A FREIGHT TRANSPORT MODEL FOR SCOTLAND

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1. INTRODUCTION

The Freight Model for Scotland version 4 (FM4S) is a multi-modal transport model, specifically designed to model freight transportation. It covers the entire land area of Scotland, including the Scottish islands, and also has connections to major external freight trading areas such as England, Ireland, Wales and international origins / destinations.

FM4S has been developed independently by Scott Wilson Ltd, originally as an in-house system to make good use of available transport data, and has been applied to many studies over the years. Like all good models it is continuously updated with new data and improvements based on its application in various projects.

All four modes of freight transport are modelled (road, rail, sea and air) and the Scottish network includes all the main road links (with some local roads), railway lines and terminals, strategic and medium-sized ports and associated routes, and airports where freight cargoes are handled. The model zone system is capable of covering all 32 local authority areas in Scotland as well as the 7 Regional Transport Partnership (RTP) regions, thereby providing the basis to test the effects of schemes and policies / strategies at all levels of Government in Scotland (local, regional and national).

The FM4S quantifies the amount of freight expected to be transported on the transport network. The model results are used to estimate the impacts of constructing new or improved freight transport infrastructure and facilities, and implementing alternative transport services or demand management activities.

The model is capable of quantifying freight movements by vehicle type, by type of cargo and in terms of volumetric data with future infrastructural developments in place. These may include the removal of rail freight line restrictions and the response to specific travel demand management policies. In addition, the model results are used to provide detailed information, such as road and rail traffic volumes, and impact analysis for use in the design of facilities.

This information is used in the Transport Planning process to aid decision making in the selection of transport plan alternatives, policies and programmes. The model is run on fast microcomputers using the CUBE modelling suite of transport models. The major elements of the FM4S system mirror the hierarchy of decisions faced by the freight industry, such as whether to make a trip, where to make a trip, what mode to use, what time of day to travel and what route to take.

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2. MODEL OVERVIEW AND STRUCTURE

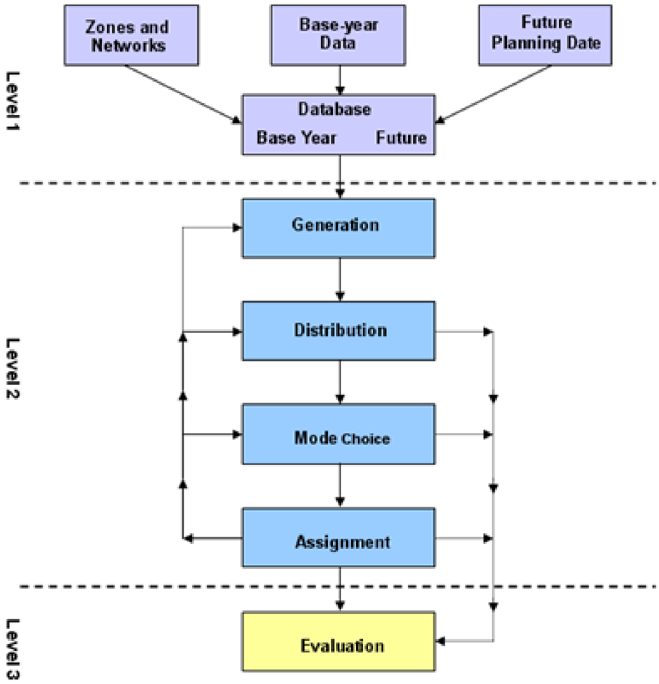
2.1 Model Overview

The Figure (inset right) shows the structure of the model. As can be seen, there are three levels to the model. Level 1 includes a database of planning and economic data, a representation of the freight transport networks and other information to build Base and Future Year scenarios.

Level 2 is based on a traditional 4 - stage model approach (Generation, Distribution, Mode Choice and Assignment), which represents the various decision-making procedures in the freight sector.

Level 3 takes the outputs from the other level models and evaluates the impacts of freight on the transport system. The evaluation model consists of various sub-models which consider the economic, environmental, safety and network operational impacts.

Figure 1: Model Structure



Each of the three levels of the model are described in more detail in the sections below.

2.2 Level 1 Models (Land Use and Network Databases)

Scotland was split up into 125 strategic zones, based on existing ward boundaries and the prevalent transport network. To this another 11 strategic zones representing the rest of the UK and a further 14 zones representing 14 countries and international regions were added. At the local modelling level, the zone system is more detailed and varies depending on the part of Scotland being examined. This variation depends on the key freight generators and attractors which, naturally, vary by geographical characteristics.

Surveys carried out produced *prior* observed matrices for 2008, and this represents the most recent year for which data exists. The year 2008 also represents the start of the current economic recession period and therefore offers a realistic, if conservative, base year for the seed matrix from which future year estimates can be derived for different categories of freight.

The freight data commodity types selected for the model were based on the Government Standard Industrial Classification (SIC) codes. However, this selection also took into account the freight variations across the country and the different economic sectors.

Therefore, within the model the freight data was refined to 10 commodity types representing:

- agriculture;

- construction;
- manufacturing;
- mining & quarrying;
- retail & wholesale;
- recycling & refuse;
- machinery & transport equipment;
- solid fuel & petroleum;
- forestry & forestry products; and
- other.

Data was processed and coded into the model separately for each of the freight commodities above, allowing for a more refined analysis of future freight demand.

The FM4S modelling system comprises both land use and transport sub-models. These are designed to take into account land use policy initiatives that may impact on the future demand for transport, and also the way in which the locations of activities respond to major transport policies. The land use sub-models contain the following elements which affect the demand for transport:

- the representation of demographic trends, of household and employment location and of land-use planning policies;
- the representation of the level of economic activity given by Gross Value Added (GVA);
- the representation of freight generation and freight distribution patterns;
- the assignment of transport demand to particular routes; and
- the appraisal of the effects of the travel patterns predicted, including the implications for revenues, network operations and socio-economic impacts.

The transport sub-models contain the following elements which relate to the supply of transport and to policies that might influence the costs or nature of this supply:

- characteristics of the freight networks and facilities available;
- characteristics of the highway network;
- monetary costs of travel;
- representation of the choice between competing modes;
- adjustment of highway travel times to take account of congestion on the road network;
- extraction of travel costs for input to the land use model; and
- post estimation analysis including estimating revenues, network impacts and to meet requirements of STAG appraisals.

The transport sub-models have been designed to allow the use of detailed travel categories in order to represent the differences in response by individuals/companies who have access to different transport modes. Within the transport sub-models, freight transport operators can change their route and mode in response to changes in the supply, the quality or the pricing of any transport characteristics on any mode. The choice of mode is handled within the mode choice sub-model, while the route choice is handled in the assignment sub-models.

The model uses detailed data on highway, marine and rail infrastructure, including geometric and spatial information on over 4,200 links (road and rail segments) and over 1,620 nodes (junctions and freight depots).

Information on each segment includes its location, length, number of lanes or tracks, functional classification, travelling speed (covering various travel conditions ranging from ‘free-flow’ to heavily congested flows), link capacity / geometric layouts, and area type.

2.3 Level 2 Models (Freight Transportation)

The model is a function of a number of stages as follows:

Freight Generation Model
This estimates the volumes of freight generated by each zone in the study area, based on the different land-uses in each zone. These estimates are for all the freight modes, road, rail, sea and air.

Distribution Model
This matches trip generations with trip attractions to produce a matrix of trip movements, also for road, rail, sea and air.

Modal Choice Model
This takes the matrix of freight volumes produced by the Distribution Model and estimates the principal mode by which the trips will be made.

Assignment Model
This takes the freight matrices, and assigns them to the network. The assignment is undertaken using a multi-mode assignment model where road freight, rail freight, sea freight and air freight are processed separately.

2.4 Level 3 Models (Evaluation)

The evaluation is based on standard Government appraisal procedures which are outlined below.

Air Quality Assessment
Takes the outputs from the assignment and carries out an air quality appraisal based on the flows on the road network represented in the model. The air quality predictions are Carbon Dioxide (CO2), Carbon Monoxide (CO), Nitrogen Oxide (NOx), Hydrocarbons (HC) and Particulate Matter Level 10 (PM10).

Road Traffic Noise Assessment
This undertakes an analysis of the likely noise levels due to traffic flows on the road network, and also estimates the percentage of people affected by these noise levels.

Accident Forecasting
This predicts the numbers of accidents within the highway network, and the different casualty types, as a result of the traffic flows on the road system.

Fuel Consumption and VOCs
This estimates the fuel and energy used by vehicles on the network. Vehicle operating costs (VOCs) are also estimated for the different freight transport modes.

Economics
Takes the necessary output from all of the models above and estimates the total costs throughout the network as a result of the freight transport flows.

3. MODEL CALIBRATION / VALIDATION

Scott Wilson Ltd has considerable hands-on experience of freight modelling and studies, and the modular approach to FM4S has enabled the outputs from each sub-model to be benchmarked against identifiable features and trends in the freight market, enabling a good representation of how the freight market actually works. Model validation exercises were carried out and overall results show there is a good match between model outputs and observed flows.

Because of the varying characteristics of the model, the estimated freight tonnes were converted into Twenty-foot Equivalent Units (TEUs) which standardise the containers / methods of modelling freight movements. These were then factored back into tonnes when the forecast flows were produced from the model for use in the more detailed analysis. However, for the purposes of computing the calibration accuracy of the model, the validation statistical goodness-of-fit tests are shown as TEUs. The exception to this is the road model tests which are in vehicles since they also include car trips, which are necessary to take into account the effects of highway congestion.

In order to validate the trip distribution across the network for all four modes (road, sea, air and rail freight), demand matrices were contracted to sector level to reflect freight movements to and from the seven Regional Transport Partnership (RTP) areas. This also allowed the validation of the modal split between these sectors. Table 1 overleaf shows the observed total yearly tonnage of freight from/to each RTP area, for each mode of transport, compared to the values given by the model.

Table 1: Modelled and Observed Distribution

RTP Area	Total Tonnes (x1000)	Road		Sea		Air		Rail	
Modelled Distribution									
ZetTrans	14,932	2,120	*1%*	12,812	*14%*	1	*2%*	0	*0%*
HITRANS	48,956	33,304	*9%*	13,238	*15%*	2	*4%*	2,413	*12%*
Nestrans	37,454	33,162	*9%*	3,566	*4%*	4	*9%*	722	*3%*
TACTRAN	30,361	29,382	*8%*	979	*1%*	0	*0%*	919	*4%*
SEStran	148,742	100,674	*28%*	40,188	*45%*	12	*26%*	7,868	*38%*
SPT	165,117	141,685	*40%*	14,761	*16%*	27	*59%*	8,645	*41%*
SWestrans	20,358	15,657	*4%*	4,449	*5%*	0	*0%*	252	*1%*
Total	**465,921**	**355,983**		**89,992**		**46**		**20,819**	
Observed Distribution									
ZetTrans	15,091	2,259	*1%*	12,832	*14%*	1	*2%*	0	*0%*
HITRANS	49,181	33,583	*9%*	13,218	*15%*	2	*4%*	2,378	*11%*
Nestrans	37,962	33,679	*9%*	3,570	*4%*	4	*9%*	708	*3%*
TACTRAN	30,445	28,539	*8%*	1,000	*1%*	0	*0%*	906	*4%*
SEStran	148,187	100,097	*28%*	40,183	*45%*	12	*27%*	7,895	*38%*
SPT	165,626	142,295	*40%*	14,658	*16%*	27	*58%*	8,647	*42%*
SWestrans	20,427	15,728	*4%*	4,401	*5%*	0	*0%*	298	*1%*
Total	**466,920**	**356,179**		**89,863**		**46**		**20,833**	

Once it was ascertained that the freight distribution in the model was correct, it was then necessary to determine and to validate that the modal split is a good match to the observed mode shares. For this validation, the same matrices aggregated to sector level were used in order to obtain a representation of mode shares for flows between RTPs. The resulting mode split is illustrated in Table 2.

Table 2: Modelled and Observed Modal Split

RTP Area	Modelled				Observed			
	Road	Sea	Air	Rail	Road	Sea	Air	Rail
ZetTrans	14%	86%	0.01%	0%	15%	85%	0.01%	0%
HITRANS	68%	27%	0.00%	5%	68%	27%	0.00%	5%
Nestrans	89%	10%	0.01%	1%	89%	9%	0.01%	2%
TACTRAN	95%	3%	0.00%	2%	94%	3%	0.00%	3%
SEStran	68%	27%	0.01%	5%	67%	27%	0.01%	5%
SWestrans	77%	22%	0.00%	1%	76%	21%	0.00%	1%
SPT	86%	9%	0.01%	5%	85%	10%	0.02%	5%
Total	**76%**	**19%**	**0.01%**	**5%**	**76%**	**19%**	**0.01%**	**4%**

A comparison of observed and modelled flows using regression analysis was undertaken. For this analysis, the more R^2 (the correlation coefficient) tends to 1, the better the model representation. Given the scale of the model, it was considered than any value above 0.75 would be deemed suitable. T-stat values were also computed and are shown in Table 3 overleaf.

Table 3: Adjusted R^2 and T-Stat Values

Mode		Adjusted R2 Value	T-Statistic
Road	Production	0.833	9.5
	Attraction	0.833	11.9
Water	Production	0.843	5.6
	Attraction	0.844	5.4
Air	Air Domestic	0.795	10.3
	Air International	0.811	12.0
Rail	Production	0.793	9.0
	Attraction	0.780	8.4

Modelled traffic for modes was compared to observed flows using the GEH statistic, as recommended in Government Guidance. The recommended level of fit for a transport model is for 85% of all GEH measurements to be less than the required criteria. For strategic models covering a large area such as the FM4S, a GEH criteria value of 10.0 is a suitable level of accuracy and was therefore used to validate the model. However, results with a GEH criteria value of 5.0 are also included to further represent the model performance.

Table 4: GEH Measurement Results

Mode	Average
Road	2.7
Sea	4.1
Air	0.4
Rail	1.6

In addition a series of range and logic checks were carried out, including:

- movement logic checks;
- freight flows;
- travel times and distances; and
- network congestion indicators.

This allowed for a 'common sense' examination of the model.

4. MODEL OUTPUTS

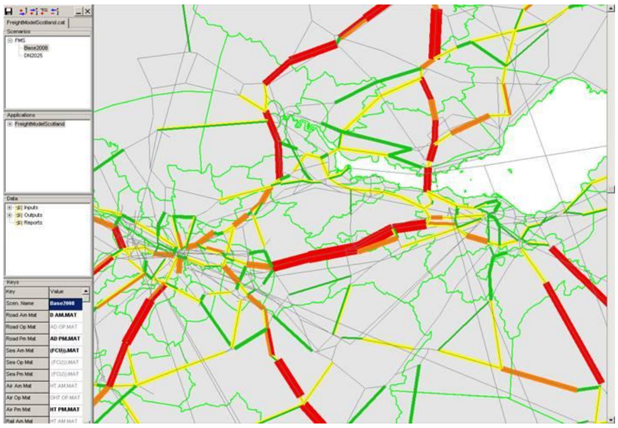
4.1 Overview

The final step in the process of model development is the running of tests using the completed model to provide inputs for a set of freight transport circumstances. For each scenario it is possible to assess different transport conditions which include tests not only for new transport infrastructure and services, but also for pricing and other policies such as demand management. The main outputs produced from the modelling system include, where relevant:

- freight flows and revenues;
- freight flows on the network, which can be graphically representative by bandwidth;

- demand, revenues, freight-kms and speeds on specified services, networks or corridors;

Figure 2: Sample Model Output



- unit or tonne hours (or minutes) of travel by time period;
- unit or tonne kilometres (or miles) by freight commodity;
- average trip lengths by distance and time;
- summary statistics and indicators describing the physical, socio-economic and environmental impacts; and
- movements of freight by commodity or mode and costs, disaggregated by the various times of freight movements for different commodities.

4.2 Assumptions for Initial Tests

We performed a series of trial runs based on the following input assumptions:

- A planning year of 2025 was set for forecasting future demand. This allows a medium to long-term view of how freight transport will develop. In addition, it also allows for the lag effects of the recent economic downturn.
- Forecasts for GDP growth sourced from HM Treasury.
- Base population / employment was sourced from the 2001 census and factored to future years using GROS Projections Scotland (for population) and NOMIS (for employment).
- Base values for average values of time were sourced from WebTAG. This also includes the growth in future values of time.
- The Governments National Road Traffic Forecasts (November 2005) were used to factor up the Base Year car matrices to represent future year car demands.
- For future growth estimates in fuel costs, the Government’s WebTAG modelling guidance was used.
- Non-fuel Vehicle Operating Costs (VOCs) are assumed to remain constant in real terms over the forecast period.

4.3 Future Forecasts

Using the base assumptions, a series of model runs were performed and some observations made. All RTPs are expected to experience growth in freight tonnes, with the exception of ZetTRANS which has been significantly affected by the trend over recent years to move fuel and petrol through pipes. This trend is expected to continue in the future with associated impacts on freight tonnage in ZetTRANS.

Another RTP area affected by the trend in piping fuel and petroleum is SEStran. Historic data on freight movements through ports in the Forth Estuary has shown that bulk fuel has fallen by circa 1% per annum over the last decade. This trend is expected to continue, albeit there may be a reduction in the rate in the future. Since bulk fuel accounted for over 85% of tonnages through the Forth in 2008, this decline is expected to offset growths in other commodities in the SEStran area.

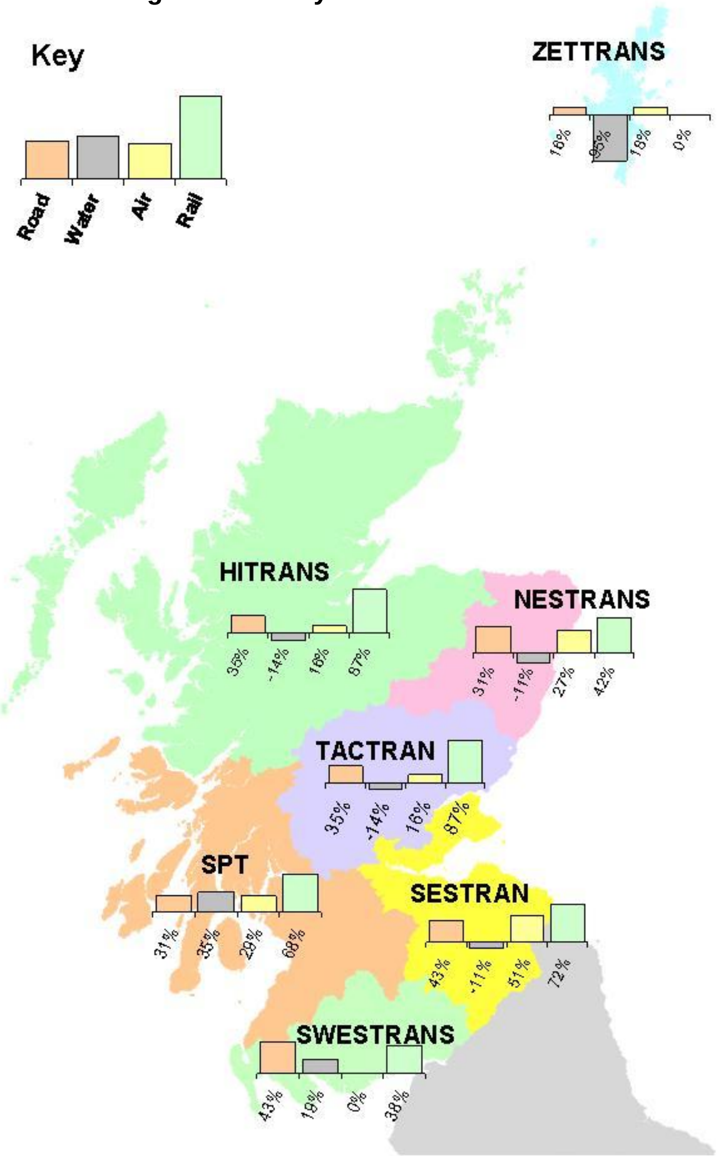
To a certain extent the above scenario also occurs in other RTPs which have traditionally had a significant volume of bulk fuel passing through or to/from their areas.

However, in all cases, the estimates are baseline conditions and do not take account of any policies and interventions being pursued by key stakeholders in the relevant RTP areas.

All other commodities are forecast to grow in the future by varying levels.

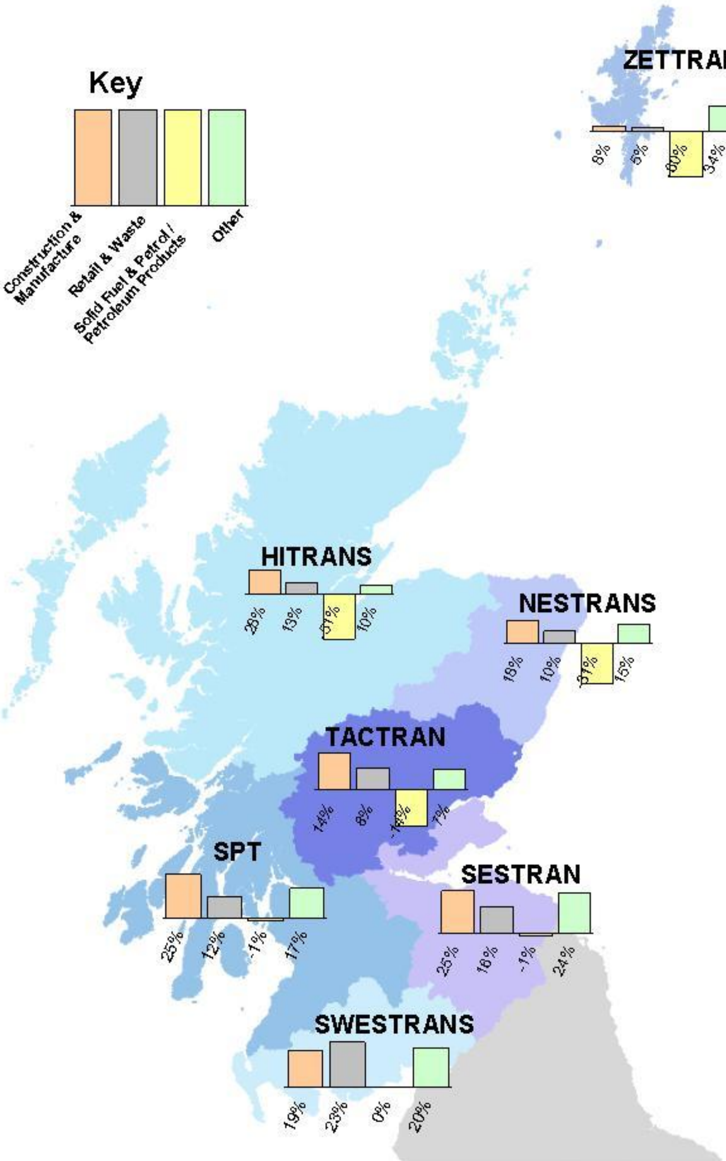
An important factor of the model has been to maximise practical useability through a graphical user interface (GUI) and geographical information system (GIS) to allow presentation of results to the lay-person in easy-to-understand figures and plans. The following results are presented as figures, displaying the main trends within each RTP area.

Figure 3: Forecast Freight Growth by Mode



As can be seen in the Figure 3 above freight transport grows in all sectors except water in some regions, due to the increase in piping of oil related products. Rail sees an increase in all regions excluding ZetTRANS with an 87% increase in Hitrans and TACTRAN. Air sees the greatest increase in the SEStran region at 51%, although these increases are from a small base. Road transport increases at around 30% in most regions, continuing its dominance as the mode of choice.

Figure 4: Forecast Freight Growth by Commodity

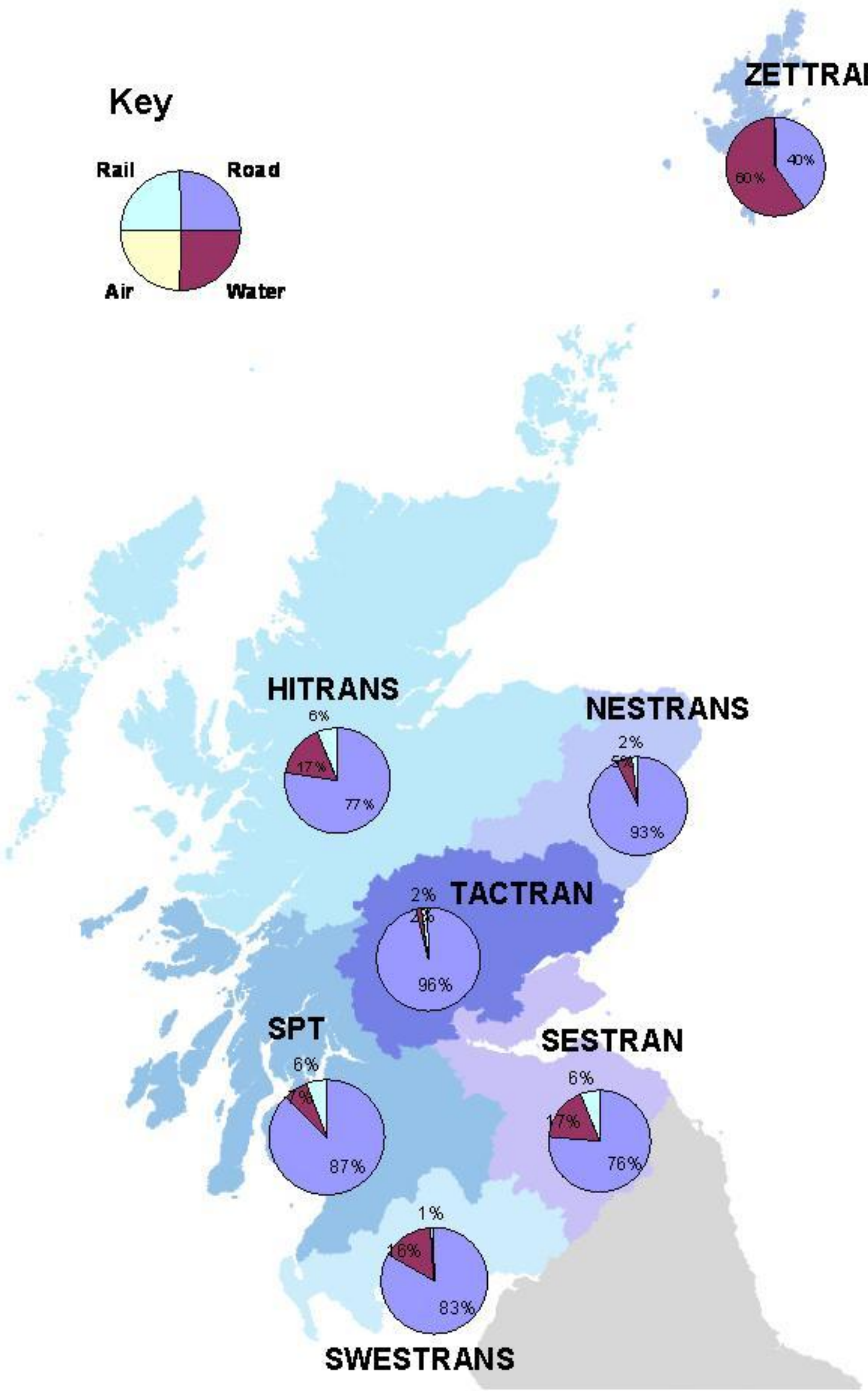


The above figure shows the growth in freight transport by commodity (some commodities have been grouped together for ease of presentation). This shows a marked decrease in the transportation of Solid Fuel and Petrol / Petroleum Products in all regions which have previously handled oil related products. This is due to the trend over recent years to move fuel and petrol through pipes rather than ship or road freight.

The other sectors all show increases across the regions of varying degrees.

The largest increases in construction and manufacture are seen in Hitrans and SEStran and SPT at 28% and 25% respectively. Other increases to note are increases in other between 7% in TACTRAN and 34% in ZetTRANS and retail and waste between 5% and 23%.

Figure 5: Modal Split by RTP

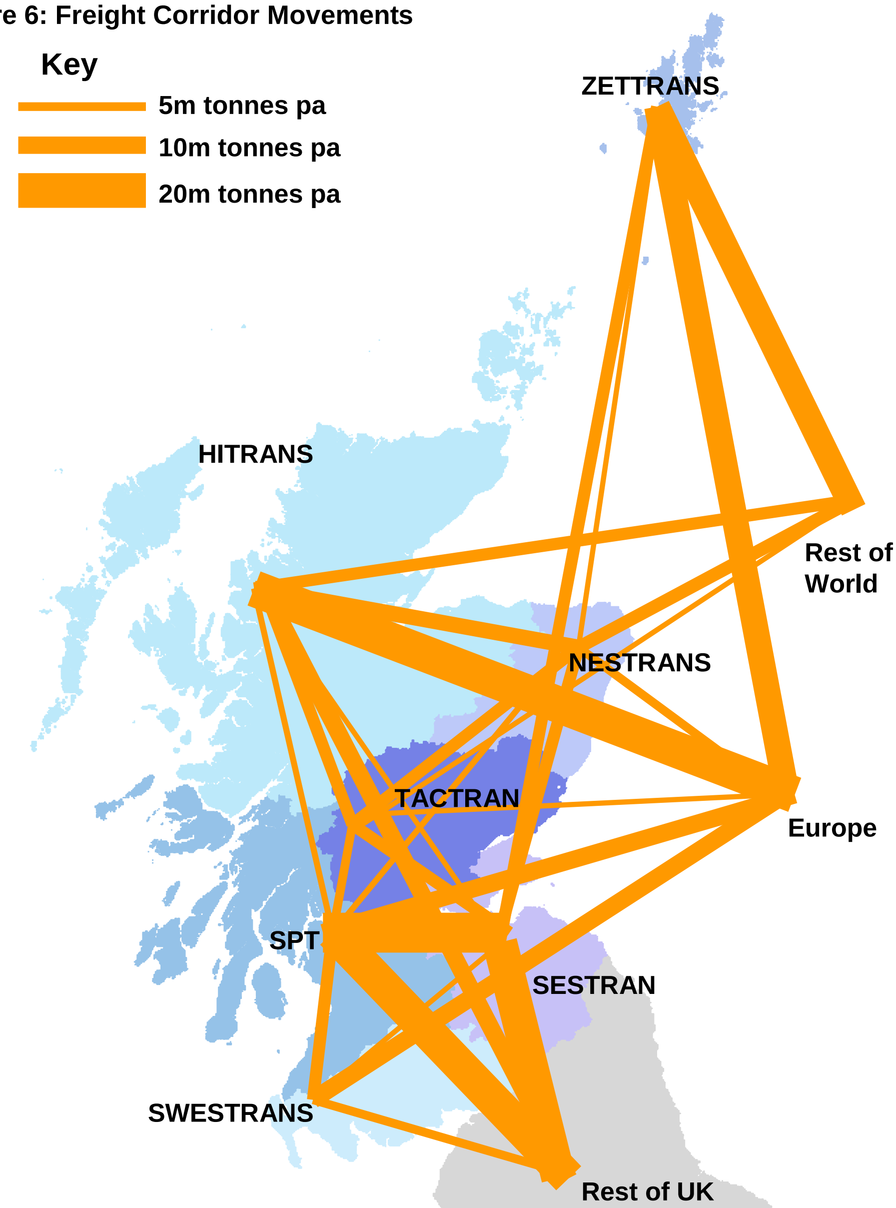


The above figure shows road is the predominant mode of transport in most of the regions ranging from 76% to 96%. The exception to this is ZetTRANS where the islands rely on water transport for the transhipment of goods to and from the islands, accounting for 60% of all transport movements. TACTRAN and Nestrans see the largest amount of road freight movements at 96 and 93% respectively. SEStran, Hitrans and SWestrans see around a fifth of freight moved by water.

Regarding rail freight movements Hitrans, SPT and SEStran see the largest share of rail freight accounting for 6% in each of these regions. The other areas all see very small shares representing the lack of infrastructure and rail freight facilities in these regions.

The above figure does not include air freight on the diagram as the volumes moved by air are negligible.

Figure 6: Freight Corridor Movements



The Figure above shows the main freight corridor movements between and from RTP areas. This is based on total commodities. This shows the largest flows within Scotland are between SEStran and SPT (over 20m tonnes) as would be expected given the concentrations of population and industry in these regions. There are also significant flows between TACTRAN and

SEStran, Nestrans and Hitrans and SEStran and ZetTRANS.

The highest concentrations to the Rest of the UK are from SPT, SEStran and Hitrans.

Heading to Europe the highest flows are from Hitrans and ZetTRANS, followed by SPT and SWestrans. These regions also have high flows heading to the rest of the world.

5. LESSONS LEARNED

From the building of the model we can conclude with a review of some of the problem areas encountered by Scott Wilson Ltd in developing models of this type, including the particular issues arising from emerging changes in the freight marketplace.

5.1 Economic Recession

At this period in time, one of the most influential factors on the base data was the current economic recession and its effects on freight volumes and flows. There are differences in building a model with a recession baseline versus the pre-economic downturn as growth rates are subject to more fluctuation. There is also the need to take into account the economic lag effect and the time it takes for the economy to pick up again.

The time horizons used within the model can significantly impact on the predictions made. If the future year is too near to the current time, the impacts of the economic lag will still impact on the model and the results may not be as good as expected. Similarly if we try to forecast too far into the future there is a lack of data available on future land use plans which reduces the reliability of the model.

5.2 Sensitivities of Different Freight Commodities

Another factor which has to be considered in all freight models is the different commodities which are being transported. Different commodities exhibit different levels of sensitivity to time inputs and therefore different cargos require modelling as separate entities. For example Forestry non-perishable products are not as time sensitive as perishable foods being delivered to supermarkets etc. In this case Forestry can use high volume slower modes such as water freight or rail freight where as food relies on the rapid speeds and turnarounds of road transport.

5.3 Geographical Variations

The geography of an area must also be considered when building a model and defining the zonal properties. Geographical characteristics are influencing factors depending on the key freight generators and attractors which, naturally, vary by geographical characteristics. Also the main areas of population and industry can influence the final zone boundaries.

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5.4 Type of Data

One highly important factor which also impacts on the quality of the model is the availability and accuracy of freight data. We found the following issues when developing the model:

- small sample sizes for Scotland meant there were few opportunities to examine freight demand patterns at regional and local levels;
- freight data is often collected for individual journeys, so it was at times difficult to gain an insight to the through-movement of consignments in a supply chain;
- industry and commodity classifications were often too broad to distinguish between product groups / logistical requirements; and
- differences in commodity classification and area coverage can make it difficult to compare modes.

5.5 Network Details

When creating the transport network, the level of detail included can have several effects on the model:

- if the network is too detailed with large volumes of junctions / interchanges, it becomes more difficult to reach an acceptable level of convergence; and
- similarly if the network is too detailed run times can take several hours to reach convergence. This limits the number of tests which can be performed in a day.

Furthermore, given the size and area the model is covering, this can lead to variable levels of accuracy with regards to modelled travel times. When deciding on the level of aggregation in the model the accuracy of modelled travel times is one of the key criteria.

5.6 Choice between Model Complexity Versus Running Speeds

There is a balance to be found when developing the model with regards to the complexity of the model and running speed. If the model is overcomplicated with vast amounts of input data it is likely that the model will take an overly long time to run. Therefore it is important to consider the types of projects and scenarios tested, and to limit them to reduce running times.

This type of model is best suited to testing the impacts of new infrastructure or improvements. However the model can also test a limited number of policies such as pricing impacts, land-use developments, different operating plans, user charging, distribution plans etc.

In addition the model layout is and important factor to consider when developing large scale strategic freight models. For the FM4S we have employed a modular structure split over three levels. This layout suits the model as each module can be run as and when required, without having to re-run previous model procedure thereby further reducing run times.

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