FREIGHT MODELLING

Transport Markets, Model Requirements, Transport Strategy

by Sean Newton and Mike Garratt, MDS-Transmodal Ltd.

Background

This paper was prepared for the 2002 European Transport Conference, within the freight and logistics theme. It draws on recent practical experience in designing, building and applying freight modelling techniques within the UK, as well as the current (2002) review of freight modelling techniques undertaken by the UK Department for Transport (DfT). By examining the interaction between freight markets and the external forces that shape them, it develops a set of model requirements. Finally, it provides an example of how freight models can inform transport strategy.

The technical ideas contained within this document have evolved from a series of reports, presentations, seminars and discussions held within the DfT's Review of Freight Modelling Techniques. We therefore would like to acknowledge the contributions of our team members: Marcial Echenique & Partners (project leaders), Institute of Transport Studies, Rand Europe, Katalysis Ltd, Oxford Systematics, Parsons Brinckerhoff, Imperial College, University of Westminister, and the client team: Department for Transport – ITEA division, the Strategic Rail Authority, the Highways Agency, and Transport for London. However, the views expressed here are not necessarily shared by all participants.

The results and analyses are based on the GB Freight Model, GBFM version 4.1, developed by MDS-Transmodal, and used by the UK Department for Transport (DfT), the Strategic Rail Authority (SRA), the Scottish Executive, the French Transport Ministry, various multi-modal studies, including the M1 corridor, and numerous private sector projects. The software is related to the STEMM freight model, developed for the European Commission in 1997.

Introduction

There are many ways to construct transport models. Some are designed around their immediate user requirements, others are designed to work around particular data inputs or data deficiencies. Most are built to run within tight deadlines.

Modern computer systems and programming languages make it possible to add finer levels of disaggregation and realism, to mix different software approaches and to link transport models to other related software. It is therefore hardly surprising that areas of specialisation have developed.

During the DfT review of freight modelling, MDST have been asked to consider the question of what is needed, focusing on rail freight.

However, it has become abundantly clear that what is needed to analyse rail freight is exactly the same as what is needed to analyse other modes, and that there is a significant advantage in taking a comprehensive approach. It is computationally cleaner, it is more realistic, and it avoids the pitfall of forecasting rail, based on its past performance and not on its ability to compete and win. Ultimately it allows different mode sectors to be treated equally.

First Steps

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 1.

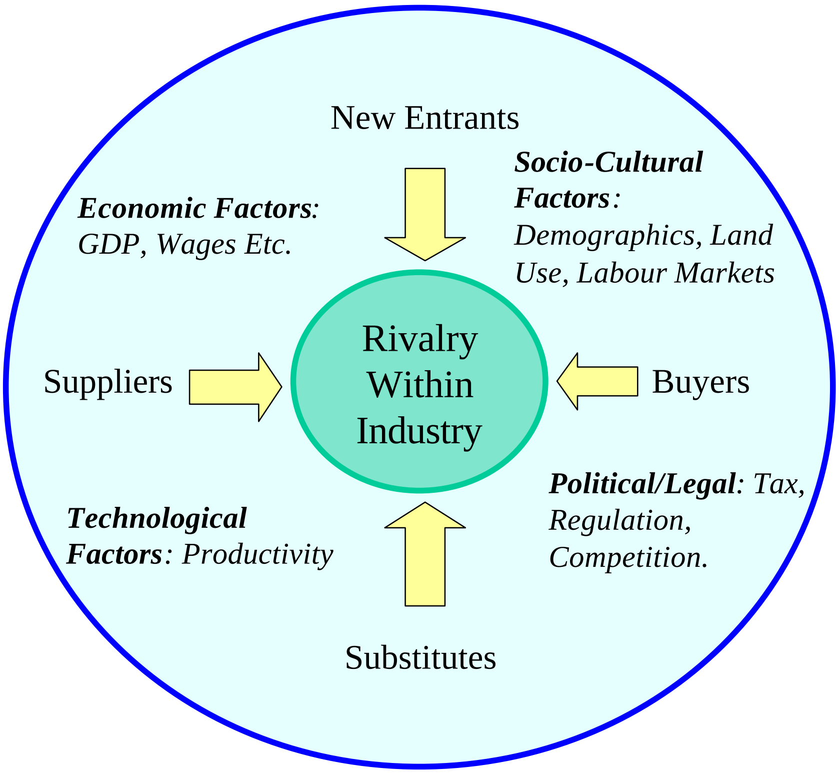


Figure 1: The Industry and Its Environment

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

This diagram considers the freight transport industry within a simplified, general framework designed for the purpose of analysing 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 1 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 infrastucture industry has high barriers 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.

This is essentially 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 2, as a restatement of the general framework.

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.

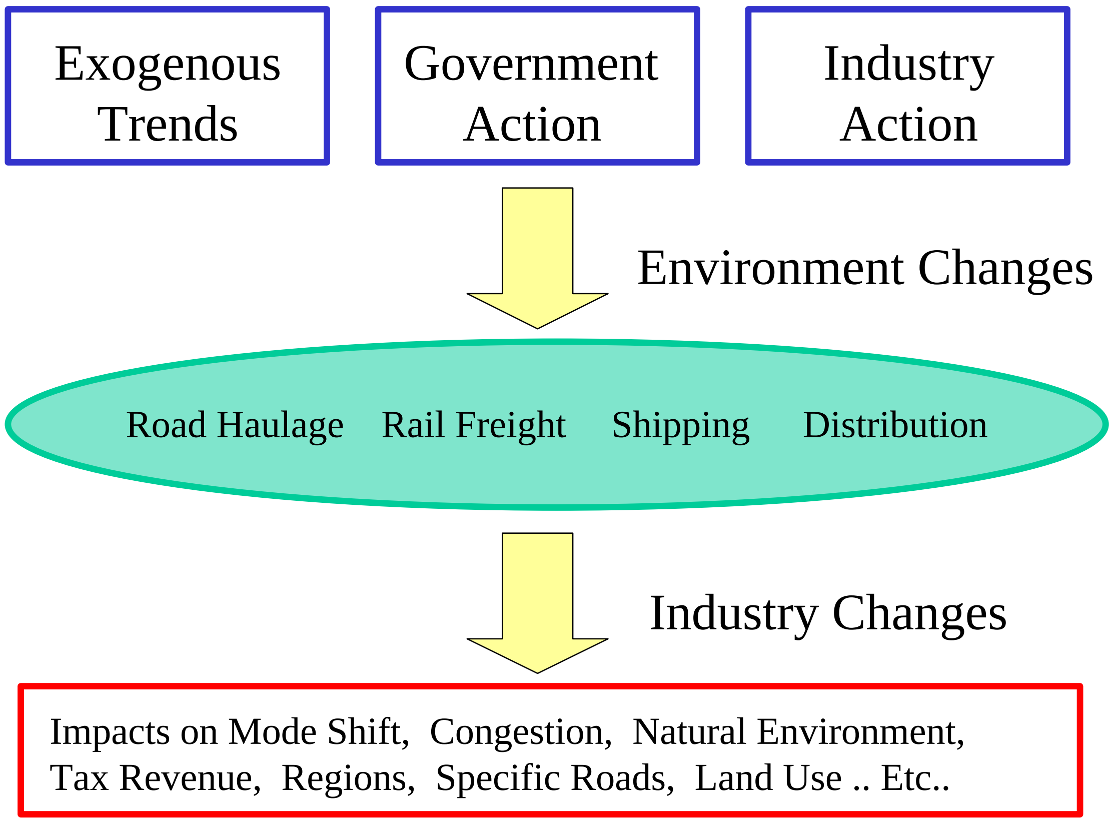


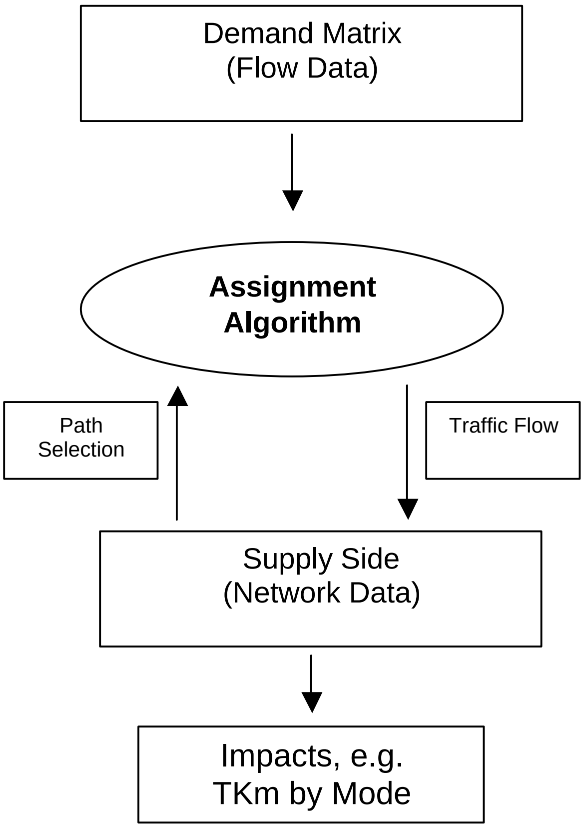
Figure 2: The Role of a Transport Model

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, and specific transport links attract customers (tonne kilometres).

Thus, following this approach, the simplest freight model structure might be:

Figure 3: Level one - Minimal Approach



Here it could be envisaged that the demand matrix, encapsulating forces such as macro-economic trends, industrial sector linkages, regional development, and logistics systems, generates shipments: tonnes of specific commodities that need to be transported across the network, between given end points.

The supply side, represented by a database of links allows different route solutions to be generated. The assignment algorithm decides which flows select which network links, and the traffic is assigned back to the network. By holding the parameters of the assignment process constant, the impacts (for example, tonne kilometres by mode) become dependent on the exogenous demand conditions and the network structure itself.

Advancing Beyond Level One

The level one design is surprisingly complete. It can apply many of the required mechanisms: those affecting the degree of competition, and the price formation process, and the external forces acting on the industry such as the economy and technology. It can produce many of the results that would normally be required such as traffic volumes by link category.

There is a single reason why the minimal approach would not be applied successfully in practice. The missing ingredient concerns buyer and supplier power within the freight industry, and the increasing need for producers, consumers, and freight companies to co-ordinate their transport and storage activities through the process of supply chain logistics. Through vertical integration, haulage operations have evolved into third-party logistics suppliers, and freight buyers have developed their own in-house logistics networks.

The ability of freight customers, e.g. manufacturers to integrate vertically with freight operators, changes the modelling problem significantly.

On the demand side, it is evident that subsets of the demand matrix are linked, either through the companies that control the traffic, or within a hierarchy of trips e.g.

Factory -> National Distribution Centre (NDC) -> Regional Distribution Centre (RDC) -> City Centre Outlet.

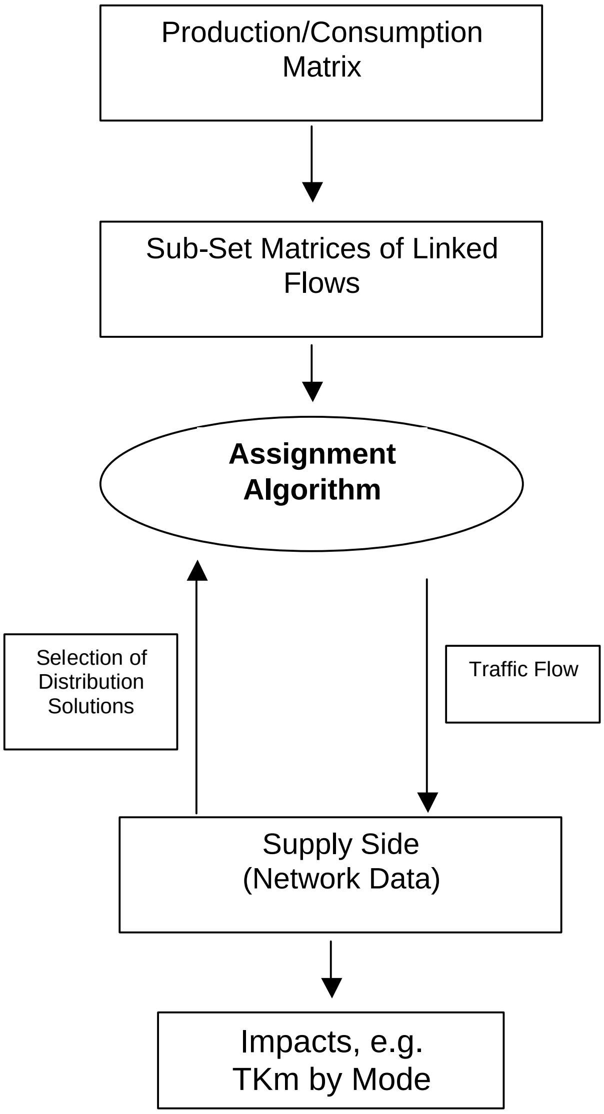
It is therefore apparently advantageous to reflect this within the model, as it provides more information that will be relevant for the assignment process, e.g.

NDC->RDC leg is more likely to be carried out by rail than RDC->Outlet.
NDC->RDC is unlikely to be time constrained, it is single drop, and returning full.
RDC->Outlet could be time constrained, multi-drop, and returning empty.

Conversely, the assignment process benefits from this additional detail.

The preferred design is therefore:

Figure 4: Level Two Approach



In this framework, the idea of a demand matrix containing independent cells or OD pairs, has been dropped. Instead the demand matrix has been simplified into a production and consumption matrix, with all trips involving intermediate storage having been removed. From this matrix, sub-sets are extracted representing individual companies, or industries, which can include numerous production and consumption locations, and more than one commodity.

The assignment algorithm as the market-making agent, which is still the main focus of the model is no longer looking for a set of paths between two points, but for a set of "distribution solutions". They can include intermediate storage, trans-shipment, in which the object is to minimise the generalised cost of the whole solution, rather than any specific trip contained within it.

The structure does not rule out the simplest possible structure:

Producer -> Full truck/train load -> via shortest path -> Consumer

However, this can be seen as a special, though not unusual case.

The additional computational complexity involved in taking this approach, is compensated for by the additional realism it offers, the ability to solve a greater part of the overall problem set in one assignment iteration, and in the ability to treat the logistics components as endogenous. For example, the requirement for warehousing in a specific region can be determined by the model.

Final Additions

Two important components are hidden within the level two structure; transport costs and the link between the economy and the production consumption matrix. However, these are potentially two of the most important areas in which transport policies may be transmitted through the model.

Cost Functions

Cost functions can, like the rest of the design, be constructed in a way that is comprehensive for different modes of transport. The suggested structure would be:

Table 1: Cost Structure

	Road	***Rail***
Track	Road tax, distance based charges	Track access charges, track access grants, speed, gauge
Traction	Tractor unit, depreciation, fuel consumption, driver, drivers' hours	Locomotive costs, crew, power consumption
Wagons	Trailer cost, depreciation	Wagon hire or ownership costs
Terminals	Standing costs, while loading and unloading	Lift costs, availability of freight facility grants
Service Provider	Agent or forwarder	Agent or forwarder

If network links for other modes are included (ferries, inland waterways, air services, container shipping etc), the structure can be adapted easily.

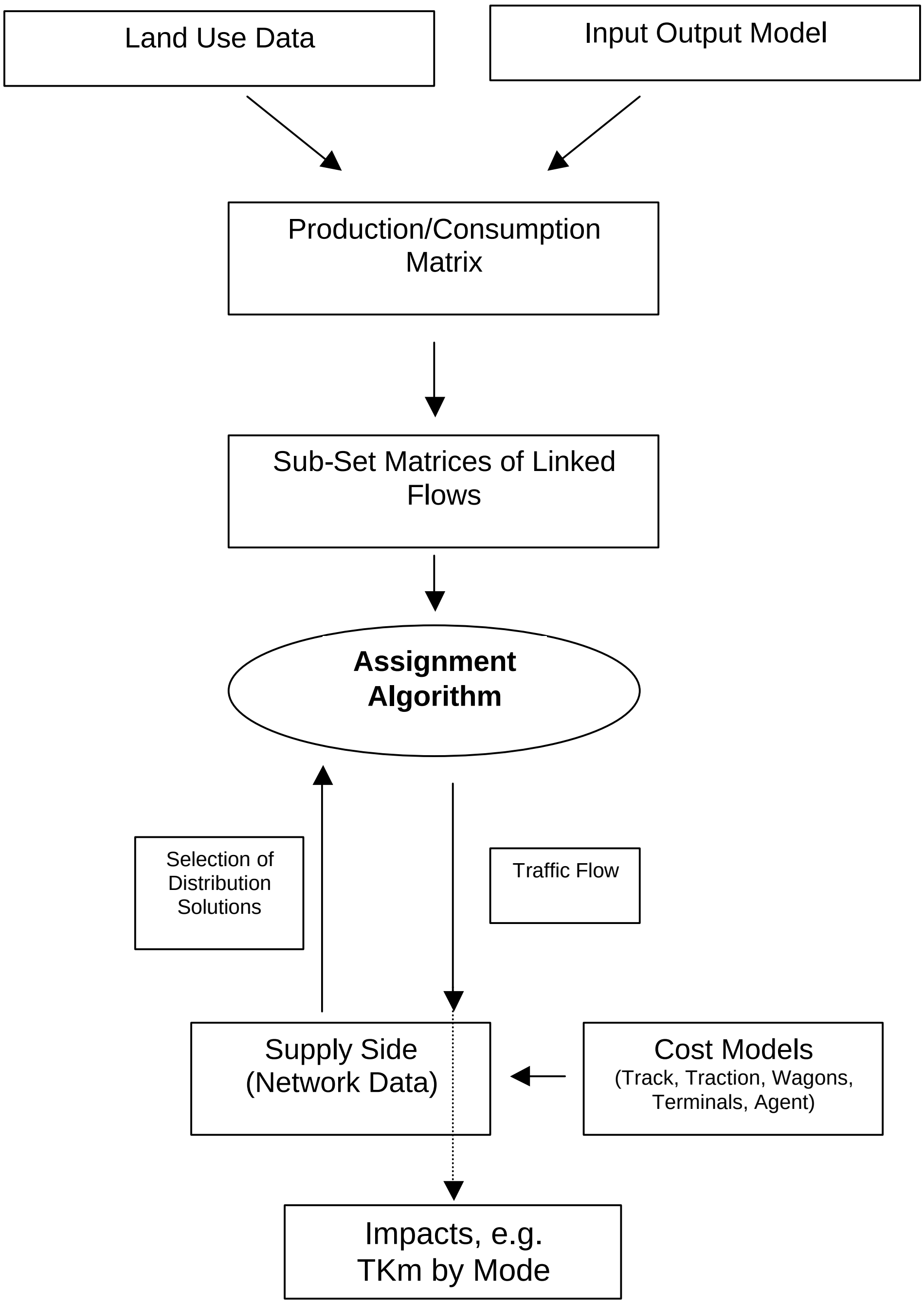
Derivation of Production Consumption Matrix

On the demand side, it is unlikely that it will be possible to obtain production consumption (P/C) matrices in a form that could be used as a straightforward data input for a model. It is therefore necessary, and potentially advantageous to add an additional step linking land use and input-output data in order to produce derived P/C matrices.

This process allows greater interaction between the evolution of industrial sectors, the regional dimension, the performance of those industrial sectors and the rest of the model.

The final specification is shown in

Figure 5: Level Three – Final Specification



Thus having set out to design a rail freight model operating at the national scale, a more general structure has been produced. It can applied at different scales (local, regional, national, and within limits, international) without alteration. It is not limited to any given definition of modes, and it attempts to mirror real market mechanisms.

Transport Policy

One of the objectives, so far, has been to develop a model design that would be suitable for interpreting and modelling transport policy. The suggestion has been that if the models are designed to be more realistic, then they will be more useful.

A case study is presented here, building on the theme that if the model structures for road and rail can be the same, then so can the policy implications. It considers the case for public sector investment in the rail freight network, arguing that if rail freight is not modelled according to same principles as road traffic, it can produce a distortion in investment decisions, actually leading to a diversion of traffic from rail to road.

The background to this example, is the UK Government's Ten Year Plan for transport, incorporating a forecast of 80% rail freight growth between 2000 and 2010. MDST's GBFM model was one of three models used by the Strategic Rail Authority (SRA) to develop this forecast. The case study examines how a model such as GBFM, or an application based on the design presented here, can solve some of the appraisal requirements, and therefore provide a level playing field for investment decisions.

Case Study: Rail Freight Appraisal

It is apparent in the UK that public investment in roads takes into account user benefits, such as (usually) small decreases in journey time, and improved transport economic efficiency. These benefits are evaluated, using value of time estimates, and set against project costs and non-user costs such as noise, severance, contribution to accidents, air pollution, and so on.

Transport models play an active part in this process, providing traffic forecasts, journey time savings, and environmental impacts.

Conceptually, UK road and public transport investment decisions are made in exactly the same way, using an appraisal process.

The 1998 *Integrated Transport White Paper* introduced the New Approach To Appraisal or NATA, specifying five criteria: safety, environment, the economy, integration, and accessibility. This approach mixes quantifiable, including monetised sub-criteria based on cost-benefit analysis with qualitative assessments, within a scoring system that is overtly multi-modal.

Thus, under NATA a new rail freight investment should be appraised according to:

- non-user costs: safety and the environment, e.g. noise, air quality, accidents, severance
- non-user economic benefits: wider economic impacts, e.g. jobs

- user benefits: known as transport economic efficiency (TEE), including reductions in travel time, vehicle operating costs, and user charges,
- accessibility: including option values derived from greater choice, and
- integration: additional reliability and interchange benefits, beyond the level assessed as user benefits.

If anything, the need to demonstrate accessibility and integration benefits, suggests that the balance is in favour of public transport, for a given level of net benefit on the other criteria. In the SRA's *Freight Strategy,* there is specific reference (page 30) to the development of an approach which will 'enable both passenger and freight schemes to be assessed within a common framework'. The Strategy points out that OFRAF's Planning Criteria (for rail passenger services) are themselves based upon NATA.

However, the record of public investment in rail freight indicates that historically, the main lever for funding has been non-user costs/benefits alone. Principally, this covers the net benefit to the environment and to road users of switching traffic from road to rail, through lower emissions, and reduced road congestion.

It is clear that if this approach were adopted for road schemes, no more roads would be built, unless they could cover their construction costs with non-user benefits such as reductions in emissions or accidents. Very unlikely.

There are several historical reasons why rail freight failed to attract investment on the basis of user benefits.

- Rail freight was part of a vertically integrated industry where track costs were poorly understood.
- Any freight activity was poorly understood by the modelling fraternity. Road construction was justified mainly by savings in non-work time made by car users. Generally speaking, HGVs simply "piggybacked" onto road space justified by the estimation of non-work time savings made by car users.
- The railway industry received large amounts of Government cash in any case. It was up to the British Railways Board to spend it on freight if it wished. It chose not to and sought to make freight self financing (freight doesn't vote).

Essentially, the rail freight industry had no coherent and quantified case couched in the terms which could be interpreted by the modelling techniques used by Government to underpin transport policy.

As a consequence, the case for rail freight continues to be made on the basis of cash revenue and a limited interpretation of non user benefits. The road network with which it competes continues to also justify capital expenditure on the basis of user benefits (which, of course, include the savings made by a haulier in being able to make more efficient use of his lorry).

Such cost benefit analysis, often put forward as a left of centre device to improve resource allocation, has in fact been the intellectual device which has diverted traffic from rail to road. Although the principle of cost benefit analysis remains neutral, it is evident that if the modelling which underpins the analysis is applied unevenly, the outcome will be distorted.

The opportunity now exists to address this distortion.

- Firstly, EU legislation now dictates that rail infrastructure is accounted for separately. In Britain, the Office of the Rail Regulator (ORR) has now established non discriminatory rail freight track charges to cover long run maintenance and renewal. Rail track can therefore be considered in a similar light to road track.

- Secondly, on-rail competition means that in principle, the benefits of any measures to enhance the infrastructure network will be passed onto end-users; it will not be captured by monopolistic suppliers within the transport chain. The forthcoming application of the Company Neutral Revenue Support (CNRS) system by the SRA, will ensure that it will be end-users who will derive the consequent benefits of grants, and not operators. Benefits of network enhancement will therefore end up with users!

- Thirdly, and crucially, data and modelling techniques are now available to establish both the demand and the supply conditions for the provision of rail capacity. This allows the road and rail freight industries to be modelled simultaneously, on precisely the same model structures, so that both user and non-user benefits can be calculated. The technique which has hitherto only been available to road can now therefore be applied to rail and, for that matter, coastal and short sea shipping.

This can now be exemplified using results from GBFM.

A simple comparison between two scenarios (labelled ‘U’ and ‘C’) for 2010 has been made using GBFM, employing two different methods for calculating user benefits.

In Scenario ‘U’, meaning unconstrained capacity, the central, Ten Year Plan, 2010 forecast has been modelled. This is sufficient to raise rail freight tonne kilometres (net) to 32.8 billion per annum, including “own haul”. Year 2000 volumes are approximately 18 billion tonne kilometres.

In Scenario ‘C’, meaning constrained capacity, the same cost and efficiency assumptions have been made for both road and rail, but a “gateway” levy of £50 per unit has been added to unitised rail flows to represent a capacity limit. Non-unitised flows are not assumed to be affected, as any capacity issues are most likely to affect scheduled services. This levy is sufficient to cap rail freight tonne kilometres at 27.3 billion per annum, including “own haul”.

Adjusting for the “own haul” category, and taking a 2000 benchmark of 18 billion, implies that scenario ‘U’ represents rail freight growth of 77% (2010 vs.

2000), and scenario 'C' 47%. Equivalent changes in tonnes lifted by rail are also given in Table 3.

Table 2: 2010 Forecast Rail Freight Volumes–Annual Net Tonne Kms (Bn)

	2010 'U'	***2010 'C'***
Bulk (Not Constrained)	14.08	14.08
Non-Bulk (Constrained)	18.80	13.21
Total	32.88	27.29
MDST Estimates, June 2002, GBFM V4.1		

Table 3: 2010 Forecast Rail Freight Volumes – Annual Tonnes Lifted (Mn)

	2010 'U'	***2010 'C'***
Bulk (Not Constrained)	85.9	85.9
Non-Bulk (Constrained)	50.6	33.3
Total	136.5	119.2
MDST Estimates, June 2002, GBFM V4.1		

Note, that in this analysis, the definitions of bulk and non-bulk have been linked to the idea of constrained and not-constrained, and are not necessarily the same as the definitions used within the Ten Year Plan.

The total volume is consistent.

The outcome of the constraint is that the non-bulk (i.e. unitised) sector declines by 5.59 billion tonne kilometres, equivalent to 17.3 million tonnes.

User Benefits and Option Values

Two methods have been applied to calculate the net user benefits resulting in the release of capacity within the network. The first takes a more literal, system optimal approach, imputing a generalised cost saving (higher utility) only when the capacity improvement causes the minimum generalised cost for a specific trip to fall. This is equivalent to stating that users only benefit from a change if it improves the best option available to them.

The second takes a broader, more liberal, view of consumer utility, using a composite cost measure. Under these circumstances, the addition of any viable option to a choice set reduces the composite cost, irrespective of whether it is the optimum as calculated by the generalised cost function. It implies that the provision of new, relevant choices, which are attractive enough to be considered, reduces generalised cost for all consumers. More choice is a good in itself.

The first method is a more readily understandable as a measure of user benefits, but the concept of option value, which the second method includes, is consistent with NATA, via the "accessibility" criteria. In the UK's GOMMMS literature (Guidance on the Methodology for Multi-Modal Studies), one of the sub-objectives of accessibility is option values, previously recognised by OPRAF (now the SRA), for passenger rail services, but “equally applicable to other public transport modes … *[listed]*.. and to freight facilities”.

The two stage procedure, described below allows both the user benefits (satisfying the economy-transport economic efficiency objective) and the option values (satisfying the accessibility-option value objective) to be quantified.

Table 4: Stage 1: Calculation of User Benefits

		Generalised Cost		
		Unconstrained (£Bn)	***Constrained (£Bn)***	***Difference (£Mn)***
Road	Bulk	8.262	8.278	16.0
	Non Bulk	21.364	22.131	767.1
	Total	29.627	30.410	783.0
Rail	Bulk	1.088	1.088	0.1
	Non Bulk	2.181	1.555	-625.8
	Total	3.269	2.643	-625.7
Total	Bulk	9.351	9.367	16.0
	Non Bulk	23.545	23.687	141.3
	Total	32.897	33.054	157.3
MDST Estimates, June 2002, GBFM V4.1				

Table 5: Stage 2: User Benefits and Combined Option Values

		Generalised Cost		
		Unconstrained (£Bn)	***Constrained (£Bn)***	***Difference (£Mn)***
Road	Bulk	8.244	8.259	15.9
	Non Bulk	21.222	21.983	760.4
	Total	29.466	30.243	776.4
Rail	Bulk	1.074	1.074	0.1
	Non Bulk	1.768	1.235	-532.7
	Total	2.842	2.310	-532.7
Total	Bulk	9.318	9.334	16.0
	Non Bulk	22.991	23.218	227.7
	Total	32.309	32.553	243.7
MDST Estimates, June 2002, GBFM V4.1				

Summarising the differences, and separating user benefits from option values:

Table 6: User Benefits and Option Values for an Unconstrained Network (£ Mn)

	User Benefits	*Option Value*	*Total*
Bulk (Not Constrained)	16.0	0	16.0
Non-Bulk (Constrained)	141.3	86.4	227.7
Total	157.3	86.4	243.7
MDST Estimates, June 2002, GBFM V4.1			

Summarising both user and non-user costs and benefits:

Table 7: Appraisal Summary

	Cost (£ Bn)		*Cost (£ Mn)*
	Unconstrained	*Constrained*	*Difference (C-U)*
Rail User Cost	3.269	2.643	-625.7
Road User Cost	29.627	30.410	783.0
Total User Cost	32.897	33.054	157.3
Total User Cost (incl. Option Value)	32.309	32.553	243.7
Non User Cost (*)	1.772	1.828	56.4
Total System Cost	34.081	34.381	300.1

(*) Non user costs have been estimated using standard rate of 12.5 pence per HGV kilometre saved. The constrained scenario ‘C’ adds 5.864 billion road tonne kilometres, equivalent to 451 million vehicle kilometres (assuming 13 tonnes per vehicle), or £56.4 million.

The NPV (in 2002) of the streams of benefits resulting from the increase in capacity represented by the switch from scenario ‘C’ to scenario ‘U’, using a discount rate of 6%, and a planning horizon of 2032, would be:

Table 8: Net Present Value, by Appraisal Method

Appraisal Method	*NPV (@ 6% discount rate)*
Non-user benefits alone	£598 million
User and non-user benefits	£2,214 million
User, non-user and option benefits	£3,083 million

Between 2002 and 2010, the level of annual benefit is phased in, using a straight-line formula.

It will be instantly obvious that the value of the extra capacity created is far higher if user and non-user benefits are both taken into account, as they would be in evaluating a road scheme.

Software tools for analysing operational railway capacity are now available from Multimodal Applied Systems, and have been used in conjunction with transport models (GBFM) for the Dibden Bay public inquiry.

Conclusions

This paper has attempted to link together transport markets, transport model design, and transport policy. It is our conclusion that the three aspects are inseparable. The wrong models, built upon frameworks that are not comprehensive across scales and transport modes, that do not provide satisfactory representations of the true market mechanisms cannot be successfully applied within an integrated transport policy framework.

References:

MEAP et al (2002) *Review of Freight Modelling*, A study carried out for the Department for Transport

Garratt M.G., Newton S.E. (2002), *Freight Forecasting, User Benefits and Capacity Measurement: Making the Case for Rail Freight*, published in Railfreight News, Railfreight Users Group.

DETR (1998) *A New Deal for Transport Better for Everyone,* The Stationery Office, London

DETR (1999) *Sustainable Distribution: A Strategy,* The Stationery Office, London

DETR (2000) *Transport 2010 The 10 Year Plan*, The Stationery Office, London

Office of the Rail Regulator (2001) *Review of Freight Charging Policy: Final Conclusions,* Published by the Office of the Rail Regulator, London

Strategic Rail Authority, (2001) *Freight Strategy*, Available from the SRA, London

Strategic Rail Authority, (2002) *National Rail Trends 2001-02*, Available from the SRA, London