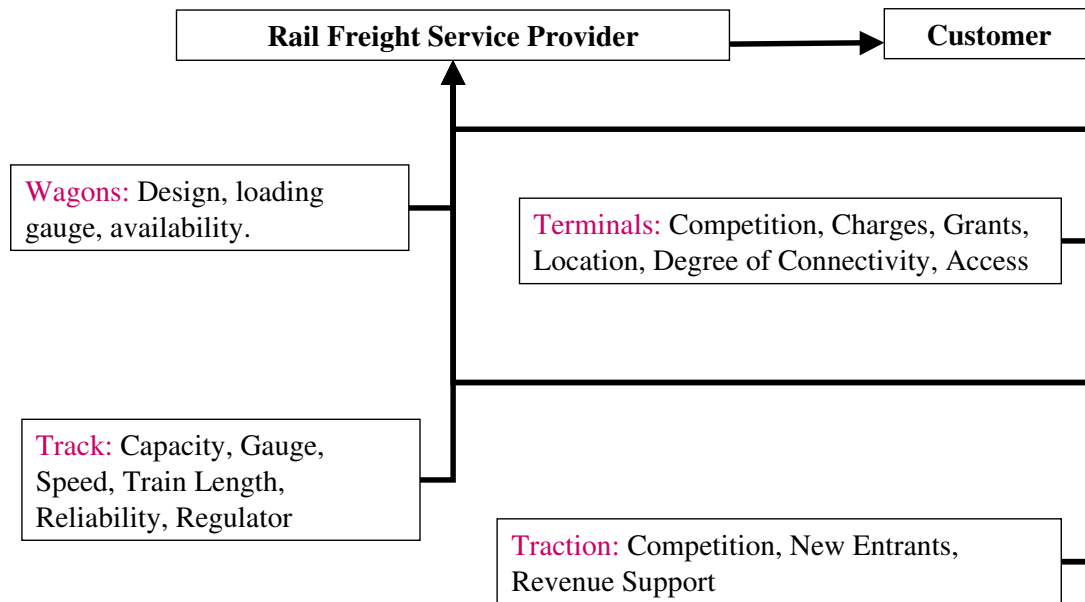
Figure 15: Rail Freight Value Chain

Rail Costs: Track

The key issues for rail freight, highlighted in the SRA's May 2001 Freight Strategy are:

• Capacity - reserved slots in the timetable for freight trains.

• Loading gauge – the height and width restrictions on the freight units.

• Network speed – the ability to schedule paths for trains of different speed, and the need to raise overall transit times.

• Train Length – the ability to handle 750 metre trains on the main freight routes, resulting in greater efficiency and lower costs for operators.

• Reliability – the minimisation of network-related delays.

• Charging Structure – currently set by the regulator.

Outside Railtrack's network, it is also important to consider the role of Eurotunnel, operating the only through rail link to the Continent, and its charging structure. So far, Channel Tunnel through freight has not enjoyed the same levels of growth as Eurotunnel's own shuttle service.

Rail Costs: Traction

The privatisation of the railways resulted in a traction market where freight operators could run national services in direct competition with one another. However, the market is concentrated with two large operators (EWS, who control around 90%, and Freightliner) and two smaller companies, (DRS – who handle the nuclear waste, and GB Rail Freight who are new entrants to the freight market).

EWS is the clear market leader in terms of tonne kilometres, having taken over BR's bulk rail services (coal, construction, steel etc.), as well as the automotive, mail and Channel Tunnel services. Freightliner's main business is handling deep-sea containers from terminals located at ports. However, they have also been successful in winning a share of other markets. Over time, this degree of specialisation can be expected to decline.

At present, traction operators can apply for revenue support in the form of track access grants.

Key issues are:

•   The potential for new entrants into the market.

•   Changes to the revenue support mechanism.

Rail Costs: Wagons/Rolling Stock

Wagon design is one of the major issues affecting the transport of intermodal freight units. Different configurations of container wagons, for example, determine the number and combination of 20' and 40' boxes that can be carried for any given train length, and therefore the cost per unit kilometre.

New wagon technology is one of the key success criteria in developing piggyback services in the UK, and in helping rail to access new markets such as fast moving consumer goods, and parcels.

The design and availability of specialist intermodal units such as swap bodies and road trailers modified for lifting are related issues in wagon design. In some cases it has been possible for companies such as Safeway to obtain grants for equipment such as refrigerated swap bodies, in order to meet the constraints of existing wagon technology and loading gauge restrictions.

Rail Costs: Terminals

The rail freight industry has been forced to recognise significant changes in the structure of the wider freight market, particularly in the types of goods that are carried, their handling requirements, and the needs of the logistics systems they are supporting. The classic rail-friendly industries such coal and steel were originally developed around the rail network, with direct access and dedicated train-load services.

In contrast, the emerging growth areas in freight have developed around the motorway network, requiring potential rail customers to use road haulage to connect their distribution centres to the rail network. Thus a typical rail journey for an intermodal unit may require two sets of terminal charges and two road haulage connections.

Key issues are:

- Terminal costs – per unit.

- Access to Terminals – the availability of public facilities close to the trip ends.

- Rail Connectivity – the volume of freight loaded and unloaded at rail connected sites.

Rail: Cost Models

GBFM uses two rail cost models, each constructed using the structures outlined above. The values contained in these models were initially derived from commercial studies undertaken by MDS Transmodal (Garratt M.[14]). They have been discussed and reviewed by the SRA and Network Rail, as well as EWS, GB Railfreight and Freightliner.

As the dynamics of the rail freight market are more complex than the road sector, it cannot be assumed that rail freight costs accurately reflect actual rates. Nevertheless, cost models adjusted to take account of revenue support schemes, have proved to be the only sound basis for relating industry and policy variables to rail's competitiveness.

Table 6 and Table 7 show the cost settings assumed for 2001. Intermodal and Bulk trains are based upon separate cost models.

Table 6 : Intermodal Rail Costs

Cost Item	Description	£	Basis
Traction			
Capital Cost	Type 66 Locomotive	1,600,000	One off Cost
Depreciation	Over 25 Years (20% Residual)	51,200	Per Annum
Interest	7% Per Annum	112,000	Per Annum
Crew	3 @ £35000	105,000	Per Annum
Fixed Maintenance		50,000	Per Annum
Insurance	Assume 2% of Capital Cost	32,000	Per Annum
Cost Excluding Overheads		350,200	Per Annum
Overheads	Assume 15% of Cost Excl. OH	52,530	Per Annum
Cost per Annum		402,730	Per Annum
Hours Worked	250 Days * 12 Hrs Per Day	3,000	Per Annum
Cost per Hour	Cost PA/Hrs Worked	134.24	Per Hr
Variable Maintenance		0.15	Per Km
Fuel		0.85	Per Km
Cost per Km		1.00	Per Km

Cost Item	Description	£	Basis
Wagon Hire			
Capital Cost	Megafret Wagon	70,000	One off Cost
Depreciation	Over 20 Years (10% Residual)	3,150	Per Annum
Interest	7% Per Annum	4,900	Per Annum
Maintenance	4 Bogies*0.5p*160000km	3,200	Per Annum
Annual Cost		11,250	Per Annum
Days used Per Annum	Assume 300: 6 Days*50 Weeks	300	Per Annum
Cost Per Wagon Day		37.5	Per Day
Cost Per Unit Day	Units Per Wagons Using Load Factor	22.50	Per Day
Cost Per Unit Hr		0.9375	Per Unit Per Hr

Cost Item	Description	£	Basis
Track Charges			
Track Charge	Per 1000 Gross Tonne Kms	2.775	Per KGTKm
Maximum Trailing Weight	Tonnes	1,010	Tonnes
Track Charge	Per Train Km	2.80	Per Train Km
	Per Unit Train Km	0.112	
Continental Rates			
Track Charge	Per 1000 Gross Tonne Kms	1.750	Per KGTKm
Maximum Trailing Weight	Tonnes	1,010	Tonnes
Track Charge	Per Train Km	1.77	Per Train Km
	Per Unit Train Km	0.071	

Continued...

Terminal Charges			
Sidings	3850 metres @ £250	962,500	One Off
Turnouts	12 @ £50000	600,000	One Off
Paving	60000 sqm @ £40	2,400,000	One Off
Fencing & Security	Assume £500000	500,000	One Off
Connection (Signalling)	Assume £1000000	1,000,000	One Off
Land Costs	7 hA @ £500000	3,500,000	One Off
Total Construction Cost		8,962,500	One Off
Depreciation	On Total Const Cost (Excl land)/25 Yrs	218,500	Per Annum
Interest	At 7% on Total Const Cost	717,000	Per Annum
Maintenance	Assume £100000	100,000	Per Annum
Labour	8 people * 2.5 shifts @ £20000	400,000	Per Annum
Reach-stackers	4 @ £70,000	280,000	Per Annum
Overheads	Assume £150,000	150,000	Per Annum
Total Cost		1,865,500	Per Annum
Productivity	4 Trains/Day * FEU *2*300	60,000	Per Annum
Full Cost Per Lift		31.09	Per Lift
Marginal Cost Rate	Less Depr. & Int. on all except Cranes	18.49	Per Lift
Rate to Carry Forward		31.09	Per Lift

Miscellaneous Assumptions			
Train Speed	50 kph	50	kph
Cargo Speed	40 kph	40	kph
Maximum Trailing Length	550 metres	550	metres
Load Factor	83%	83%	
Preparation Time	8 Hrs	8	Hrs
Weight Per Wagon	37 Tonnes	37	Tonnes
Weight Per Loco	130 Tonnes	130	Tonnes
Gross Weight Per Unit	13 Tonnes	13	Tonnes
HQ Overhead Costs	£8	8	£ Per Unit
Interest rate	7%	7%	Per Annum
Maximum Wagons	Trail Length/18.333/2	15	wagons
Average Load	FEU Units	25	FEU
Gross Train Weight	Engine + Wagons + Units	1,010	tonnes

Source: MDS Transmodal Estimates

Table 7 : Bulk Rail Costs

Cost Item	Description	£	Basis
Traction			
Capital Cost	Type 66 Locomotive	1,600,000	One off Cost
Depreciation	Over 25 Years (20% Residual)	51,200	Per Annum
Interest	7% Per Annum	112,000	Per Annum
Crew	3 @ £35000	105,000	Per Annum
Fixed Maintenance		50,000	Per Annum
Insurance	Assume 2% of Capital Cost	32,000	Per Annum
Cost Excluding Overheads		350,200	
Overheads		52,530	Per Annum
Cost Per Annum		402,730	Per Annum
Hours Worked	250 Days * 12 Hrs Per Day	3,000	Per Annum
Cost per Hour	Cost PA/Hrs Worked	134.24	Per Hr
Fixed Cost Per Km	At Constant Train Speed	2.68	Per Km
Variable Maintenance		0.15	Per Km
Fuel		0.85	Per Km
Cost per Km		1.00	Per Km
Total Cost Per Train Km		3.68	Per Km

Wagon Hire			
Capital Cost	Bulk Wagon	70,000	One off Cost
Depreciation	Over 20 Years (10% Residual)	3,150	Per Annum
Interest	7% Per Annum	4,900	Per Annum
Maintenance	2 Bogies*0.5p*160000km	1,600	Per Annum
Annual Cost	Sum of Lines 16-18	9,650	Per Annum
Days used Per Annum	Assume 300: 6 Days*50 Weeks	300	Per Annum
Cost Per Wagon Day	Annual Cost/Days PA	32.17	Per Day
Cost Per Tonne Per Hour		0.036	

Track Charges			
Track Charge	Per 1000 Gross Tonne Kms	2.577	Per KGTKm
Track Charge	Per Cargo Tonne Km	0.005	Per Train Km

Terminal Charges			
Market Rate/Tonne		0.75	Per Tonne

Continued…

Miscellaneous Assumptions			
Train Speed	50 kph	50	kph
Cargo Speed	35 kph	35	kph
Load Factor	50%: Going out Full, Returning Empty	50%	
Preparation Time	8 Hrs	8	Hrs
Weight Per Wagon	28 Tonnes	28	Tonnes
Maximum Wagons	18 Wagons	18	wagons
Weight Per Loco	130 Tonnes	130	Tonnes
Interest Rate	7%	7%	Per Annum
Tonnes of Cargo/Wagon	74 Tonnes * Load Factor	37	Tonnes
Average Cargo Load	Loaded Cargo Weight * Load Factor	666	Tonnes
Gross Train Weight	Engine Plus Wagons Plus Cargo	1,300	Tonnes

Source: MDS Transmodal Estimates

Sea Networks

GBFM represents maritime links as simple port-to-port connections for unitised services. Bulk cargo flows are always introduced at the UK port, without tracing the maritime routes, so they are not modelled against a network structure.

Supply-side information for ro-ro services is relatively straightforward to obtain, with the transport trade press being the obvious source[39].

Ro-ro services are defined according to:

• UK Seaport

• Overseas Seaport

• Crossing Time

• Frequency

Container or lo-lo services are also readily available. MDS Transmodal maintains a databank of container vessel deployment[40]. The databank has been used to generate port-to-port services with the same attribute fields shown above.

The full specification of the containership network data is shown in Table 8.

Table 8: Containership Network Data Specification

Vessel Number	comprising the last three digits of the Lloyds classification number plus the hull number
IMO	IMO number
Name	Current name of the vessel
Former Name	Former name of the vessel
Route 1	Current route on which the vessel is deployed - numeric code. All trade routes have been classified into 75 groups. For multi- sector itineraries, vessels are given more than one route code.
Route 2	Current route on which the vessel is deployed - numeric code. A more aggregated classification in which all trade routes have been classified into 30 groups. For multi-sector itineraries, vessels are given more than one route code.
Alpha Route	Text description of current route of the vessel, e.g. EUR/FE
Port	Ports served on a regular basis by the service, (inducement calls are not included). Ports are coded into a three digit alpha code - An example for a vessel deployed on a transpacific service is: HKG/KAO/BUS/KOB/YOK/LGB/OAK/SEA/BUS/HKG
Service	Name of the service on which the vessel is currently deployed
Vessels	Number of vessels deployed on the service
Partner	Names of carriers involved in offering the service : joint sailings, space and vessel sharing
Slot	Names of carriers chartering slots on the service
Alliance	Name of the "global alliance" in which the vessel is operating
Operator	Current operator of the vessel
Corp	Name of the overall controller of an operator e.g. HAMBURG-SUD is the CORP for OPERATOR = COLUMBUS, ALIANCA, CAT.
Service Frequency	Frequency of the service on which the vessel is currently deployed in terms of the number of sailings for the service per year
Owner	Name of the registered owner of the vessel
Beneficial Owner	Name of the beneficial owner of the vessel
Sort Code	Relationship between the owner and operator of the vessel
Owner Nationality	Nationality of the beneficial owner of the vessel - see file COUNTRY for country codes and countries
Flag	Flag of the vessel - see file COUNTRY for country codes and countries

TEU	Vessel capacity in TEU
Reefer Capacity	TEU capacity of refrigerated holds
Reefer Plugs	Number of reefer plugs
Vessel Type	Vessel type: e.g. Fully Cellular, Converted to Full Cellular, Ro-ro/cellular etc.
Post Panamax	Whether vessel is of post panamax dimensions
Dwt	Dead-weight of the vessel
Gear	Code Y = geared Code N = gearless
Speed	Vessel speed in knots
Year of Build	Original year of build of the vessel
Month	Month of delivery of vessel
Yard	Yard of build/Yard of conversion, e.g. MITSUI/MITSUBISHI
Hull	Yard hull number
Jumbo/ Conv	Indicating whether the vessel has been jumboised or converted to full cellular:
Year 2	For relevant vessels, showing the latest year of conversion or jumboisation
Crew	Crew numbers

Sea Costs

While it has been possible to obtain network data for maritime services with great detail, the sea cost element is relatively under-developed within GBFM. Ideally the sea networks would be linked to cost models similar to those used the road and rail networks. Cost models for container shipping and ferry services are available (LINCOST[41] and the Ferry Competition Model[42]), but they are not currently linked to GBFM. Instead, a set of rates have been entered, based indirectly upon the cost models, but also on information available within the market place. This is clearly an area in which the methodology could be improved relatively easily.

6 Software Implementation

Before the calculation processes within GBFM are examined in detail, it is necessary to describe in brief the software platform upon which the model is based, as this has many implications for how the model can be integrated and developed. The following pages also introduce some of the terminology which is used within the next section.

The emphasis within GBFM has been on application rather than theory, so the software development and the development of the modelling methodology have proceeded together. To an extent, the rapid improvement in "everyday" Microsoft/Intel programming platforms through the 1990s has been an invisible catalyst for GBFM.

Outline

GBFM is a single executable, (a "dot exe" file) written in C++, compiled with Microsoft Visual C++ (Version 6.0), for Intel hardware, running under the Win32 operating system (Windows 95 onwards).

The software has been designed to work alongside Microsoft Excel (version 8), so that user inputs are collected within Excel spreadsheets.

In general, the idea has been to allow users to use familiar tools such as Excel, Access, and GIS software (e.g. Manifold or Map-Info) to set up the model runs and to analyse the results. The GBFM executable provides the bridge from the input data (flows, networks etc) to the estimates (mode split, network assignments etc).

On reflection, this approach differs from many other recent transport model implementations, in which dedicated software packages (such as Saturn[43]) are typically used. In those circumstances there is a clear distinction between the model and the transport modelling software. One software package can be used to develop a series of different models, with obvious efficiency benefits for transport planning applications.

C++

It is not possible to make a direct comparison here between the adopted approach and transport modelling packages such as Saturn, as we have not

tested them. However, it is possible to consider the rationale behind the implementation of GBFM, and the use of a general-purpose language.

Quoting the C++ language's author[44], C++ is a "general purpose programming language with a bias towards systems programming that supports efficient low level computation, data abstraction, object oriented programming, and generic programming."[45] Like other popular languages (e.g. Java, C, Basic, and Pascal/Delphi) it can be applied to a wide range of scientific or business related applications. The extent to which it has been adopted by programmers in the 1990s has reinforced its position, with over 1.5 million claimed users.

The main arguments for using C++ (many of which would also be true for Java) within GBFM are:

- Cost: C++ compilers can be downloaded freely (see for example http://www.delorie.com/djgpp). Modelling packages may cost in excess of £10,000. This is a major factor for small businesses developing experimental software with no research budgets. Moreover, compiled executables can be distributed freely, and there are no barriers to collaboration between programmers.

- Speed: The language closely resembles the underlying machine code understood by the computer, allowing key sections of code to be optimised. Conversely, it compensates for relatively inefficient programming styles.

- Flexibility: since all the algorithms within GBFM have to be supplied by the programmer, there are no software imposed restrictions upon how the model operates.

- Object Oriented Programming: The ability to define 'objects' resembling tangible components (nodes, links, zones, vehicles) within the software has proved ideal, providing a "human's view of the task being performed by the computer".[45]

- User Base: The widespread use of the language has resulted in every aspect being tested and examined. Developers can therefore be fairly confident that the language works, and that their application is not going to "outgrow" the language. Furthermore, a large collection of optimised components exist in the public domain (e.g. graphical interfaces, maths libraries, network search algorithms, database extensions). See http://www.cuj.com/link/index1.htm for verification.

- Standards: C++ is covered by American National Standards Institute (ANSI) and International Standards Organisation (ISO) standards. It is therefore not tied to a single vendor, e.g. Visual Basic and Microsoft.

- Portability: Since GBFM is based as far as possible on ISO C++, without the use of language extensions, such as Microsoft's MFC library or other proprietary standards it is feasible to create models for alternative operating systems such as Linux or future versions of Windows. This feature has allowed GBFM to reuse code from earlier pre-Win32 software.

- STL: The Standard Template Library[46], covered by the ISO standard, and therefore portable, provides a number of generic objects (templates) for data storage and complex low-level manipulation. GBFM has made extensive use of STL.

Therefore, although C++ is an approachable and inexpensive technology, this is mainly because it is non-proprietary, and not because it represents in any sense a compromise.

7   Model Processes

Previous sections have discussed the outline structure of GBFM and the principal influences upon the choice of components. In this section, an attempt has been made to describe the actual sequence of processes within the software, so that the relationship between the main program elements can be understood. It is also an opportunity to highlight processes which have not yet been described, and which need to be understood in context.

As a starting point it makes sense to review Figure 4 and Figure 6. Figure 4 can be regarded as an overview of the complete sequence of processes, with three levels and two stages in each.   Figure 6 is an exploded view of each level.

However, outside this main thread, there are a number of subsidiary objects that provide access to databases or routines shared by a number of processes within the main sequence. The subsidiary objects are generally accessible through global pointers, and they need to be constructed and initialised before the matrix building or assignment routines can begin. These steps also need to be described as they indicate how the various data sources are incorporated.

Therefore, to clarify the presentation, a simple "step 1, step 2,… " naming convention will be used, following the exact ordering of events within the program. The sequence can be verified by observing the status messages reported by the software as it proceeds.

As mentioned in the previous section, C++ programs are built up from objects encapsulating data and "methods", meaning processes. The objects are termed "classes". These will be referred to by the names used within the program so that this section can also serve as a road-map for the underlying source code. GBFM has (in version 4.12) 68 "classes", ranging from relatively simple composite data types to more complex structures with 2-3,000 lines of code each. The discussion will therefore focus upon the more important program elements.

The three 'levels' and their internal 'stages' will also be used as reference points. The objective here is to show how the program arrives ultimately at Level 3 Stage 2, with road traffic assigned to a large road network.

Step 1: GBFM Loads the Scenario

User interface for GBFM is handled through an Excel spreadsheet called:

```
c:\multimodal\scenarios\nScenarios.xls
```

The spreadsheet is loaded directly into the application using Microsoft's OLE (Object Linking and Embedding) technology. It is one of the few non-portable components of the program, but it is a convenient solution, allowing users to build cost models in a spreadsheet where all the steps are trace-able. One of the future draw-backs is that it requires Excel 8 to be installed on the host computer. It is therefore possible that a web-page or a dedicated Windows interface could be used in future.

As expected, the loaded scenario contains a number of transport cost settings which are used within the model run. However, it also contains a set of text strings representing filenames, which also form part of any scenario. The reference to the file containing the GDP assumptions is loaded in this way.

Read and write operations upon `nScenarios.xls` are handled by the `xlLink` class.

Step 2: Scenario Cost Settings are Passed to the Internal Cost Models

Using the road and rail costs extracted from the `nScenarios.xls` file, two internal cost models (`RoadCost` and `RailCost`) are constructed. The `RoadCost` object is relatively simple, combining time and distance based costs. The RailCost object is more complex, combining all the main rail cost elements (track, traction, wagon hire and terminals) for either bulk or intermodal services.

Thus, whenever the program needs to impute a cost or a generalised cost on a link or a path, these objects are invoked, so that the underlying methodology is always consistent.

Step 3: Three Road Networks are Constructed

Separate road networks are constructed for GB, Ireland and the Continent: `GBNetwork`, `IreNetwork`, and `EUNetwork`. The Irish and Continental networks are straightforward distance and journey-time tables which are loaded straight from files stored on disk.

The `GBNetwork` class, however, is one of the principal components of GBFM. It contains all the primitive GIS data (towns, county zones, post-code district zones, and road links), and it acts as a server of high level data from these resources. `GBNetwork` constructs an internal set of distance and journey-time tables. These can, of course, respond to changes in the underlying network structure.

In addition, `GBNetwork` has methods for calculating full trip costs, allowing for drivers' breaks, the use of unaccompanied transport modes, access/egress waiting times, and repositioning.

Step 4: GBNetwork has an Internal Dijkstra Object

To convert a database of links and nodes into meaningful path information, `GBNetwork` can construct instances of a `Dijkstra` object, an implementation of Dijkstra's short-path algorithm. The `Dijkstra` object is relatively light-weight, being constructed with a reference to the `GBNetwork` network data. The efficiency of this algorithm is paramount to the speed of the model, and this has been significantly improved by employing an STL `priority_queue`. This is an all-purpose stack container, that keeps its elements in sorted order.

Step 5: GBFM Constructs a set of Rail Subsidies

The information within the cost models and network structures allows the software to calculate SLM based subsidies internally. It can compare road and rail costs to check economic need, and it can use SLM values attached to specific network links to calculate external costs. There are three batches of algorithms in the `Subsidy` class for calculating port-based, Channel Tunnel-based, and domestic subsidies from the CNRS[32] formula. Recently these processes have been over-ridden with a method for loading pre-set rates from a database as draft "official" CNRS values have become known.

Step 6: GBFM Constructs a Commodity Map

One of the fundamental data problems is the need to convert between commodity classification schemes. Trade statistics use the SITC system, CSRGT uses NST, Rail Statistics are different again. Generally, it is a good idea to use the maximum level of detail available at any specific stage of the program, so data needs to be converted as one stage hands over to another. In GBFM, this task is handled by the `ComLU` class. It is a straightforward container for the look-up tables, with methods to perform the translation function.

Step 7: Domestic Rail Traffic Calibration

Throughout the GBFM project, we have opted to base the choice algorithms upon realistic cost figures, modified with values of time and values of reliability obtained from external ITS studies. Therefore it has not been necessary to fit the data using econometric models. Instead, the results based on a-priori settings have been tested for validity, and then, if necessary adjusted using calibration for specific dimensions.

Only two areas of the model are calibrated. The first is the trailer volumes on the ferry crossings, and the second is the total volume of rail freight by commodity. The `DomRailCalib` class manages the calibration of domestic rail freight. During a calibration sequence (i.e. when the model is run continuously to establish the calibration values), this class stores and saves the calibration parameters. However, during a normal estimation run it simply retrieves the parameters and serves them to other classes in the model.

Step 8: Morphing

Within the rail-freight sector, it has been evident that there is synergy between rail-side development and demand for rail services. The FFG programme embodies this concept.

The development of new, rail connected sites is a predictable process as there are lengthy lead times from a scheme being proposed, through the planning process into realisation. Since the size of these rail schemes is often known in advance, it is possible to build them into a forecast scenario.

The model uses a simple land-use iteration to "morph" an existing traffic matrix into one where zones containing future freight facilities divert demand from neighbouring zones.

A four-zone example is shown graphically in Figure 16 and Figure 17 (below). Zone 2 is forecast to benefit from inward investment, drawing traffic from neighbouring zones. The total volume of traffic remains constant at 400 units, but all of the matrix cells, T_{ij}, are morphed. The degree of change is dictated by the expected size of the new facility, and the distances between the "active" zone (coded '2' in the example) and the individual "passive" zones. Clearly any number zones (0 to Z) can be modelled simultaneously.
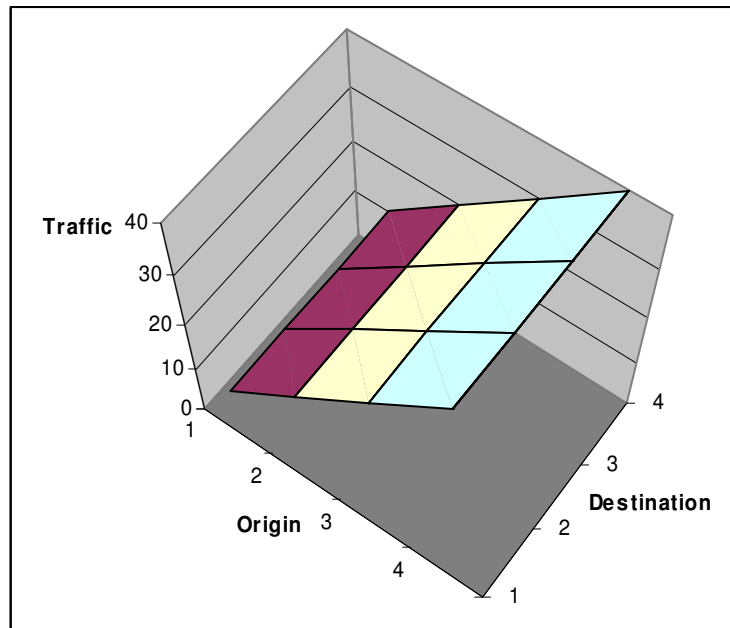
Figure 16: Example of Four-Zone Traffic Distribution
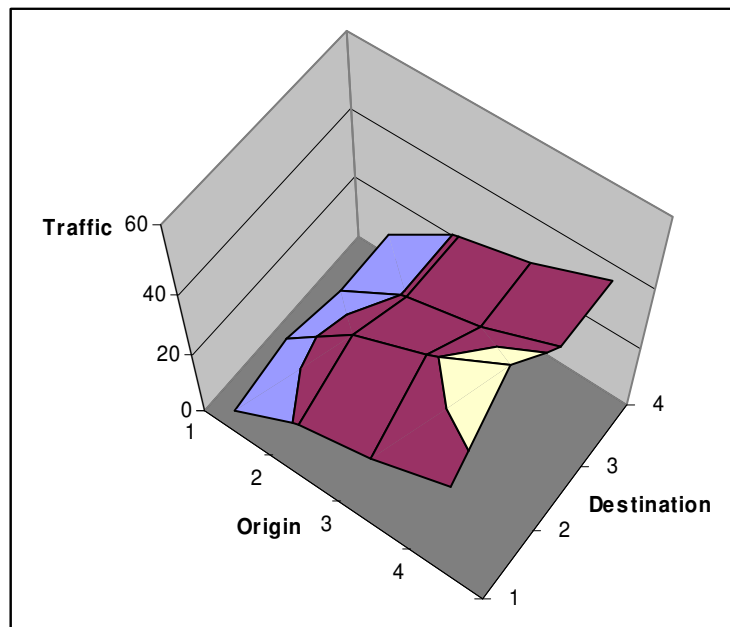

Figure 17: "Morphed" Distribution

These effects (designed and implemented by C. Wright, MDST) are handled by an external spreadsheet, selected within `nScenarios.xls`, and managed by the `Morph` object inside GBFM. `Morph` contains the Furness algorithms (see Ortúzar and Willumsen[15] , Second Ed., Chapter 5) for re-distributing a county based trip matrix.

Step 9: Trip Matrix Raw Data Loading

Using file handles generated from the settings in `nScenarios.xls`, GBFM now loads the raw data for the domestic (GB) matrix. The `GBMatrix` object uses a reference to `Morph` so that any scenario based, land-use effects can be added.

Forecast impacts, both to the size of the base matrix, and to the distribution are made here. A GDP-based macro model is loaded from a spreadsheet by `GBMatrix` to set total tonnes lifted by commodity. Each commodity stream is forecast separately.

The forecast also involves redistributing the base matrix to simulate the trend for increasing average length of haul within certain commodity streams. The rates of growth are forecast in an external spreadsheet, and but stored as constants within `GBMatrix`. They cannot therefore be affected by any scenario, since the underlying causes of these changes to length of haul are not modelled adequately. The concurrent work on developing production-consumption matrices based upon spatial input-output models can potentially address this problem.

Finally, `GBMatrix` contains algorithms for adjusting the domestic freight matrices to identify international streams. This is required further on.

Step 10: Non Road Services

So far, the model only has data on three "islands" of road networks (GB, Ireland, and the Continent). Connecting links, and links employing non-road modes are therefore required.

The `Services` class solves this problem by loading the supply side data referred to in section 5.2. It uses references to the road networks to estimate costs (based upon road distances) and to relate them to the services. The `Morph` class is also used to build new services to and from any new, assumed freight facilities.

Like the `GBNetwork` class, `Services` also acts as a container for assignment data, so that it maintains a list of volumes assigned to the links it generates. It is also used to calibrate flows against maritime links.

Sections of code have been written to deal with potential new rail services such as domestic intermodal and piggyback.

Step 11: The STEMM class

The `Stemm` class, originating from the freight model designed for the STEMM project[6] contains the logic for the discrete choice processes. It is constructed with references to all of the network data, including the multi-modal data constructed in Step 10, and the cost models.

`Stemm` has its own instance of an object called `Ideal`, representing the F-Logit algorithm (the F-Logit model was originally termed the 'Ideal' Freight Model Shell). It can therefore perform the network path search, apply the cost models, convert from cost to generalised cost, invoke `Ideal`, and produce shares for all the paths in the choice set. Two different versions of F-Logit are available within `Ideal`, but the model has been configured to use the sequence described in 4.3.2. The alternative specification relates to the final draft within the STEMM project.

As one of the older (and messier) components, the path comparison routines do not make good use of available technology such as STL. Also, certain policy settings such as subsidy responses have to be manually edited within the source code, and re-compiled which is not at all ideal.

Stemm has one further function which is critical. It converts sets of cost, time taken, and reliability into generalised cost. These values dictate which paths are preferred for the assignment. The conversion is based upon three possible parameters:

```
m_Param.dValOfTime =  0.0104167 ; //1.04167% Of Freight Rate/Hour

m_Param.dValOfRely =  0.050 ; //5.0% Of Freight Rate Per 1% Late

m_Param.dValOfRail =  0.0 ;   //0.0% Of Freight Rate
```

Thus, generalised costs are constructed using values derived from parameters obtained from Stated Preference interviews. The rail mode specific value has been tested, but has now been set at zero, since the cost models can adequately explain road/rail modal split.

The generalised cost function (named `CalcGCost`) also allows paths for different equipment types to be compared. Clearly, a path for a 20 tonne vehicle is not the same as a path for a 40 tonne vehicle, unless it is sufficiently volume constrained. Furthermore, routes which allow the driver to accompany the unit may be preferred for certain commodities (e.g. chilled or high value goods). `Stemm::CalcGCost` (this notation means that the function belongs to the encapsulating class) has therefore been configured to consider the type of unit involved, and the commodity group, which itself is summarised by two attributes; value per tonne and volume per tonne. The generalised costs are adjusted to take this into consideration. The extent of the adjustment originates from an exercise carried out for the STEMM project, using ODIT91[14] data for which the market shares by path were known. It would make sense to update this work, partly because it is now out-of-date, and partly because the original estimation procedure (a binary logit model, calculated by MDST) may not have been satisfactory.

Nevertheless, small adjustments to the choice process, reflecting commodity differences do improve realism. They are not accessible to the scenario building process, and therefore relatively inert.

Step 12: Three Ancillary Classes

At this point, three relatively minor classes are created:

- `StanoxOP`: Allows rail outputs to be traced back to their original STANOX codes.

- `BulkPort`: Relates county zones to UK ports for bulk traffic, using ODIT91 data.

- `Hinterland`: keeps track of the estimated inland volumes from British ports, matching them to trade flows.

At this point, the preliminary data preparation is complete, and the program opens the databases which will contain the outputs.

Step 13: Matrix Sequence

Level 1, the completion of the international freight matrix and its assignment to the international links in the network now begins. GBFM builds matrices for:

- Intra EU Arrivals (imports)

- Intra EU Dispatches (exports)

- Extra EU Imports

- Extra EU Exports

The traffic is then assigned in that order, using the `Stemm` object.

Step 14: Hand-over from Level 1 to Level 2

There is an intermediate step in which the domestic legs of international journeys are subtracted from the CSRGT/Railtrack domestic OD matrix. In this way, a matrix of purely domestic traffic is obtained. The `GBMatrix` class performs the subtraction.

Step 15: County Zone Inland Assignment

With the domestic data now split into two sets:

- International, or port related trips, where one end of the journey is an international terminal.

- Pure Domestic, where the trip does not involve import or export cargo, and is simply defined against two county zones.

This is Level 2.

The international flows are reassigned to a more complex multi-modal representation of the GB domestic network. Thus a container at Felixstowe can be assigned to a Freightliner rail service to Manchester, or to road links, or both.

The purely domestic flows are assigned (for the first time) to the same domestic multi-modal network, using county zones.

The flows assigned to road are also split into six vehicle categories, handled by the `VehicleType` class. It uses known (from CSRGT) distributions of vehicle usage, broken down by distance band and commodity to make the split.

The main output from this level is an estimate of national mode split by commodity and county.

At this point, many of the program objects involving international or multi-modal functions are tidied up, emptied onto disk, and cleared away.

Step 16: Postcode District Zone Inland Assignment

The `GBNetwork` component now completes the run by carrying out the detailed assignment of road traffic, using an internal instance of the `Assign` class. This (Level 3) is the slowest part of the model, and the software can be halted here if it is not required.

A number of assignment algorithms have been prepared. They can be selected through the command line.

The default algorithm was designed principally with the recent work on Road Tolls in mind. It maintains the vehicle type split, produced by Level 2, but it subdivides the population of traffic further into seven categories of rigid HGV and eleven categories of articulated HGVs.

Until now, the main impact of road tolls has been to affect port choice and the split between road and rail inland. However, the main impacts are dealt with here.

The model loads separate road cost models for each of the 18 vehicle types, and is also able to read separate toll levels for combinations of vehicle type, road type and area type, following the FORGE framework.

The county-based input data is broken down into postcode district (PCD) zones. The delivery point weighting intrinsic within postcode classifications is used to distribute the traffic. The idea behind this, in the absence of a PCD matrix, was to simulate a dispersed pattern of generation and attraction, biased towards urban areas.

There is an iteration variable (pre-set to 5) which controls the level of dispersion. It has been estimated that beyond the value 5, the trade-off between accuracy and run time is not worthwhile.

The Dijkstra algorithm is used, along with a very simple (`CalcVTShares`), calibrated multinomial logit model (i.e. not F-Logit) to perform a multi-path assignment for each cell of the PCD to PCD matrix. This is performed in an interactive way, so that congestion impacts can be reflected.

Allowing for congestion improves the final assignment, but if the model is being used to provide inputs for FORGE, it is advisable to avoid double-counting and not to include this process. FORGE will carry out the final iteration and calculate externalities.

Step 17: The End

The final product of all these processes is a set of databases, suitable for analysis within Excel, Access, SPSS, Map-Info or many other desktop data analysis packages.

The main outputs are:

• A database of unitised maritime flows – a ferry model.

• A ports database, showing inland and maritime flows – a ports model.

• A database of inland traffic with mode split and regional information – a rail model.

• A road network with assigned traffic by vehicle category – a road model.

All of the above can be forecast, and they are collectively consistent. They also establish and maintain consistency between CSRGT, SRA rail statistics, Trade Statistics, and Maritime Statistics. They connect these snapshot databases by building trip chains.

8   The Way Forward

GBFM, having been conceived as a stand-alone freight system, is now part of a wider scheme to develop the Department for Transport's National Transport Model (NTM).

In itself, this process raises questions about the scope of the model, delegating tasks efficiently within the entire structure and maintaining consistency with other elements of NTM. However, the DfT's Freight Model Review (2002) has set out a concept for a full-scale National Freight Transport Model (NTFM), which provides a long-term design goal, satisfying the objective of integrating freight modelling into the national model.

The NTFM model design is shown in Figure 18. Significant additions to the GBFM structure are evident, particularly in relation to matrix estimation and the use of production-consumption matrices from which to estimate origin destination tables. The structure allows a much higher degree of inter-dependence between trip generation and the supply side of the freight industry, going beyond the GBFM approach of trying to estimate freight flows directly from available data, and not attempting to consider the underlying socio-economic conditions producing the demand for freight services.

Implicitly, Figure 18 has a broader scope, allowing for LGV trips, and interaction between HGV and LGV trips. In many other respects, although there are areas of consensus, the NTFM concept should be regarded as a new design, depending upon data as yet not available, for which GBFM provides a "stop-gap".

For the immediate future, the Freight Model Review outlines a development plan, containing Task Sets A to F, in which Task Set A involves the documentation and audit of GBFM, potentially leading to further development within the NTM framework.

Figure 18: Freight Model Review: Concept for NTFM
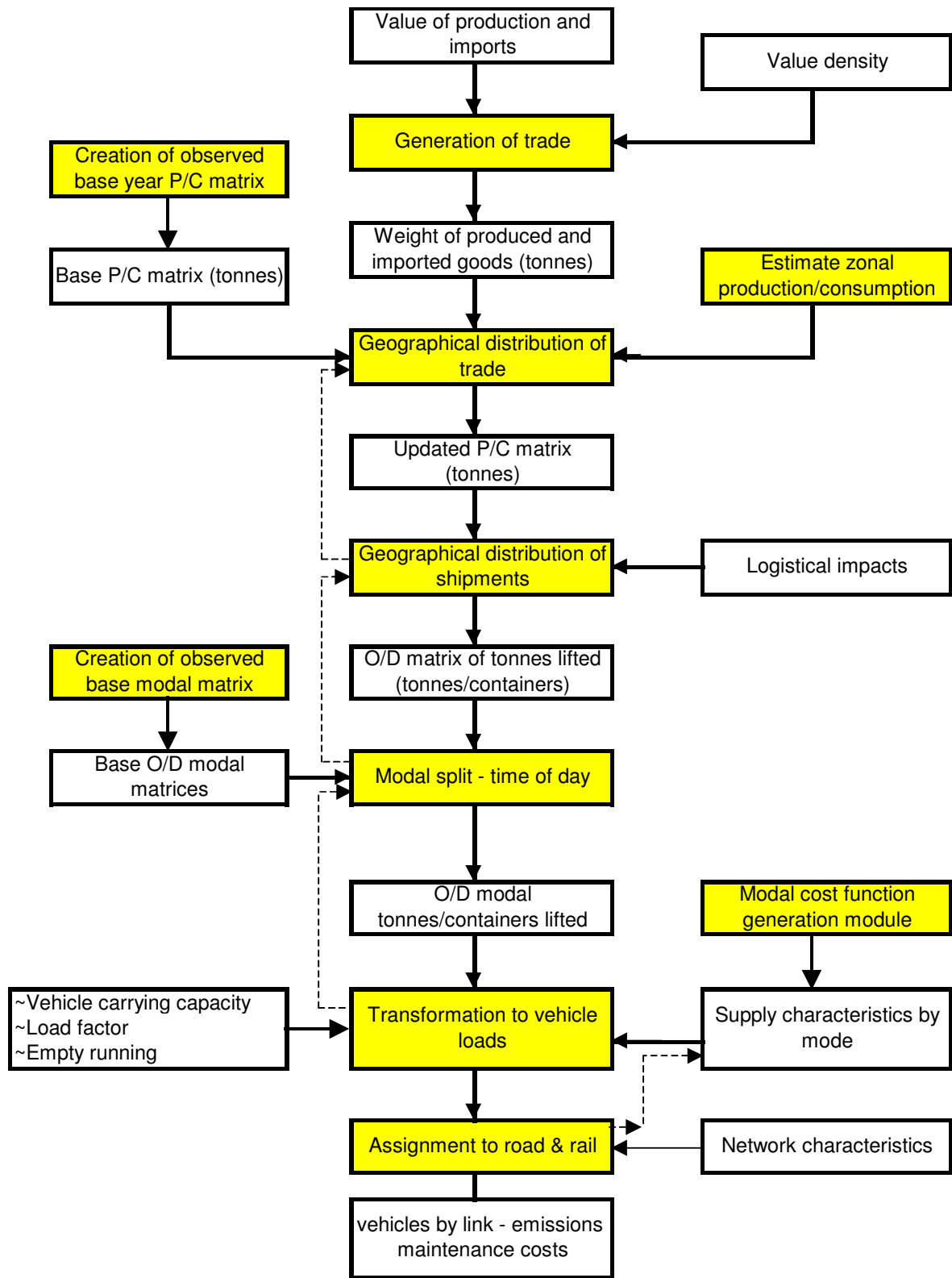
Beyond the requirements of the NTM as set out in the Freight Model Review, there are two other recent studies, suggesting development synergies with the GBFM project:

- The West Midlands Freight Study[34] (2002, Mott MacDonald and MDS Transmodal) provides direction in terms of estimating freight flows from land use data, using a practical survey technique. The method would help to improve the model's accuracy at regional and local level.

- The Container World Project[47] (ongoing research project, led by Imperial College, Earth Science and Engineering) focuses upon the deep sea container market, modelling worldwide demand and supply, simulating complex adaptive systems. It offers the potential to explain the flows of deep sea cargo arriving at GB ports, taking into consideration the changes in the market such as ship size, deployment, costs and competitive dynamics. It could therefore replace what is currently an exogenous factor within GBFM.

However, in the context of the immediate need to maintain a freight modelling capability, it is appropriate to complete the documentation with a critique of the current GBFM system and to provide a set of recommendations, relating to the short term use of the model.

The critique considers:

- Methodology

- Validation

- Data Resources

- Scope, and

- Implementation

8.1 Methodology

In many ways, the fundamentals of GBFM are conventional, and parallels can be drawn with the four-stage models of the 1970s. However, this apparent consensus does not prove that the method is correct, or more accurately whether a method designed for highways models and passenger vehicle patterns thirty years ago can be transplanted into a new multimodal freight model.

8.1.1 C1: Methodology and Data

One of the principal criticisms of GBFM's ability to reflect strategic processes within the freight market must be that, by its very design, it has been constructed around available data (usually mode specific and geographically constrained), and not from a fresh perspective looking at how the freight market, or more accurately, the supply chain, functions. Certain behavioural responses are absent. There is a strong counter-argument that the system would simply not exist if this approach had been taken, and that valuable data would not have been used, but the need to provide greater realism remains.

The first main concern is that the model is driven by a database of independent origin-destination combinations, representing trips. These may be transfers from producer to consumer or transfers to/from intermediate storage locations. One of the recommendations from the Freight Model Review[2] is to divide the trip generation/distribution stage into distinct production-consumption and origin-destination stages, so that the question of intermediate storage can be directly addressed.

It follows that if the model is responsible for analysing the supply chain in this way, then it is necessary to group sets of related produce-consume entries, and to provide the functionality to optimise warehouse location. This issue is discussed in the 2002 AET paper by MDS-Transmodal[20], arguing that the optimisation problem has to be re-assessed to consider storage and production costs.

The second important concern, related to the first, is that the derivation of the OD matrix simplifies the interaction between trip generation and the supply side. The model can introduce an interaction, e.g. a negative elasticity with respect to composite transport cost, using the Fowkes and Toner formula[27], but it cannot reproduce the full range of responses, using the rules-based approach that would allow the user to translate a policy response into a logical sequence of rational changes.

R1: Resolving the supply-chain issue is one of the main strands of work arising from the Freight Model Review. It is an area where data is required. However, in the short run GBFM should be adapted to use the trip generation approach adopted for the West Midlands Freight Study[34]. It adds a greater land-use element to the model, and allows the impact of new warehousing to modify the pattern of trip generation. The gravity model approach also relates generalised costs to freight volumes, and, being commodity specific, it allows different

economic sectors to be distinguished. The possibility also exists to continue the data collection process designed for that study, so that a more representative sample of the country is obtained.

8.1.2 C2: Three Level Approach and Internal Consistency

The way in which results are cascaded from one level (e.g. international) to another (e.g. domestic multimodal) has proved to offer practical benefits, particularly in reducing run-time if detailed road assignment is not required. However, it is becoming increasingly evident that the more advanced techniques employed within the third level (road assignment) could be adapted to the second level (domestic multimodal), thereby eliminating one level.

The inconsistency arises because level two and three both produce summaries of road traffic, but they are not constrained to be the same. Furthermore certain information, such as the detailed vehicle costs, is only used in the final stage, and therefore cannot impact mode share.

The full set of domestic trips could be converted from a county-based system to a postcode district based system, and rail paths could be enumerated and assigned to using an interactive rail network. Data is already available to implement this revision.

R2: A rail equivalent for the `GBNetwork` class, which is road-only, should be constructed. Assignment to rail remains a problem that GBFM is unlikely to solve, but the ability to interrogate a rail network for paths of a specific loading gauge with more accurate speeds and capacity constraints would be a major improvement. Levels two and three should be combined into a single stage dealing with domestic freight at a post-code district level. Apart from removing the current inconsistencies, it will improve the ability of the model to deal with more complex issues of rail policy, including land-use, network upgrades, and assignment of trains to the network. R2 depends upon R1.

8.1.3 C3: Assignment Algorithm

The choice of assignment algorithm has not been fully resolved. There appear to be three options:

- Keeping the existing prototype F-Logit structure,

- Revisiting the more complex F-Logit structure published within STEMM,

- Adopting a structure based on C-Logit, using the option to weight the links.

Adopting a new structure would also raise the question of estimating parameters based upon GBFM's input data and cost models.

R3: Theoretical problems have been treated as beyond the immediate scope of the GBFM project. Therefore, we would seek collaboration.

8.1.4 C4: Assignment Method

One of the problems that has arisen recently is the need to detect impacts of lorry road user charges, which may be specified according to certain criteria such as road type and vehicle type. This has led to a need to link the assigned volumes to the stock of vehicles., and to be able to detect different path choices for different vehicle types.

As stated in the previous section (Step 16), GBFM versions up to 4.12 have split the demand between eighteen vehicle categories, defined in terms of GVW and number of axles, representing about 70% of the vehicle stock. Furthermore there has been a hierarchical procedure in which Level 2 has split the demand into six categories, and Level 3 has subdivided these into eighteen categories, keeping the original shares intact. There has therefore been a fairly strict constraint, preventing a full range of traffic diversion between vehicle categories.

It has become increasingly evident that these limitations are too severe. Therefore an alternative method, implemented in the "alpha" version 4.13 (September 2003) has been developed. This has 56 vehicle categories, representing 98.5% of the vehicle stock. It also introduces calibration against the vehicle stock, so that estimated average mileages within each vehicle category are sensible. Version 4.13 eliminates the hierarchical structure, so that (potentially) a charge applied to one vehicle category can affect any other.

The penalty for this additional processing is a six-fold decrease in runtime speed, which for many applications is unacceptable for the small increase in accuracy this gives.

The uncertainty over whether or not to constrain the range of diversion possibilities between vehicle types highlights the fact that the degree of cross-

elasticity between categories is not easily derived from existing data. The problem is compounded by the lifespan of the vehicles, so it could be expected that the degree of cross-elasticity would be higher for longer forecast horizons. Stronger econometric evidence in this instance would be beneficial.

R4: The behaviour of the slower (v 4.13) model should be investigated, and opportunities for improving the performance, for example by sampling a fixed number of postcode zones per county, possibly in rotation could be attempted.

8.2 Validation

8.2.1 C5: Validation

There are three possible routes towards achieving accuracy within the model:

• Calibration

• Econometric Techniques

• First Principles

GBFM relies heavily upon the third route: first principles. The problem is segmented into a large number of consignments. A relatively small number of "sensible" paths are generated for each consignment, and relatively simple rules are used to decide what happens. Attention is therefore focused upon the methodology for comparing options (the accuracy and detail within the cost models), and the extent to which the problem can be segmented (the number of zones, commodities and so on). The first test within the validation process is that any randomly selected cell should produce believable results, and that the pre-calibration results should be accurate at the strategic level.

The calibration option is only applied to two dimensions: the split of rail traffic by commodity, and the split of ferry and short sea container traffic by service. Clearly, many other aspects of the model could be improved by calibration.

Within GBFM, all of the parameters for generalised cost and within the assignment algorithm have been imported from external studies. No attempt has been made to reformulate these functions or re-estimate their parameters by building econometric models from GBFM's input data or cost models.

R5: The most likely new candidates for calibration appear to be road tonne kilometres by road type and vehicle type, inland rail share at seaports, and rail flows (tonnes or trains) by region, and by rail link. We would again seek specialist advice on the question of functional forms and parameter estimation.

8.3 Data Resources

8.3.1 C6: Age of Data

Most of the data inputs for GBFM can be updated annually. It is implied that the current version, which is calibrated for 2001, contains a full set of 2001 inputs, but this is not strictly true. The trade data and the CSRGT data are already out

of date (1999 or 2000), but can be updated. The ODIT data is from 1991, but cannot be updated.

R6: All of the data inputs should now be updated for 2002, and the model recalibrated. Updates to the ODIT survey, and changes to CSRGT, relating inland traffic flows to seaports would help to improve the model. A far more extensive database of rail freight flows has been made available through the SRA, allowing significant improvements in how the model describes rail in the base year. This may lead to the use of more rail cost models, providing greater accuracy for commodity sectors such as cars and semi-bulks where specific equipment is used.

8.3.2 C7: Gaps in the Data

There are a number of areas where data coverage is incomplete. In some cases the data is not collected, and in others it exists, but has not been used within GBFM.

• Inland waterways – Exists, but is not used.

• Coastal maritime – Exists, but is not used.

• Air freight – Exists, but is not used.

• Inland road freight in overseas registered HGVs – Data is not available. There is an inconsistency here because the international sections of the model do estimate HGV traffic by country of registration. When these flows are subtracted from the CSRGT database of inland GB-registered HGV movements, the residual domestic traffic will be underestimated.

• Irish land bridge traffic – Not directly available, but could be estimated.

R7: It is likely that none of these omissions influence the model's predictions to a great extent. It is however recommended that the data from the DfT's 2003 survey of foreign lorries be used when it is available.

8.4 Scope

8.4.1 C8: Light Goods Vehicles

One of the clearest differences between the National Transport Model specification and GBFM is that GBFM does not contain any coverage of LGV traffic. The decision partly reflects a shortage of data in this field, but also a degree of uncertainty as to whether LGV trips are more relevant for a wider model of business trips in car or van based vehicles, or for a multimodal freight model. The Freight Model Review recommended a classification system, and a data collection exercise is under way. The key issue for GBFM is the extent to which complementarity and substitutability exist between light and heavy freight.

If, as has been asserted, demand for LGV and HGV trips is determined independently, it makes sense to develop a new model for LGV trips.

R8: No action is recommended in this area, until basic OD data can be compiled.

8.4.2 C9: Shipping and Port Costs

Cost models with disaggregated ("accounting") items have been implemented for road haulage and rail freight. Clearly visible, open cost structures have been a convenient way of involving the freight industry in a discussion about costs without requiring disclosure of commercially sensitive data. They have also created a link within the transmission mechanism from policy assumptions to traffic impacts. But similar devices have not yet been constructed for maritime services (in practice meaning maritime, scheduled, unitised services; ro-ro and lo-lo) or port costs.

R9: Models of port and shipping costs exist (see endnotes 41 and 42), and should be implemented within GBFM.

8.5 Software Implementation

8.5.1 C10: Issues of Software Design and User Interface

Now that the GBFM system is being used within organisations unable to access the program source, two questions have to be addressed.

- The usability of the software interface, and

- The ability to "track and trace" a result to understand the sequence of causality.

One conspicuous feature of the GBFM software is that it runs within a console window. Most of the run preparation is delegated to external software (Excel, Access and GIS for example). While this strategy has simplified development and maintained a high degree of code portability, it is acknowledged that the system is likely to fall short of expectations in terms of the interface, and that the Windows platform (or equivalently Dot Net) now imposes relatively few constraints or upgrade problems.

On the output side, it is impossible for the user to trace results back through the software to understand why a new setting has produced a particular outcome.

R10: As far as possible, the dependence upon specific versions of external software should be reduced. This can be achieved by converting many of the data inputs into Access tables, and retrieving the data via ODBC. A Windows shell should be built, providing a greater degree of control over runtime settings, and the ability to run batches of jobs and select which results are generated and saved. During the model run, status reports should indicate step-by-step results, and this should be summarized as a result.

8.6 Conclusions

The 1999 report on Transport and the Economy by the Standing Advisory Committee on Trunk Road Assessment (SACTRA) recommended that:

> "substantial new research effort is devoted to the development of more robust freight forecasting models which take account of .." [the organisation of the supply chain, Para 6.55]

In July 2003, the GB Freight Model still falls short of this objective and cannot be described as capable of providing adequate insight into the relationship between the structure of the economy and the wider context of the supply chain.

Instead, GBFM focuses attention upon more rudimentary issues; the harmonisation of datasets, the need to represent the supply side and understand competition and cost structures within the freight industry, the importance of freight facilities, warehousing and trans-shipment points, and the relationship between policy and markets.

The experience of working with a multi-product and multi-modal system suggests that attempting to fit a relationship between freight demand and UK macro-economic activity, expressed perhaps by a trend in real UK GDP growth, hides the heterogeneity and the degree of industrial and structural change that may exist in the market.

The freight market is sectoral, visible and quantified in terms of physical weight, volume and vehicle numbers. The performance of the economy refers increasingly to monetary quantities and service activities play a major part in determining growth rates in economic output. This macro definition of the economy may only relate to specific freight markets, e.g. parcels delivered in vans, or e-commerce.

Maritime flows (over 500 million tonnes per annum) depend on trade volumes, and therefore on worldwide trends in production. Intermodal rail flows, currently dominated by international traffics also depend on import volumes, rather than domestic production. Bulk rail flows are closely aligned with the performance of traditional industries, and not those sectors more closely identified as driving economic growth in the past decade.

Many domestic road haulage sectors: bulk products, chemicals, and miscellaneous products, accounting for 80% of domestic road tonnes lifted remain at the same levels recorded in 1991, despite a 30% increase in GDP. Within road haulage, only the food sector, at approximately 320 million tonnes,

accounting for 20% of domestic road tonnes lifted, has grown over the last decade, but it has still been declining since its peak in 1998.

Import freight flows have been rising consistently, with ro-ro traffic volumes having doubled over the last decade. Referring to the container market, Lloyds List (June 2003) reported that:

> "Fundamental changes in the world economy have broken the historical link between container shipping volumes and gross domestic product growth, industry evidence suggests."

Globalisation and out-sourcing are cited as the reasons for this change.

Evidently, the experience drawn from the GBFM project combined with these statistics and comments from the freight industry support the SACTRA recommendation, and suggest that an explanation of industrial location and distribution patterns will improve the forecasting methodology. Execution of this objective nevertheless depends upon elements of the kind developed within the supporting framework of GBFM. It is hoped that this project will help to provide a practical context, and highlight the sectoral and international dimensions within freight.

9   Annex 1: Glossary of Terms

10YP	Ten Year Plan
AA	Automobile Association
AETWPP	Assessing the Effect of Transport White Paper Policies (on National Traffic)
ARGV	Accompanied Road Goods Vehicle
B2B	Business to Business
B2C	Business to Consumer
CNRS	Company Neutral Revenue Support
CSRGT	Continuing Survey of Road Goods Transport
DETR	Department for the Environment, Transport, and the Regions
DfT	Department for Transport
DG-TREN	European Commission – Directorate General – Transport and Energy
EWS	English Welsh and Scottish Railways – the largest UK rail freight operating company.
FMCG	Fast Moving Consumer Goods
FORGE	The DfT's model for 'Fitting-On' traffic forecasts, calculating externalities.
FFG	Freight Facilities Grants
GBAM	Great Britain Assignment Model
GBFM	Great Britain Freight Model
GIS	Geographical Information Systems
GVW	Gross Vehicle Weight
HMC&E	Her Majesty's Customs and Excise
HETA	Highways Economics & Appraisal Division of the DfT
ITEA	Integrated Transport Economics & Appraisal Division of the DfT

ITS	Institute for Transport Studies, Leeds University
KPS	Kent Ports Strategy
Lo-lo	Lift-on Lift-off (Containers)
MNL	Multinomial Logit Model
NTM	National Transport Model
NTFM	National Freight Transport Model
NUTS3	Nomenclatures des Unités Territoriales Statistiques: Standard EU definition for a hierarchical zoning system. NUTS3 means counties in the UK, and départements in France.
NST	Nomenclature uniforme des marchandises pour les Statistiques des Transports. A standard terminology for classifying commodities within transport statistics.
OD	Origin Destination (Matrix)
Ro-ro	Roll-on Roll-Off (Ferries)
SITC	Standard International Trade Classification
SLM	Sensitive Lorry Miles
SRA	Strategic Rail Authority
STEMM	Strategic European Multimodal Modelling
TKms	Freight Moved: Tonne Kilometres
URGV	Unaccompanied Road Goods Vehicle
VKms	Freight Moved: Vehicle Kilometres

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