DRAFT DELIVERABLE REPORT

WORK PACKAGE N° : WP 2

TITLE : Analysis of Transport Decision-making Processes

WORK PACKAGE LEADER : Logistics Research Centre, Heriot-Watt University

PARTIES INVOLVED : ZLU, RC/AUEB, LB SA

REPORTING PERIOD : FROM January 1st TO June 30th 2000

Work Package Start Date : January 1st Duration : 6 months

Date of issue of this report : 11 August 2000

Project funded by the European Community under the ‘Competitive and Sustainable Growth’ Programme (1998-2002)
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1. **Introduction**

It is claimed, particularly by environmental pressure groups, that companies generate excessive amounts of freight traffic and under-utilise transport capacity. They are accused of sacrificing transport efficiency in the pursuit of other corporate goals (e.g. Whitelegg 1995, Holman 1996, Pastowski, 1997). For example, the replenishment of supplies on a just-in-time (JIT) basis cuts inventory levels but often has the effect of reducing vehicle load factors and inflating transport costs. The use of roll cages facilitates material handling, but again at the expense of vehicle fill. Sales promotions destabilise the flow of freight, making it more difficult to use transport assets at a uniformly high level.

By compromising transport efficiency in these various ways, however, firms are not necessarily behaving irrationally. On the contrary, they are usually trading-off different cost elements in an effort to maximise overall profitability. Such cost trade-offs are fundamental to the management of any logistics operation. Their optimisation need not result in either the minimisation of freight transport requirements or maximum utilisation of vehicle capacity.

It can, nevertheless, be argued that logistical cost trade-offs attach insufficient weight to transport and that, as a consequence, are systematically biased against the efficient use of the transport system. There can be several reasons for this:

1. **Many firms do not explicitly model the trade-off between logistical cost elements.** Logistical decision-making is therefore based on a limited knowledge of the relevant cost functions. Lack of knowledge is one of the prime causes of 'market failure'. If under-reporting of transport costs and defective cost analysis were widespread across industry, such a 'failure' might exist in the freight transport market. As little research has been done on accounting practices within the logistics function, it is not possible to test this hypothesis on the basis of available data. This is not one of the aims of the present work package. The issue, nevertheless, warrants further investigation.

2. **The transport costs that companies incur do not reflect the full environmental and social costs of freight movement.** This is not in dispute. Several studies have attempted to quantify these external costs and estimate by how much freight transport costs would rise if these costs were internalised in higher taxes (Kageson, 1992; Royal Commission on Environmental Pollution, 1994; European Commission, 1996). The resulting transport cost increases would alter the economic balance between transport and other logistical activities, giving companies an incentive to rationalise their transport operations. Simulation modelling suggests, however, that in many industrial sectors, logistical cost trade-offs are fairly robust and that very large transport cost increases would be required to induce large changes to logistics structures and practices (McKinnon, 1998). This has been confirmed by surveys of logistics managers (Cooper et al. 1995; McKinnon and Woodburn, 1996). So far little research has been done on the likely behavioural response of logistics management to varying levels of transport cost increase. Again, this has not been one of the central concerns of this work package, though some of the research undertaken sheds important light on the subject.

3. **Transport management typically occupies a low position in the corporate hierarchy and wields much less bargaining power than functions such as production, marketing and finance.** This can be attributed to several factors:
   - freight transport accounts for only a small % of sales revenue, averaging around 2-3% across manufacturing industry (Touche Ross, 1998). In recent decades, the real cost of freight transport in Europe has declined and so to has its share of sales revenue (A.T.Kearney, 1999). Improvements in the efficiency of transport operations have had the effect of reducing the transport element in the balance sheet and further marginalising transport in cost terms. (This trend is likely to have been partly offset by the increasing concern for the quality and reliability
of transport services as order lead times have shortened and increasing numbers of companies moved to JIT delivery).

- prevailing view of transport as a 'derived demand' and hence having a subservient role to other activities.
- belief that transport is seldom a core competence or major source of competitive advantage.

Even where adequate cost data are available, organisational structures and power imbalances within the business can result in much greater priority being given to activities other than transport. Transport decisions are made within a wider logistical and business context and are invariably subordinate to wider corporate goals. This work package has explored the relationship between transport decisions and some of these wider goals, particularly those relating to new product development and system design.

1.1. Work package Objectives

The work package has three objectives:

1. To discover how transport decisions are taken within a logistical and broader corporate framework and how this varies by sector and size of company.
2. To examine the effect of management restructuring on the transport decision-making process, particularly the move from functional to process-based management.
3. To establish what can be done to give greater priority to transport in strategic decisions on new product development and the system design.

1.2. Methodology

The work package is based on a review of literature on the following subjects: logistics strategy, transport decision-making, freight traffic modelling, new product development, packaging and vehicle utilisation. This review of previous research has been supplemented with primary data from two sources:

1. Interviews with senior management in thirteen large companies in Austria, Germany, Greece, the UK and the US. These companies were drawn from the following sectors: automotive (luxury), chemicals, computing equipment, food and drink (brewing, fruit juice, snack foods), fast moving consumer goods (personal hygiene products), construction materials (roofing), paper, semiconductors, telecommunications equipment, textiles, white goods (refrigerators). The interviews were semi-structured and based on the questionnaire in Annex 1. Where possible, interviews were held with managers representing different functional areas to gain a broader perspective on the role of transport decision-making within the organisation.

2. The results of an earlier interview survey conducted in the UK in 1993-4 with a sample of 90 logistics / distribution managers in 76 manufacturing companies and 24 retail chains, in eight sectors characterised by a rapid rate of road freight traffic growth. In the course of these interviews, many managers outlined logistical decision-making processes and the commented in the inter-relationships between transport and other functions. The use of this larger empirical base provided a firmer basis for generalisation.

In both the interviews and the earlier survey participating companies were offered anonymity. This version of the deliverable must be considered commercial in confidence and not be made available for public release. An anonymised version of the deliverable can be made available, if required, for publication.

1.3. Structure of the Report

This report is divided into six sections. Chapter 2 briefly describes the evolution of logistics management over the past 40 years, showing how the broad context within which transport decisions are made has changed over this period. Chapter 3 identifies the main freight transport parameters likely to be of interest to public policy-makers and shows how they are affected by different types of corporate decision. It also reviews previous research on the freight transport decision-making process, much of which focuses on the modal choice decision. Chapter 4 examines the new product development process,
drawing attention to recent efforts to greater account of logistical factors in the design of new products. Chapter 5 assesses the impact of different product attributes on freight transport requirements. It emphasises the importance of packaging and handling equipment as key determinants of vehicle utilisation and explores the trade-offs that managers must make between marketing, materials handling and transport objectives. Chapter 6 examines the higher level trade-offs that must be made in the design of production and distribution systems and enquires about the rigour and objectiveness of these trade-off decisions. Chapter 7 concludes with a summary of the main findings and a review of the measures that public policy-makers might take to increase the relative weight attached to transport decisions in the development of corporate strategy.
2. The Changing Managerial Context

The management of logistical activities has been transformed over the past forty years by a series of major developments (e.g. McKinnon, 1989; Bowersox and Closs, 1997).

2.1. Physical Distribution Management

Up until the 1960s, responsibility for distribution / logistics activities, such as transport and warehousing, was fragmented. The outbound delivery of finished product, for example, was typically controlled by the production or sales department. Its costs were absorbed in the budgets of these departments and often not separately identified. As transport was considered ancillary to the main goals of these departments, it seldom attracted the attention of senior management. There was also a failure to co-ordinate the transport operation with related logistical activities, such as warehousing and inventory management, which were under the control of other departments.

Physical Distribution Management (PDM) aimed to overcome these problems. It required the creation of separate distribution departments to control the movement and storage of finished products. Within a PDM framework, companies could much more closely co-ordinate the management of transport, warehousing, inventory management, goods handling etc. The related realignment of cost accounting systems also gave companies much more information about their expenditure on distribution activities. This often revealed, for example, that a large proportion of companies’ total output was being distributed in small quantities at high delivery costs per unit. In pursuing their prime objective of maximising revenue, sales departments were prepared to supply very small orders, in some cases at loss. Following more detailed analysis of distribution costs, companies began to raise minimum order sizes, stopping deliveries to small outlets and effectively rationalising their delivery networks. Within the new management and accounting structures it was possible for the first time to analyse the trade-offs between transport, warehousing and inventory costs and co-ordinate them in a way that minimised total distribution costs. PDM was first implemented by large US corporations in the early 1960s. It has since diffused widely both internationally and across industrial sectors. There are, nevertheless, still many small and medium-sized business which have yet to embrace this principle.

2.2. Integrated Logistics Management

PDM was initially concerned only with the distribution of finished products. The same general principle was subsequently applied to the inbound movement of materials, components and sub-assemblies, generally known as ‘materials management’). By the late 1970s, many firms had established ‘logistics departments’ which overall responsibility for the movement, storage and handling of products upstream and downstream of the production operation. Logistics also took on a higher level strategic role in recognition of its possible contribution to the overall competitiveness and profitability of a business. As a key element in the more broadly defined logistics function, transport was able to improve its status within the corporate hierarchy. In many companies, logistics is now represented at board level, though in most it still tends to yield less clout than the traditional functions of production, operations, engineering, marketing and finance. Only one of the manufacturers interviewed for this Work Package did not have representation for logistics at board level.

2.3. Business Process Re-engineering

Christopher (1998) has noted that ‘amongst experienced observers of the logistics management process, there is general agreement that the major barrier to the implementation of the logistics concept is organisational … a major impediment to change in this crucial managerial area is the entrenched and rigid organisational structure that most established companies are burdened with’. Most businesses have a ‘vertical’ structure built around a series of discrete functions such as production, purchasing, marketing, logistics and sales, each with their own objectives and budgets. These functions are often represented as ‘silos’ or ‘stove-pipes’ (Figure 1). Senior managers are often guilty of putting the interests of their
functions before the profitability of the business as a whole. This presents particular difficulties for logistics as it interfaces with most other functions and is essentially a ‘boundary spanning’ activity.

Traditional, functional organisation

![Vertical Organisation Focus](image)

**Figure 1. Vertical Organisation Focus**

Business process re-engineering was advocated in the early 1990s as a means of overhauling internal management structures (Hammer and Champy, 1993). It identifies a series of core processes that cut across traditional functional areas and are customer-focused. Effective management of these processes requires the development of new working relationships between functions and the formation of more cross-functional teams. There are generally acknowledged to be a series of core processes that drive the typical business. ‘Order fulfilment’ is often considered the dominant process, with new product development in second position (Table 1).

<table>
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<tr>
<td>Order fulfilment</td>
<td>Order fulfilment</td>
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<td>New product development</td>
<td>New product development</td>
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<tr>
<td>Marketing planning</td>
<td>Sales acquisition</td>
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<td>Information management</td>
<td>Supplier integration</td>
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<td>Profitability analysis</td>
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**Table 1. Core Business Processes**

Little research appears to have been done to assess the effects of BPR on the management of the freight transport operation. As transport is a key element of order fulfilment, its profile should, in theory, have been raised. BPR should also have fostered closer co-ordination between transport and other activities, both inside and outside the traditional areas of logistics. As discussed below, the core process of ‘new product development’ also has an important logistical dimension.

### 2.4. Supply Chain Management

All the developments discussed so far have related to the management of an individual business. If all the businesses in a supply chain were to optimise their logistical activities in isolation it is unlikely that the flow of products across the supply chain would be optimised. To achieve wider, supply chain
optimisation it is necessary for companies at different levels in the chain to co-ordinate their operations. This is the essence of supply chain management (SCM). The main driver of supply chain management over the past twenty years has unquestionably been the desire to minimise inventory. Supply chain (or ‘pipeline’) mapping has shown that much of the inventory in a supply chain is concentrated at ‘organisational boundaries’ where products are transferred from one company to another. Uncertainty about the behaviour of the suppliers and customers causes firms to accumulate buffer stocks. This is clearly revealed by ‘pipeline mapping’, in which the ‘idle’ time products spend in storage is presented as vertical lines (Figure 2) (Scott and Westbrook, 1993). More open exchange of information and closer co-ordination of logistical activities enables companies to reduce stocks, to their mutual advantage and the benefit of the supply chain as a whole.

![Figure 2. Supply Chain Pipeline Map (Source: Scott and Westbrook, 1993)](image)

While there has been some acknowledgement of the role of freight transport in the development of successful supply chain links (Gentry, 1995), this subject has attracted very little research. It raises, nevertheless, several important issues:

- How should responsibility for transport be divided between members of the supply chain? This has traditionally been determined by the terms on which the goods are sold (ex works, FOB etc.), but does not necessarily allocate transport responsibility to the firms with the most efficient delivery system.
- How does the choice of handling equipment used at different levels in the supply chain affect vehicle utilisation and how is this choice made?
- To what extent do production and distribution cycles across the supply chain permit the rescheduling of deliveries?
- What opportunities exist for backloading and the shared use of vehicles?
- What role can logistics service providers play in improving transport efficiency across the supply chain?

These issues are explored in detail in Chapter 6.
3.  Freight Transport System

3.1.  Freight Transport Parameters

In examining the effects of management decisions on freight transport, it is important to specify which aspects of the transport operation are likely to be of greatest interest to public policy-makers. The following six transport parameters are likely to be of major interest:

1. *Volume of freight movement*, measured by tonne-kms or unit-load-kms: this is a function of the number of links in the supply chain (i.e. handling factor) and the average length of these links (i.e. average length of haul). All governments forecast trends in the volume of freight movement mainly to determine the future requirements for transport infrastructure. These forecasts can also be used to calculate future energy needs and emission levels.

2. *Mode choice*: trends in the relative use of particular transport modes are a key input into infrastructure planning. Many governments also have a policy objective of shifting freight from road to rail and water-based transport to reduce environmental costs per tonne-km and to relieve congested road infrastructure.

3. *Nature of the vehicle*: track costs and externalities correlate with the weight, size, age and axle configuration of a vehicle. Policy-makers therefore have an interest in the composition of the vehicle fleet and often try to alter it by a mix of fiscal and regulatory measures.

4. *Vehicle utilisation*: (by weight, volume and time) weight and volume-based utilisation measures determine how much traffic (measured in vehicle kms) is required to handle the volume of freight movement (measured in tonne-km). By promoting greater utilisation of the available vehicle capacity, policy-makers can improve the overall efficiency of the transport operation, reducing both economic and environmental costs and well as easing pressure on congested infrastructure. Time utilisation is primarily an economic variable indicating the productivity of the vehicle asset and efficiency of the transport operation. More intensive use of vehicles, particularly road vehicles, can also yield an indirect environmental benefit by accelerating the replacement rate and hence the uptake of new, greener technology.

5. *Routing of flows*: this defines the spatial pattern of freight flow. Policy-makers not only require information on the aggregate quantities of freight traffic and its modal split. For the purposes of infrastructure planning, environmental management and regional development, they also need to understand the geography of freight movement at different spatial scales.

6. *Scheduling*: this determines the flow of freight traffic through time. This too has a major bearing on infrastructure planning as traffic volumes can vary enormously on daily, weekly and monthly cycles. Externalities associated with freight movement are also time-sensitive, particularly in environmentally sensitive urban areas.

3.2.  Research on Transport Decision-Making Behaviour

A review was made of previous research on the decision-making processes affecting the parameters listed above. This revealed an extensive literature on the choice of transport mode and carrier, but relatively little work on decisions influencing the other transport variables.

3.2.1.  Volume of freight movement

Official forecasts of freight traffic growth have relied almost exclusively on econometric modelling. This has mainly involved the extrapolation of past freight traffic trends or modelling of the relationship between tonne-kms and output measures either at a national or sectoral level. Fowkes et al. (1993) and Black et al (1995) have attempted to model component elements of the tonne-km statistic (tonnes-lifted, average length of haul and handling factor) using macro-level data. Very little effort has been made to explore the underlying causes of the growth in demand for freight transport. Surveys by McKinnon and
Woodburn (1996) in the UK and Cooper et al. / NEA (1995) at a European level enquired about the factors affecting companies' demand for freight transport. These factors were ranked in order of importance. McKinnon and Woodburn (1996) classified these factors into four levels of logistical decision-making:

1. **Logistical structures**: numbers, locations and capacities of factors, warehouses, terminals, shops.
2. **Supply chain configuration**: patterns of trading links within these logistical structures.
3. **Scheduling of flows**: manifestation of these trading links as discrete freight movements.
4. **Management of transport resources**: relating to choice of vehicle, utilisation of vehicle capacity, routing of delivery etc.

The growth of freight traffic is the result of a complex interaction between decisions made at these different levels. Decisions at levels 1 and 2 determine the level of freight movement measured in tonne-kms while decisions at levels 3 and 4 translate this movement in vehicle traffic on the ground, measured in vehicle-kms. This decision-making framework was subsequently adopted by the EU REDEFINE and TRILOG Europe projects and has since been advocated by the UK government's Standing Advisory Committee on Trunk Road Assessment (SACTRA) (1999) as a basis for future road freight forecasting.

A subsequent interview survey of 90 companies revealed wide variations both within and between sectors in the relative importance of different factors in influencing freight traffic growth (McKinnon, 1998). This was confirmed by a series of in-depth case studies in seven sectors undertaken as part of the EU REDEFINE project. Closely competing companies with similar product ranges, serving similar markets and of similar size can produce widely varying amounts of freight traffic per tonne of sales. Research by the Wupperthal Institute, for example, has revealed enormous variations in the transport intensity of companies in the German mushroom industry (Holzapfel, 1996).

A major point to emerge from this earlier work is that a firm's demand for freight transport is the consequence of wide range of separate decisions made over different time-scales by managers in different functional areas and at different levels in the management hierarchy. No company deliberately plans to generate a certain amount of freight traffic. To understand the reasons for a particular company demanding a particular amount of traffic it would be necessary to gain an intimate knowledge of the production, marketing and sales strategies and the complicated inter-relationship between decisions in these functional areas. As outlined in the introduction, transport managers usually have little input into the development of these strategies and must take the resulting transport requirements as given.

### 3.2.2. Choice of Mode and Carrier

Some researchers have viewed the purchase of transport services from an outside carrier as simply another form of industrial buying and employed standard market research methods and concepts to analyse it (e.g Saleh and LaLonde 1992). The results of this research have been used by transport operators in the development of their service offerings and marketing strategies. Much of the modal choice research, however, has been strongly motivated by public policy considerations. As government transport policies have favoured a reallocation of freight between modes, studies have been commissioned to explain shippers' preferences for particular modes and establish what measures are required to alter modal choice behaviour.

There is a large literature on companies' choice of transport modes and carriers. General reviews of this literature can be found in Gray (1982), McKinnon (1989) and Hall and Wagner (1996). The research has examined many different aspects of the choice decision:

#### Factors influencing the mode / carrier choice decision

Numerous surveys have asked shippers to rank or score lists of selection criteria. Murphy and Hall (1995) have consolidated the results of surveys done over the past three decades to produce overall rankings of six criteria (Table 2). This confirms reliability as the dominant criterion. Ranking selection
criteria in this way, however, provides only a superficial insight in the decision-making process. For example, the fact that a particular attribute is considered important does not necessarily mean that it has a bearing on the final choice. If all modes perform equally well on a particular attribute it will have little influence on the decision.

<table>
<thead>
<tr>
<th>Factor</th>
<th>1970s</th>
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<th>1990s</th>
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<tr>
<td>Reliability</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Carrier considerations</td>
<td>6</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Freight rates</td>
<td>4.5</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>Shipper market considerations</td>
<td>4.5</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>Transit time</td>
<td>2</td>
<td>3</td>
<td>5.5</td>
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<tr>
<td>Over short or damaged product</td>
<td>3</td>
<td>5</td>
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Table 2. Ranking of Factors Affecting the Choice of Freight Mode or Carrier

Factor rankings also give no indication of the inter-relationships between them and extent to which companies are prepared to trade-off one factor against another. Some researchers have used factor analysis to combine groups of criteria into a smaller number of composite factors and related these to firms' actual choice of mode or carrier (e.g. McGinnis, 1980). The inventory-theoretic approach to modal choice analysis advanced by Baumol and Vinod (1970) provides a two-dimensional framework for differentiating 'abstract modes' with respect to pairs of criteria, such as transport cost and transit time and relating this to shipper's preferences. Other techniques, such as discriminant analysis, logit models (Spencer et al., 1992) and the analytical hierarchy process (Lehmusvaara et al., 1999), have been used to predict mode choice on the basis of shipper, carrier and shipment attributes, with varying degrees of success. Sophisticated 'stated preference' tools, such as the computerised 'adaptive' stated preference tool developed by Fowkes et al. (1996), have been used to forecast the demand for new freight services studies and the impact of new policy measures on the freight modal split.

A major shortcoming of all this econometric modelling is that it sheds little light on the actual decision-making process. As Pisharodi (1991) argues, there has been too much emphasis on listing and ranking choice criteria and too little attention paid to the way that firms actually collect and use relevant information.

Nature of the decision-making process

Relatively little empirical research has so far been done on this process as it relates to mode and carrier choice. Pisharodi is one of the few researchers to attempt to model this process, in his case using a 'script-theoretic' approach. D'Este (1992) reviewed various approaches that could be used to explore the modal selection process, though few appear to have been applied in practice. No examples have been found, for example, of 'cognitive mapping' being used to analyse the reasoning underlying managers choice of particular modes and carriers.

Although there has been limited modelling of the selection process, several studies have highlighted particular features of modal choice behaviour. Key observations have been that:

- Many firms do not rigorously compare the cost and service quality of different modes and carriers before making their choice.
- Where companies do compare modes, the comparison can be biased by managers' perceptions of particular modes, perceptions that often deviate from actual performance.
- Some companies exhibit a high degree of loyalty to particular modes or carriers and are reluctant to consider alternatives and to switch.
- The choice of transport mode is often regarded as a strategic, long-term decision made at the time when the company is replanning its production, marketing and distribution systems.
This final point is of particular relevance to the present study as it suggests that several management functions have an interest in the modal choice decision. The choice can constrained, for example, by decisions on plant location, distribution channel and packaging. On the basis of available data, it is very difficult to make a general assessment of the extent to which the implications for modal choice are considered in the strategic planning process.

3.2.3. Nature of the Vehicle

Vehicle acquisition, like modal split, presents managers with a discrete choice. It is received much less attention from researchers, however. Several market research studies have been undertaken, primarily for the benefit of commercial vehicle manufacturers and dealers, which enquire about companies’ policies on vehicle replacement and the factors influencing the choice of vehicle (e.g. Reed / NOP 1998). In the case of modal split studies, this ranking of selection criteria provides a very superficial view of the vehicle purchase decision. Anecdotal evidence suggests that the quality and rigour of vehicle purchase decisions have been improving as a result of several trends:

- Increase in the amount of comparative information on vehicle specification and performance
- Availability of fleet management software to assist the decision
- Adoption of whole-life costing as a basis for cost comparisons

There is, nevertheless, a need for more research on vehicle purchasing behaviour both to improve understanding of the decision-making process and to model the impact of policy changes. The UK government, for example, has recently commissioned research on the likely effects of changes in vehicle excise duty (VED) on the composition of the truck fleet. It is interested in using VED to promote the adoption of low emission technology and use of vehicles that are less damaging to the road surface. Attempts have also been made to forecast the impact of changes in vehicle weight limits on the allocation of freight traffic between truck weight classes and transport modes (Commission for Integrated Transport, 2000).

3.2.4. Vehicle Utilisation

There is very little published research on the nature of the trade-off decisions which affect vehicle loading. Much of the available literature relates to the effects of JIT on vehicle utilisation and presents either case study data (e.g. FTA, 1995) or the results of generalised modelling (Allen, 1993; Swanseth and Buffa, 1990).

3.2.5. Routing

The routing of freight flows can be analysed at three levels:

1. Macro-level: the international and inter-regional pattern of flow between points of production, storage and sale
2. Meso-level: the sequence in which orders are delivered within multiple-drop / collection round.
3. Micro-level: path the vehicle follows across the transport network.

The routing of flows at the macro-level is determined by decisions at levels 1 and 2 in the decision-making hierarchy outlined above. It is largely dictated by production, procurement and distribution strategies and outside the immediate control of transport managers. As the configuration of a route can be shaped by the location of intervening warehousing, break-bulk and intermodal exchange points, logistics management can have a major influence on the pattern of freight movement. Whitelegg (1994) cites examples of the circuitous routing of products via intervening intermediate production and warehousing locations which he regards as 'absurd'. Very little research has so far been done on the spatial structure of supply chains and even less on the multi-functional decision-making processes that produce it. Most of the modelling of freight flows has been based on trip-specific data, relating to
Effects on Transport of Trends in Logistics and Supply Chain Management

Work package 7 of the Sulogtra project will involve the mapping of cross-border supply chains.

The routing of vehicles at the 'meso-level' has generated an enormous literature in the field of operations research exploring methods of optimisation. Much of this optimisation research has found application in commercial vehicle routing software. Over the past 10-20 years many companies have upgraded their vehicle routing by the use of computerised vehicle routing (CVR) packages. Some research has been done on the factors influencing companies' adoption of this software and the resulting benefits (e.g. Eibl, 1998).

Micro-routing decisions relating to the choice of roads was traditionally left to the truck driver. Increasingly, however, drivers are being given routing instructions either as paper-based outputs from the CVR packages or in the form of real-time route guidance from telematic networks. The trade-press contains references to companies employing this technology, but little research has been done on the decisions underlying the purchase, implementation and operation of this technology (Anderson et al., 1996).

3.2.6. Scheduling

Like vehicle routing, the scheduling of freight flows and related activities has generated a huge operations research literature concerned almost entirely with optimisation methods. Relatively little research has been done on the actual procedures companies use to schedule their logistical operations and in particular transport. Several studies have examined the opportunities for rescheduling deliveries into the evening and night and the constraints likely to imposed by production and sales departments (Cooper and Tweddle, 1988; Freight Transport Association, 1989). As congestion on road networks worsens, companies are likely to respond by rescheduling deliveries to off-peak periods. This will involve trading-off transport costs against a range of operational and marketing costs. Little research has so far been done on the internal management mechanisms for articulating these trade-offs.

3.3. Impact of Management Decisions on the Freight Transport Parameters

For the purposes of this discussion, thirteen types of management decision likely to affect the transport operation have been identified and grouped with respect to the core business processes discussed earlier:

1. Product Development
   • Product design
   • Packaging
   • Product range

2. Marketing planning / Sales acquisition
   • Market area
   • Marketing channels
   • Sales strategy, promotional activity

3. Order Fulfilment
   • Location of production and distribution facilities
   • Sourcing of supplies
   • Production system
   • Inventory management
   • Materials handling
- After sales service
- Recycling / reverse logistics

Table 3 indicates which transport variables are significantly influenced by each of the thirteen types of management decision:

<table>
<thead>
<tr>
<th></th>
<th>Freight volume</th>
<th>Mode choice</th>
<th>Vehicle Type</th>
<th>Vehicle Utilisation</th>
<th>Routing</th>
<th>Scheduling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Development</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product design</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Packaging</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Product range</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td><strong>Marketing planning / Sales acquisition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market area</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Marketing channels</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Sales strategy / promotional activity</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td><strong>Order Fulfilment</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Location of production and distribution facilities</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Sourcing of supplies</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Production system</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Inventory management</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Materials handling</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>After sales service</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Recycling/reverse logistics</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

**Table 3. Inter-relationship between Key Business Decisions and Freight Transport Variables**

This figure shows the close inter-relationship between transport and most other core activities of a business and highlights the difficulty of trying to disentangle the web of decision-making that culminates in the movement of freight. Wandel (1994) has developed a similar matrix for examining the relationship between transport variables and range of corporate decisions.

The rest of this deliverable focuses attention on the top three rows in the matrix, those linking the key elements of product development (product design, product range and packaging) to the transport operation and, in particular, the amount of freight movement, measured in tonne-kms or unit volume-km, and vehicle utilisation. The interviews with manufacturers focused on the first two of these factors. Throughout the rest of the deliverable evidence and examples from the interviews and earlier survey are presented in boxes accompanying the text in the style shown below.
This table introduces the basic characteristics of each of the companies interviewed. It shows the name of the company, the broad industrial sector, the nature of the business (business-to-business or business-to-consumer) and the type of major client.
4. New Product Development

4.1. Marketing Perspective

In some sectors, a large proportion of total sales is generated by products that have been on the market for less than a year. It has been estimated that the most innovative companies generate around half their sales from products launched within the previous five years, while for other companies the average is around 22% of sales (Griffin, 1997). Furthermore, new products are accounting for an increasing proportion of total sales. Despite this, a large proportion of new products introduced to the market fail to meet their sales targets and are consequently withdrawn. Much of the research that has been conducted on new product development (NPD) has, therefore, focused on the reasons for product failure and the measures that companies can take to increase the chances of a product being successful.

Researchers have compared the development of successful and unsuccessful products and identified a range of factors influencing the outcome. None of the studies reviewed specifically mention transport. It is subsumed in a more general ‘distribution’ or ‘logistics’ factor. Benedetto (1990) highlights the importance of logistics as a ‘key success factor’ in the launch, as opposed to development, of a new product. He acknowledges that ‘logistics and inventory strategy has received relatively less attention in the product launch literature’ but argues that it is ‘of prime importance as it is intimately related to the material flow from manufacturer to end-user and back again, if necessary, as in the case of product recalls.’ The logistical attributes that Benedetto considers important are the ‘reduction in products, material suppliers, logistics service providers, marginal customers and stock-keeping units, quick response programs and flexible manufacturing techniques’. The efficiency of the transport operation and utilisation of transport capacity are not explicitly mentioned in his analysis. As product availability is a critical success factor in a product launch, it hardly surprising that delivery times and inventory levels are given priority over transport efficiency.

Several studies have highlighted the need for functional integration in the NPD process. The traditional approach to NPD was sequential, with different functions being involved at different stages in the process. For many companies this took the form of a ‘phase-review’ process (Figure 3) in which research and development (R&D) staff were primarily involved at the concept development stage, design engineers at the product design stage, production planners at the ‘process design’ stage, manufacturing and purchasing managers at the ‘commercial production’ stage and marketing and sales staff in the ‘harvesting’ of the new product. Where problems arose at later stage in the process, it was a formidable task to change product design and the associated production system. This sequential process ‘had no early warning system to indicate that planned features were not manufacturable’ and ‘commercialisation cycles’ often lengthened ‘as the project iterated back through design to correct the problem’ (Griffin, 1992).
Figure 3. Stages in the 'Phase-Review' Process

In many manufacturing sectors, particularly those experiencing a rapid rate of technical change, companies have come under increasing competitive pressure to ‘time-compress’ the NPD process (Stalk, 1988). New models of products that used to take several years to develop can now be designed and launched within a matter of months. To achieve this, companies have had to replace the traditional sequential approach with new procedures in which all the relevant functions are involved at an early stage and the process controlled by a multi-disciplinary team. Different aspects of product development are undertaken in parallel with close co-ordination between the relevant functions. This new approach has been shown to accelerate the NPD process, reduce its costs and improve the quality of the final product.

The integration of different functions in the NPD process can take various forms. The longest established method is known as ‘Quality Function Deployment’ (Zairi, 1993). Its first application is reckoned to have been in the Mitsubishi shipyard in Kobe in 1972. Toyota was also an early adopter of this technique. Like JIT, which was also developed and initially perfected in Japan, QFD has been widely publicised and implemented in North America and Europe. QFD provides a formal framework for co-ordinating the various functional inputs into the NPD process. It uses a series of ‘interaction matrices’ to help cross-functional teams to translate customer needs into physical products. Table 5 shows how QFD differs from the more conventional ‘process review’ process. Few of the papers on QFD explicitly mention logistics or transport as a function to be incorporated in the multi-functional teams. R&D, engineering, manufacturing and marketing interests dominate these teams.

<table>
<thead>
<tr>
<th>QFD approach</th>
<th>Phase-review approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous development across functions</td>
<td>Sequential interactive development</td>
</tr>
<tr>
<td>All functions participate from the start</td>
<td>Functional involvement by phase</td>
</tr>
<tr>
<td>Team empowered to make decisions</td>
<td>Management approval after each phase</td>
</tr>
<tr>
<td>Consensus decisions about trade-offs</td>
<td>Functionally led trade-off decisions</td>
</tr>
<tr>
<td>Working meetings to develop results jointly</td>
<td>Presentation meetings to report results</td>
</tr>
</tbody>
</table>

Table 5. Comparison of the Phase-Review and QFD Approaches
Hart and Baker (1994) proposed a ‘multiple convergent processing’ model to show how the inputs from the various business functions as well as external agencies can converge at different points in the NPD process (Figure 4). This network model helps to define the inter-relationship between the various contributors to NPD. Again their model does not make explicit reference to logistics.

New Product Strategy

<table>
<thead>
<tr>
<th>R &amp; D</th>
<th>Suppliers</th>
<th>Marketing</th>
<th>Customers</th>
<th>Engineering / Design</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>R &amp; D projects (ongoing)</td>
<td>Changes to product lines</td>
<td>Competitor analysis, market forecasts and trends</td>
<td>Specific designs and potential improvements</td>
<td>Engineering / Design projects (ongoing)</td>
<td>Process improvement projects (ongoing)</td>
</tr>
</tbody>
</table>

Convergent point: IDEA GENERATION

Feasibility studies, Time projection(s), Initial specifications
Specification of likely changes
Market potential, Competitive comparisons, Initial budgets
Modifications to ideas, Preference inputs
Engineering / Design feasibility studies, Time projections
Capital and plant implications

Convergent point: IDEA(S) EVALUATION

Concept developed technically
Development work on changes / new products required
Fuller market assessment, Concept testing / positioning, price implications
Collaboration on concepts may be both technical and commercial
Early design(s), Cost of concepts
Evaluation of the implications of alternative concepts in terms of resources and costs

Convergent point: CONCEPT EVALUATION & CHOICE

Physical product development
Development of required parts
Marketing and launch plan
In house & functional performance test
Physical product development
Modifications to production process in light of development

Figure 4. The early stages of the multiple convergent process (after Hart and Baker 1994)
4.2. Engineering Perspective

It is in the engineering and operations management literature on NPD that the contribution of logistics is now more formally recognised. ‘Concurrent engineering’ provides a framework within which ‘all activities related to the development of a product should be focused on in the early stages of product design so that the greatest benefits of such integration are achieved’. As decisions made early in the design process can have a major impact on the subsequent manufacturing and logistics operation, full account must be taken of these activities right from the start. The expression ‘design for logistics’ (DFL) has been used to describe full incorporation of logistical considerations into basic product design. This extends the earlier concepts of ‘design for manufacture’ (DFM) and ‘design for assembly’ (DFA) which encouraged engineers to take more account of methods of production when designing new products. DFL contrasts with the traditional situation in which the logistical consequences of NPD were only recognised at a late stage in the process once irrevocable decisions had been made on product design, procurement, marketing strategy and production system (Figure 5). Mather (1992) claimed that 'an analysis of almost any product on the market today will show serious flaws in its design concept as it relates to logistics'. He cites the example of a new range of stereo equipment produced by a European company that was very well received by consumers but so badly designed from a logistical standpoint that it was plagued by delivery problems. In advocating wider adoption of DFL, Mather's main concerns are with lead times, inventory levels and standards of customer service. He makes no reference to the effects of product design on the utilisation of logistical assets, such as vehicles and warehousing.

It is also important, however, that DFL takes account of asset utilisation. This has been promoted in recent years by the adoption of life-cycle costing for new products. This involves calculating at the outset not only the costs of manufacturing and distributing the new products but also of maintaining, repairing and, possibly, recycling or disposing them. Chapman et al. (1992) have estimated that decisions...
made at the initial decision stage can determine 80% of total life-cycle costs. As logistics can account for a significant proportion of these costs, it is important that logistics managers are closely involved in the NPD decision-making process. Figure 6 shows the main product design parameters and logistical considerations that must be reconciled within a broadly based DFL programme designed to minimise life-cycle costs.

![Diagram of Design for Logistics modules](image)

**Figure 6. Product and Logistical Design Parameters (Source: Dowlatshahi 1996)**

There are typically six modules in a DFL programme: logistics engineering, manufacturing logistics, design for packaging, design for transportability, design for materials handling and design for the environment. Dowlatshahi (1996) provides a detailed outline of the factors that should be considered within each of these modules.

### 4.3. Product re-design

The design of a product is determined primarily by its functionality and aesthetics. They in turn determine its value. For over fifty years companies have been encouraged to undertake value analysis and value engineering to ensure that the design of their products meets functionality and aesthetic requirements at minimum cost. Value analysis (VA), first developed by Miles (1989) in mid-1940s at the US General Electric company, ‘is the organised, systematic study of the function of a material part, component or system to identify areas of unnecessary cost’. It was originally undertaken mainly by purchasing managers to minimise the cost of bought-in parts and materials. As Zenz (1994) observes, however, ‘value analysis' scope now ranges far beyond the purchasing function.’ This analysis has typically been applied to existing products. Value engineering (VE), on the other hand, is undertaken as part of new product development and aims to minimise the cost of components in the manufacturing process. The aim of both VA and VE is to eliminate any feature of a product which adds costs but does not enhance value. This is done by analysing the function of components and finished products, examining different designs that might achieve this function and comparing the costs of the various alternatives. In analysing the cost and value contributions of individual components or products, the value analyst try to answer a series of standard questions listed in Table 6.
1. What is the precise function of a component / feature?
2. Can the component / feature be eliminated?
3. If the component is not standard, can a standard part be substituted?
4. Are there any similar parts used by the company that can be substituted?
5. Can the component be redesigned to allow greater tolerances?
6. Will a design change permit the component to be made from a lower cost material or by a lower cost process?
7. Could the component be produced within the firm at less cost?
8. Are the finishing requirements greater than necessary?
9. If different sizes of the component are stocked, can some of them be combined to reduce inventory and take advantage of quantity buying?
10. Is there difficulty in obtaining the part at present?
11. Are there ways of economising in packaging or shipping techniques?

### Table 6. Checklist of Value Analysis Questions

Emphasis is placed on the use of standard parts, the relaxation of tolerances and the redesign of products to reduce resource and manufacturing costs. One of the questions enquires about the 'ways of economizing on packing or shipping costs.' Where this question is elaborated in the literature, the discussion relates to the choice of transport mode and carrier rate structures. No specific reference has been found to the possible redesign of components or products to make better use of vehicle carrying capacity. This can be an indirect benefit of a range of measures often recommended by a VA exercise, such as:

- Reduction in size
- Substitution of lighter materials
- Standardisation of components
- Simplification of design and construction

If value analysts were to embrace the concept of 'design for logistics' (DFL), they would give greater consideration to the effects of component or product design on the use of transport capacity. This would entail consultation with transport managers as part of the VA / VE process. Design features might then be classified in terms of their transport implications. Features which inflated transport costs but make no contribution to product value, either functionally or aesthetically, would be eliminated. Where there was a value contribution, the trade-off between the amount of value added and transport cost incurred would have to be analysed. This analysis would be complicated by inclusion of other non-transport cost factors in the calculation.

There is a two-way relationship between product design and logistics. In some instances, logistical systems need to be adapted to the requirements of new products. In other cases, logistical factors impose constraints on the design of a product or suggest design modifications that can permit more efficient use of logistical assets.
5. Product and Packaging Attributes

5.1. Product Attributes

Dowlatshahi (1996) identifies four categories of product characteristics that influence ‘transportability’, shown in column 1 of Table 7. For the purposes of the present work package, this list has been reconstituted into seven physical attributes shown in column 2 of Table 7.

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical properties: width, height, length, centre of gravity, etc.</td>
<td>Weight</td>
</tr>
<tr>
<td></td>
<td>Size</td>
</tr>
<tr>
<td></td>
<td>Shape</td>
</tr>
<tr>
<td></td>
<td>State (solid, liquid, gas)</td>
</tr>
<tr>
<td>Dynamic limitations: acceleration, vibration, deflection, leaking, etc.</td>
<td>Fragility / Stackability</td>
</tr>
<tr>
<td>Environmental limitations: temperature, pressure, humidity, etc.</td>
<td>Perishability / Temperature</td>
</tr>
<tr>
<td>Hazardous effects: radiation, explosives, electrostatics, personnel safety, etc.</td>
<td>Hazard</td>
</tr>
</tbody>
</table>

Table 7. Product Attributes

Attributes 1-4 are 'physical properties', the 'dynamic properties' are subsumed under the 'fragility' heading, the 'environmental' properties are represented by 'perishability' and need for temperature control', while 'hazard' remains as a separate property. Each of the seven factors influence vehicle loading with respect to the maximum weight and volume of goods that can be carried.

The influence of the first four factors is fairly obvious. The utilisation of vehicle carrying capacity can be defined with respect to weight, deck-area (2 dimensional view) or cubic capacity (3 dimensional view). In terms of cube utilisation, the ideal product would either be a liquid or a rectangular block whose dimensions were in proportion to those of the vehicle. The density of this ideal product would ensure that at the maximum vehicle weight limit all the available space was filled. In practice, few products conform to this ideal. Most either reach the vehicle weight limit before they ‘cube out’ or exhaust the vehicle space before attaining the maximum payload weight.

The remaining three factors also have important impacts on vehicle loading. Fragility affects the amount of packaging required and the height to which the products can be stacked within the vehicle. The need for temperature-control adds the weight of refrigeration equipment to the vehicle tare weight and also necessitates at least 30 centimetres of clear space around the load for air circulation. Rules governing the movement of hazardous product can restrict the quantity carried in a vehicle and often require the use of special equipment which adds weight and reduces cubic carrying capacity.

Table 8 illustrates key ‘transportability’ product attributes for the thirteen manufacturers. Density gives an indication of the weight and volume of products. Value density indicates the value of product for a given volume. State is self-explanatory. A Yes or No in the three columns on the right indicates if these attributes play a major role in transport decisions. Obviously, these attributes are generalised and approximate. In practice they will vary across product ranges.
Company | Density | Value Density | State | Fragility / Stackability | Perishability / Temperature | Hazard
---|---|---|---|---|---|---
BP Chemicals | Medium | Low | Liquid, Solid | No | Yes | Yes
Elida-Faberge | Low | Medium | Liquid | Yes | No | No*
Eternit | High | Very Low | Solid | No | No | No
Ferrari | High | High | Solid | Yes | No | No
IBM | Low | Medium | Solid | No | No | No
Intel | Low | Very High | Solid | No | No | No
Inveresk | High | Low | Solid | No | No | No
Norfrost | Low | Low | Solid | No | No | No
Pago | Medium | Low | Liquid | Yes | No | No
Scottish Courage | Medium | Low | Liquid | Yes | No | No
Siemens ICN | Low | High | Solid | No | No | No
Spring Industries | High | Low | Solid | No | No | No
Tasty Foods | Low | Low | Solid | No | Yes | No
*Although Elida-Faberge transports aerosols they are currently exempt from EU regulations.

Table 8. Key ‘transportability’ attributes of interview companies

High value products can have an additional attribute: the need for security. Intel explicitly trade-off the cost of transportation against the cost of ensuring a shipment arrives intact at its intended destination.

A fundamental distinction can be made between products that are transported ‘bare’, and those that require packaging, or use of modularised handling equipment or both. Into the former category fall a range of primary products transported in bulk loads in fluid, granular or solid state which are typically carried in tanker, tipper and hopper vehicles or wagons. Large pieces of machinery can also be transported without packaging. Most manufactured products, however, are packaged and moved in unitised loads. This packaging or unitisation occurs at three levels:

**Primary:** packaging of individual products

**Secondary:** box, case or tray carrying a group of products

**Tertiary:** handling unit into which secondary units are grouped for transportation and storage, comprising mainly pallets, roll cages, stillages or dollies.

Finished products destined for consumer markets are usually packaged or unitised at all three levels, while manufactured products supplied to industrial markets often only have secondary or tertiary packaging. The addition of packaging material or handling equipment at each of the three levels increases volume and weight.

The net weight of Lever Brothers product (in the early 1990s) on a full vehicle was 18.5-19 tonnes. The gross weight, including packaging and pallets, was between 22.5-23 tonnes. All three levels of packaging therefore accounted for about 4 tonnes per vehicle (approximately 18% of the total load).

The increase in volume is determined by the degree of fit between product, packaging and handling unit at each level. Samuelson and Tilanus (1997) have expressed this degree of fit as a ‘partial efficiency’ value. In an effort to assess the utilisation of transport capacity they invited an expert panel (composed mainly of operators) in the Netherlands and Sweden to estimate average partial efficiency values for the conversion of basic products into vehicle loads in the less-than-truckload (LTL) sector. Table 9 shows their estimates of the space-efficiency at each level of packaging / unitisation. The following three sections consider the factors influencing the degree of fit and hence space-efficiency loss for each of the packaging or unitisation levels.
### Table 9. Partial Efficiencies of Unitised Loading (LTL Traffic in the Netherlands and Sweden)

<table>
<thead>
<tr>
<th>Packaging Level</th>
<th>Index</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>net product factor</td>
<td>39</td>
</tr>
<tr>
<td>Secondary</td>
<td>box load factor</td>
<td>88</td>
</tr>
<tr>
<td>Tertiary</td>
<td>pallet-load factor</td>
<td>69</td>
</tr>
</tbody>
</table>

#### 5.1.1. Primary level

The shape of the product and of the module affects the degree of fit at this level. Many products have an irregular shape that inevitably results in empty space within a regularly shaped module. The shape of the module is often dictated by factors other than the dimensions of the product, particularly marketing considerations. Enlarging the packaging unit increases the surface area for advertisements. Elaborate packaging designs are more likely to attract consumers' attention. Improving the handling characteristics of products can also increase their customer appeal. These packaging design features are usually justified on the grounds that the resulting increase in sales more than offsets any loss of efficiency in transport and storage. Procurement decisions can also affect module shape particularly a desire to use standardised units to reduce packaging costs.

Table 10 indicates the partial space-efficiency of primary packaging for a range of consumer products. In many cases, the excess space is occupied by air either because the product is not damaged by movement within the packaging (e.g. breakfast cereal within a carton) or because it can be physically restrained within the packaging (e.g. CD within a software box). To minimise the risk of damage, however, it is often necessary to insert 'void fill' within the box. This cushioning can take the form of 'loose-fill', air bags, crushed paper, shredded paper or bubble-wrap. It has been estimated that in the UK around 550,000 cubic metres of loose-fill alone are used annually, equivalent to 6500 13.6 metre trailer loads (Freegard, 2000). This is a measure of the effects of poor product-packaging fit on the transport operation.

Table 10. Average Space-efficiency* of Primary Packaging for a Range of Consumer Products

<table>
<thead>
<tr>
<th>Product Description</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer game (boxed)</td>
<td>12%</td>
</tr>
<tr>
<td>Breakfast cereal</td>
<td>70%</td>
</tr>
<tr>
<td>Pack of A4 paper</td>
<td>98%</td>
</tr>
</tbody>
</table>

* product volume as % of primary packaging volume

Amongst the companies interviewed there is a wide variety of primary packaging. It is possible to suggest differences along two broad axes: consumer versus business end-users; assembled versus unassembled products. Partial efficiencies appear better for unassembled products destined for business or industrial markets. In some cases product is effectively transported bare but in unit loads e.g. roof tiles by Eternit, paper rolls from Inveresk, and textiles from Springs Industries. BP distributes a small amount of liquid product in drums that can be almost completely filled; plastic sacks can be completely filled with granular chemical solids. Marketing considerations may affect the packaging of assembled product for business or industrial markets but the main focus is on protecting the products in transit and minimising packaging costs. For example, IBM (manufacturing servers, desktop and laptop computers) and Siemens ICN (manufacturing telecommunications equipment) make use of standard box sizes for different product ranges. This helps to reduce packaging cost through reduced packaging inventory. However, the majority of Siemens ICN products are packed with styrofoam for protection in transit. IBM’s standard packages, particularly for desktops, need to be able to hold several additional products, such as a keyboard, a mouse and a user guide. These requirements reduce the partial efficiency of packaging at this level. Norfrost is an exception: they only use cardboard sleeves or shrink-wrapping to cover their freezers. Liquid products for consumer markets achieve good partial efficiency within bottles or cartons. Pago use a range of standard carton and bottle sizes. Scottish Courage similarly uses standard bottle, can and keg sizes. Tasty Foods produce potato snacks, extruded snack products and corn flakes for the
consumer market. Primary packaging is in film or plastic bag. The nature of the products means that there is a considerable amount of air within the primary packaging.

5.1.2. Secondary packaging

An important distinction can be made between those forms of secondary packaging which become merchandisable units at point of sale and those that are removed prior to final display to customers. The former, such as multi-packs of beer, have an important promotional function and are therefore affected by similar marketing considerations as primary packaging. The partial efficiencies of a 4 pack of tins of baked beans and a 12 pack of cans of beer have been calculated at 61% and 65% respectively. This reduces the benefit of being able to fill the tin or can with liquid. The latter should in theory be designed solely to meet logistical requirements at minimum cost, with an emphasis on efficient cube utilisation and the use of lightweight materials. A.T. Kearney (1997) has concluded, however, that in the European grocery sector 'average utilisation of spaces by secondary loads is poor'.

Promotional activity can have a severe effect on vehicle utilisation particularly at the secondary level. Scottish Courage provided an example of special multi-packs prepared for the football World Cup. The packs were shaped like a football stadium. They occupied the space normally used for 24 cans of beer but only contained 10. They also required manual re-packing.

Increasing use is being made at the secondary level of returnable trays, crates and tote-boxes, largely in response to official pressures to reduce packaging waste. This can often have the effect of reducing the partial efficiency of packaging at this level. The standardisation of the modules, the process of loose-filling and the mixing of different products all increase the ratio of module volume to product volume. These modules must also be sturdier and, as a consequence, heavier than the 'one-trip' packaging they replace in order to withstand multiple re-handling. None of the manufacturers interviewed appeared to be using this type of secondary packaging suggesting that it is more common at the wholesale or retail end of supply chains, or in manufacturing assembly operations, where mixed product shipments are being put together.

5.1.3. Tertiary level

Six major types of handling equipment are used at the tertiary level: wooden pallets, roll cages, dollies (wheeled platforms), stillages (metal cages), wooden crates and slip-sheets. In deciding upon the optimum type of handling equipment for their particular operations companies trade-off handling efficiency against space utilisation. Roll cages, for example, facilitate loading and unloading and the movement of products within warehouses and shops, but require roughly 40% more vehicle deck-area than wooden pallets to accommodate the same volume of product.

Figure 7 shows the relative proportions of road freight moved in the UK in 1998 using different types of tertiary handling equipment. For roughly a third of the tonnage carried, no details were given on the nature of the handling equipment, in some cases because the carrier was moving a sealed unit (such as an ISO container or swap body) whose contents could not be inspected. While it is likely that most of this tonnage will be packaged and unitised, this still leaves bulk products as the dominant flow, in tonnage terms, on the road network.
More detailed statistics on the nature of handling units were compiled by A.T. Kearney (1997) for the European grocery sector. These were based on a survey of 14 manufacturers, with combined sales of 39 billion Euro, and 11 retailers with a total annual turnover of 46 billion Euro. Approximately 98% of the manufacturer's loads were palletised, split roughly 2:1 between Euro and industry pallets. Almost two thirds of retailers' loads were of roll cages, with all but 2% of the remainder palletised, mainly on Euro pallets. At the secondary level, just over three-quarters of the manufacturers' loads were 'one-way non-modular', with modularised one-way unit accounting for 17%. In contrast, 53% of retailers loads were modularised (40% of them returnable), with the remainder one-way non-modular.

There has been much debate about which is the most efficient size of tertiary unit for the movement of grocery and other fast moving consumer goods. The ideal tertiary unit is compatible both with the internal dimensions of the vehicle and dimensions of the secondary units that it contains. As explained earlier, roughly two thirds of grocery loads despatched by food manufacturers are carried on Euro pallets (1200mm x 800 mm) and almost all the remainder on industry pallets (1200 mm x 1000mm). Table 11 shows the average vehicle deck area utilisation of different dimensions of pallet. The average utilisation is only around 64%.

<table>
<thead>
<tr>
<th>Pallet Dimension (mm)</th>
<th>% space utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200x1000</td>
<td>77.9</td>
</tr>
<tr>
<td>400x300</td>
<td>68.0</td>
</tr>
<tr>
<td>600x400</td>
<td>63.5</td>
</tr>
<tr>
<td>800x600</td>
<td>58.0</td>
</tr>
<tr>
<td>1200x800</td>
<td>52.4</td>
</tr>
</tbody>
</table>

Table 11. Average Vehicle Deck-area Utilisation for Different Dimensions of Pallet

A.T. Kearney have advocated the adoption of a standard pallet footprint of 600mm x 800mm which would be compatible with the ‘Euro-family of unit loads’. They claimed in 1997 that the resulting improvement in vehicle cube utilisation (also assuming an increase in average load height) would cut European grocery supply chain costs by 1.7 billion Euro. Standardisation on this ‘efficient unit load’ would be difficult, however, given wide international and inter-sectoral differences in pallet preferences and given their own estimate of 280 million pallets in circulation across Europe in 1993, in more than thirty difference sizes (A.T. Kearney, 1997).
Table 12 shows the type of tertiary packaging used by the companies interviewed.

<table>
<thead>
<tr>
<th>Company</th>
<th>Tertiary packaging type</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP Chemicals</td>
<td>Most of the liquid product is moved as bulk in road tankers or inter-modal tank vehicles. Approximately 40% of solids from Grangemouth plant are moved as packages on pallets</td>
</tr>
<tr>
<td>Elida-Faberge</td>
<td>Approximately 56% of products are moved on full, single product pallets. 40% are moved on mixed layer pallets. Remainder is not palletised.</td>
</tr>
<tr>
<td>Eternit</td>
<td>Pallets, full and mixed load</td>
</tr>
<tr>
<td>Ferrari</td>
<td>None</td>
</tr>
<tr>
<td>IBM</td>
<td>1200 x 1200 and 1200 x 800 pallets. Some pallets tailor-made for servers and for automated distribution centres of major retail clients</td>
</tr>
<tr>
<td>Intel</td>
<td>Information not available</td>
</tr>
<tr>
<td>Inveresk</td>
<td>Majority palletised, some large rolls of paper for large print companies</td>
</tr>
<tr>
<td>Norfrost</td>
<td>None. Product is loaded by hand into 40 foot containers for sea or 45 foot trailers for road</td>
</tr>
<tr>
<td>Pago</td>
<td>Pallets, majority full load.</td>
</tr>
<tr>
<td>Scottish Courage</td>
<td>Pallets for small pack product, moving to pallets for keg product</td>
</tr>
<tr>
<td>Siemens ICN</td>
<td>Pallets</td>
</tr>
<tr>
<td>Spring Industries</td>
<td>Information not available</td>
</tr>
<tr>
<td>Tasty Foods</td>
<td>1200 x 800 Europallets. Boxes used for secondary packaging have dimensions which are exact sub-divisions of Europallet dimensions</td>
</tr>
</tbody>
</table>

Table 12. Tertiary packaging

Almost all of the companies use one or more types of pallet. The obvious exceptions are either bulk products or cars. Norfrost do not use pallets improving vehicle utilisation.

5.2. Effect of Product Design and Packaging on the Freight Transport System

5.2.1. Volume of Freight Movement

Changes in product and packaging design can influence the amount of freight movement, measured in tonne-kms or unit volume-kms, in several ways:

- The weight of the load;
- The volume of the load;
- The type of handling equipment required for example, a switch from bags to pallet loads
- The nature of the production or supply system: new components may be required from more distant suppliers or new stages of processing may have to be undertaken at different locations.

In a postal questionnaire survey of 76 UK-based manufactures in eight sectors exhibiting a high rate of road freight traffic growth, managers were asked to what extent changes in the nature of the product had affected their company's demand for road transport over the previous five years. 24% of the companies indicated that it had increased their road freight demand, while 5% suggested it had had the opposite effect. The vast majority of companies (71%) claimed that changes in the nature of their products had not affected their level of road freight movement. There were, nevertheless, significant inter-sectoral
variations in the impact of product changes, with product changes having a more pronounced effect in the paper / publishing and electrical / electronics sectors (Figure 8).

![Figure 8. Effects of Changes in the Nature of the Product on Road Freight Requirements 1990-1993 (Sample of 78 manufacturers)](image)

Table 13, based on the same survey, puts these responses into perspective by showing the relative weightings of fourteen factors possibly affecting road freight demand. Column 1 indicates the proportion of firms experiencing a change in each of the factors over the previous five years. Column 2 shows the net proportion of firms claiming that they had either increased (+value) or decreased (-value) their road freight demand. The figures in the second column were calculated by subtracting the proportion of firms claiming that a factor had reduced their freight demand from the proportion indicating that it had resulted in more freight movement.

<table>
<thead>
<tr>
<th>Factor</th>
<th>% of firms experiencing change</th>
<th>net % of firms changing transport demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in customer requirements</td>
<td>91</td>
<td>+55</td>
</tr>
<tr>
<td>Adoption of low inventory strategies</td>
<td>62</td>
<td>+44</td>
</tr>
<tr>
<td>Change in market area</td>
<td>47</td>
<td>+36</td>
</tr>
<tr>
<td>Change in the level of sales</td>
<td>94</td>
<td>+32</td>
</tr>
<tr>
<td>Relocation of warehouses</td>
<td>59</td>
<td>+20</td>
</tr>
<tr>
<td>Change in the nature of the product</td>
<td>22</td>
<td>+19</td>
</tr>
<tr>
<td>Relocation of production</td>
<td>31</td>
<td>+16</td>
</tr>
<tr>
<td>Production/stockholding centralisation</td>
<td>69</td>
<td>+15</td>
</tr>
<tr>
<td>Change in the use of alternative modes</td>
<td>16</td>
<td>+9</td>
</tr>
<tr>
<td>Change in own account / 3rd party split</td>
<td>37</td>
<td>+9</td>
</tr>
<tr>
<td>Change in responsibility for transport</td>
<td>59</td>
<td>+8</td>
</tr>
<tr>
<td>Production/stockholding decentralisation</td>
<td>25</td>
<td>-9</td>
</tr>
<tr>
<td>Consolidation of loads</td>
<td>66</td>
<td>-53</td>
</tr>
<tr>
<td>Change in method of vehicle routing</td>
<td>59</td>
<td>-59</td>
</tr>
</tbody>
</table>

Table 13. Factors Causing Changes in Manufacturers' Demand for Road Freight Transport, 1988-1993
Those experiencing the change, but claiming that it had not impacted on freight traffic levels, were excluded from this calculation. It can be seen that 'changes in the nature of the product' was only one of a range of factors deemed to be responsible for the growth in road freight movement and made a relatively modest contribution to this trend. The main factors driving freight traffic growth were shown to be related to the downward pressure on inventory levels (the tightening of customer service requirements was likely to motivated primarily by a desire to cut inventory levels), the expansion of market areas and the underlying growth in sales volumes.

5.2.2. Vehicle Utilisation

Care must be taken in assessing the utilisation of vehicle capacity. Official statistics on road vehicle loading have traditionally been weight-based and failed to allow for the large proportion of low-density loads which 'cube-out' before they 'weigh-out'. Since 1998 Eurostat has required EU member states to collect statistics on the proportion of truckloads constrained by weight and by volume. Figure 9 shows the results of an analysis of the UK data for 1998 disaggregated to commodity level.

![Figure 9. Proportion of Laden Trips Carrying Loads Constrained Solely by Volume: UK 1998 (Source: DETR ‘Transport of Goods by Road in Great Britain 1998’)](image-url)
Effects on Transport of Trends in Logistics and Supply Chain Management

<table>
<thead>
<tr>
<th>Value Density</th>
<th>'Volume' constrained</th>
<th>'Weight' constrained</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Semiconductors</td>
<td>Luxury cars</td>
</tr>
<tr>
<td></td>
<td>Telecommunication equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personal computers</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Personal hygiene products</td>
<td>Chemicals</td>
</tr>
<tr>
<td></td>
<td>Refrigeration products</td>
<td>Textiles</td>
</tr>
<tr>
<td></td>
<td>Snack foods</td>
<td>Brewing products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit juices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paper products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roofing materials</td>
</tr>
</tbody>
</table>

Product Density

**Figure 10. Value Density versus Product Density**

Figure 10 compares the value density with the actual density of products. There is a simple split between complex, assembled products all of which, with the exception of refrigeration products, have high value density and simple products all of which have low value density. The split between high and low product density indicates whether the majority of vehicle or container loads are constrained by volume or by weight. Vehicle loads may be constrained by floor space in either case, particularly if, for some reason, product or unit loads cannot be stacked.

There is general acknowledgement that the average density of freight is declining. This is occurring as a result of several trends. It is important to understand that the decline in density is a ‘net’ result: some companies may improve vehicle utilisation as a result of these trends while others lose out.

**Changes in the nature of products**

Many consumer products have become lighter through time, as plastic and other synthetic materials have increasingly replaced metal, wood and leather. At the same time there are examples of products becoming denser as a result of technical developments.

SCA Packaging were able to trade-off handling costs and transport costs. They found that compressing waste cardboard was cheaper than making it into bales but produced a higher volume of waste to be transported. They responded by using larger vehicles with 90 cubic metre capacity rather than 55 cubic metre. Bridgewater Newsprint found that improvements in the quality of newsprint increased its density and hence increased the proportion of vehicle loads that are weight constrained. In the case of detergent products, the pressure to increase profit per square metre to both retailer and manufacturer has led Lever Brothers to develop more concentrated products and replace of boxes with bags. This has indirectly benefited the transport operation by reducing the vehicle space requirement.

The miniaturisation of components has also reduced the weight of many appliances. This is particularly true in electrical and electronics products (see box).

Until recently the latest generations of personal computers produced by IBM had dimensions similar to those of the first personal computers (excepting the emergence of laptop computers). Although internal components were miniaturised engineers left space inside the computer box for installation of accessories such as network cards or modems. The trend is now to do away with this space and create standalone components that can be linked together, increasingly by wireless technologies such as
Effects on Transport of Trends in Logistics and Supply Chain Management

**Infrared communication.** This is a customer and technology driven trend. If the number of units transported remains the same it will result in a decrease in the total volume of freight. However, other factors may stimulate an increase in the number of units sold.

### Increase in packaging

The move to self-service retailing, the growth of processed food and the more intensive use of packaging as an advertising medium have greatly increased the amount of packaging. Once again, however, there are examples of companies affected by these pressures but reducing, rather than increasing, packaging.

**Cerestar** is a food processor supplying mainly cereal-based inputs to the food-manufacturing sector. As a result of customer pressure they reduced the proportion of output distributed in packaged form and increased the amount distributed in bulk deliveries. This has improved vehicle utilisation.

Many of the new electrical and electronic products are also very fragile and require thicker layers of protective packaging.

**Unisys,** for example, strengthened packaging to reduce risk of damage in transit. This resulted in an increase in packaging volume that partly offset the reduction in product size. However, Polaroid were able to cut down on the amount of blister packaging used to protect their products and also to replace thick multi-lingual instruction manuals with thinner, lighter manuals customised for fewer countries.

### Greater use of unitised handling equipment

As outlined earlier, the growth of ‘palletisation’ and increased use of roll cages and pallets has enabled firms to improve the efficiency of handling operations at the expense of vehicle utilisation. However, in some cases vehicle utilisation may improve as a result of re-design of packaging to fit pallets in conjunction with changes in the nature of the product.

**OKI Europe** manufactures computer printers for the European market. When they switched to Euro-pallets, they redesigned the secondary packaging to fit the base dimensions of the Euro pallet. This coupled with a reduction in product size and reduction in packaging volume enabled them to increase the number of printers per pallet from 12 to 20. At the same time they were able to increase the number of pallets on a 40 foot vehicle from 52 to 60 (double-stacked). Similarly, Tasty Foods use secondary packaging with dimensions that are exact subdivisions of the dimensions of Euro-pallets. This helps to improve vehicle utilisation and handling.

Declining density is increasing vehicle space requirements per tonne of freight carried and increasing the proportion of loads ‘cubing out’ rather than ‘weighing out’. This trend is being reinforced by other developments described below.

### Reduction in the stackability of products and packaging

In some sectors, the increasing fragility of the product and weakening of packaging material is limiting the height to which loads can be stacked.

**Both Scottish Courage and Pago** use long-necked bottles because they are popular with consumers. However, they create problems for stackability. When they are shrink-wrapped the necks are pulled together at the top causing a pack of bottles to ‘nest’. This makes a pallet load unstable with a tendency to lean. When loaded onto a vehicle, this can result in gaps between pallets. This increases the risk of damage due to movement in transit. In addition Pago estimate that, on average, it takes ten minutes to load a pallet of this product compared with seven minutes for a pallet of short-necked bottles. With 32 or 35 pallets in a vehicle this can also cause a considerable increase in loading time. There is also a general trend in the Drinks sector to reduce costs by ‘lightweighting’ i.e. reducing the weight of materials used in cans and bottles. Although the dimensions of a can or bottle may not change, enabling use of existing pallet layouts, the individual packs may be less robust, and hence not support the same number
of packs or pallets as before. The earlier survey revealed similar experiences for Rockware Glass and PL Redfern. Reducing the amount of glass in bottles reduced the stackability of the product. However, since the load also gets lighter it may be possible to load more product. Barrs were able to increase the amount of product per load after lightweighting and changing the shape of the bottles.

Specific customer requirements for pallets of a certain type or height can reduce vehicle utilisation and increase handling costs.

Elida-Faberge are obliged to breakdown pallets from 1.6 or 1.7 metres to 1.2 metres for one major grocery retailer. This is to enable the pallets to be stored in an automated warehouse. Lever Brothers (now part of the same company as Elida-Faberge) experienced similar problems. Up to early 1990s they could stack pallets to 2.1 metres. At 2.1 metres, Lever Brothers achieved a high vehicle utilisation by both weight and volume. Although 2.1 metres was higher than standard RDC slot heights of 1.7 metres, many retailers were prepared to put these products on the top of the racking where there was greater clearance. To increase the flexibility of warehouse management, the retailers wanted to be able to locate any product in any warehouse slot. Lever Brothers were then required to reduce pallet height to the standard 1.7 metres. More recently quick response pressures have reduced average pallet height further. IBM are also obliged to change the type of pallet they use to suit the rack sizes of certain large retail customers.

The assembly of mixed pallet loads at an earlier stage in the supply chain (which is discussed more fully in Chapter 6) is having a similar effect. Pallets with an assortment of goods, rather than block-stacked with a single product, tend to be lower, have an irregular profile and offer less opportunity for stacking.

Eternit have traditionally delivered fixed quantities of building products on pallets. They are facing increasing customer pressure to be more flexible in the order quantities leading to lower vehicle utilisation.

Tightening health and safety regulations
These regulations have restricted the height to which pallets can be stacked to minimise the risk of injury to operatives during loading and unloading. This also reduces the amount of freight that can be carried on each square metre of deck area.

Health and safety regulations can also have indirect benefits for companies. Scottish Courage are being driven to introduce ‘locator boards’ and new plastic pallets weighing only 5½ kilos for their keg products. Previously they used saddle pallets of which, each year, they replaced approximately one third and repaired approximately one third. With the new pallets and locator boards they are able to get 432 kegs on one vehicle as opposed to 396 kegs using saddle pallets.

Increasing vehicle weight limit
Increases in the maximum legal weight of trucks over the past 20 years have relaxed weight restrictions. This can potentially help companies with loads that are weight constrained by allowing them to fit more product in one vehicle. There are also suggestions that this can affect the modal split of traffic by encouraging companies to use road freight instead of rail freight.

5.3. Holistic view of Product and Packaging Design
There is a clear interdependence between the design and dimensions of products and the different levels of packaging or unitisation in the unit load hierarchy. It is necessary, therefore, to adopt an holistic view of product and packaging design as it relates to transport. After all, changes in the size and shape of the product or packaging at one level may have no impact on space efficiency at higher levels. There are critical dimensional thresholds at each level. Where product or packaging dimensions are near a
threshold, a slight modification may be enough to trigger a step change in utilisation at the next level. As improvements in space utilisation conform to a step function, the effect of small changes at product level can be amplified. Conversely, design changes, probably motivated by marketing and sales ambitions, can also have the opposite effect. Although they may seem minor, they can cascade into a substantial loss of transport efficiency. In many companies, however, the development of more transport-efficient product and packaging design may be constrained more by organisational than technical factors. Transportation decision-makers may not be involved in product design or re-design decisions.

The extent to which companies are able to develop more transport efficient products or packaging depends on their ability to calculate the trade-offs between the different costs involved. Some of these trade-offs have already been illustrated above. In some cases they may fall wholly within the remit of the logistics department, such as a trade-off between transport costs and handling costs. In many cases, however, the trade-offs will involve other functional areas within the company. The nature of the relationships between different departments varies widely between companies.

Manufacturers were asked about the nature of inter-departmental relationships in the course of the interviews. Table 14 was put together from their responses either directly through their choice of rating or afterwards on the basis of notes taken during the interview. The table is therefore only intended to illustrate different levels of co-operation in different companies. The first figure indicates, on a scale of 0 –5 (5 = high) the extent to which transport managers are consulted on decisions in the areas in each column. The second figure, in brackets, indicates the extent to which transport managers are allowed to influence decision in these areas. There are some clear trends evident from the table. First, with the exception of Norfrost, transport managers are generally not consulted on decisions to do with product development. Where they are consulted they have little or no influence on the decisions. The same is true of decisions in the area of Marketing and Sales. Transport managers appear to have the greatest influence on decisions related to packaging and the choice of handling system. This is, perhaps, not surprising since these are core areas of logistics responsibility. Involvement in decisions regarding production scheduling fall somewhere between these two extremes.

<table>
<thead>
<tr>
<th>Company</th>
<th>Product Development</th>
<th>Packaging</th>
<th>Production scheduling</th>
<th>Choice of handling system</th>
<th>Marketing</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Elida-Faberge</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Eternit</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Ferrari NA</td>
<td>0 (0)</td>
<td>4 (2)</td>
<td>2 (0)</td>
<td>2 (0)</td>
<td>4 (2)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>IBM</td>
<td>0 (0)</td>
<td>3 (2)</td>
<td>2 (1)</td>
<td>5 (5)</td>
<td>1 (0)</td>
<td>3 (1)</td>
</tr>
<tr>
<td>Intel</td>
<td>2 (1)</td>
<td>5 (3)</td>
<td>4 (2)</td>
<td>5 (5)</td>
<td>4 (4)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Inveresk</td>
<td>0 (0)</td>
<td>5 (5)</td>
<td>5 (1)</td>
<td>5 (5)</td>
<td>3 (1)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Norfrost</td>
<td>5 (4)</td>
<td>5 (5)</td>
<td>5 (3)</td>
<td>5 (5)</td>
<td>3 (1)</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Pago</td>
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<td>0</td>
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<td>Siemens</td>
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<td>Tasty Food</td>
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<td>5 (4)</td>
<td>5 (5)</td>
<td>0 (0)</td>
<td>5 (2)</td>
</tr>
</tbody>
</table>

Table 14. Extent to which Transport Managers influence decisions
In some sectors new products share the same ‘transportability’ characteristics as existing products. In these cases there is no particular reason that transport managers should be consulted about new product development.

At Eternit the product life cycle for roof tiles and associated products is measured in tens of years. The new products are generally of the same dimensions but a different colour or texture. There is pressure to reduce weight that potentially has an indirect benefit on the volume of freight. Similarly, the paper products produced by Inveresk tend to change in colour and texture rather than in any key transportability attribute. New chemicals products also exhibit little variation in their transportability characteristics. However, the hazardous nature of some products partly accounts for the greater consultation of transport managers in the product development area. Intel is at the other end of the spectrum in terms of value density. New models of microprocessor do not change dramatically in weight, shape or density. However, the logistics department are consulted on product development issues because of the importance of on-time, error-free delivery schedules.

In those sectors where products are destined for individual consumers, or are heavily influenced by individual consumer choice (even within a company) marketing issues dominate product and packaging development. This does not mean, however, that transport managers are not involved.

Elida-Faberge have a new product development process that closely resembles the multiple convergent model described in Chapter 4. Elida-Faberge manufacture cosmetics. The structure of the new product development (NPD) process is shown in Figure 11. The process works by filtering ideas through a series of gates: Charter, Contract Book, Intention to Launch Proposal (ILP) and Launch. Ideas are generated anywhere in the organisation but usually come from people responsible for marketing the company’s brands. These ideas are passed as written submissions to the UK Operations Executive (UKOE), which consists of the Commercial Director, the Sales Director and the Logistics Director. If the UKOE approve the idea it moves into the feasibility stage. Here the initial submissions are transformed into more detailed documents based on a practical understanding of all the business process that may be affected by the idea. This practical understanding comes from the UK Operations Group (UKOG), which consists of direct reports to the UKOE. The UKOG members are responsible for assessing the feasibility of the idea from their individual perspectives. Typical issues that will be addressed by the logistics department at this stage include safety, packaging, handling and delivery time-scales. If a project passes the Contract Book stage the bulk of the financing has been approved. It then moves on to the Capability stage. Issues raised during the feasibility stage are examined through manufacturing line trials and product testing. Progress through the ILP gate is subject to the approval of the UKOG. Once through this gate the main consideration is the launch date.

![Figure 11. New Product Development Process at Elida](image)

Defining what constitutes a new product is not always straightforward. This is particularly true where the primary packaging is an integral part of the product for instance where liquids are bottled for the consumer market.

At Scottish Courage the definition of a new product is not always clear. A new liquid can be developed but sold in an existing bottle, a new bottle can be developed to hold existing liquids or both liquid and bottle may be new. This partly stems from the division of responsibility for new product development...
The effects on transport of trends in logistics and supply chain management are being split into ‘fragmented chimneys’: packaging innovation; liquid innovation; purchasing and technical development. The main considerations are: will it sell; and will it go down the line. There are changes underway which will bring the transport decision-makers greater visibility, if not involvement, in the development process. These changes are underpinned by software that allows greater speed and visibility of communication between different functional areas. However, it may take some time to overcome the situation where procurement present a new bottle as a fait accompli to the logistics department.

The area in which transport managers may enjoy the closest relationships with departments responsible for the development of new and existing products is in packaging.

At Siemens ICN packaging engineers are responsible for designing standard packaging for world-wide use. They are a part of the central logistics function giving transport decision-makers direct access to them to discuss modifications or improvements. IBM, another manufacturer of high technology products, also has a packaging engineering function. Packaging for each product is designed in the US taking account of the characteristics of each product. Packaging engineers use a dummy of the final product to test both the product and the packaging. A key assumption is that the primary packaging must be suitable to protect the product on any mode of transport. Sometimes the packaging engineers make trial shipments of the dummy products using shock sensors inside the packaging. As a general rule they try to minimise the amount of materials used leading to the smallest and lightest packaging that meets their standards. They also dictate the number of products on a pallet and the number of pallets that can be stacked. The packaging engineering function acts as an interface between logistics and the teams responsible for product design.

In unusual cases a combination of unique circumstances may give rise to strong working relationships between normally distant functions.

Norfrost is in a unique situation. With one manufacturing site in the far North-East of Scotland serving a worldwide markets for refrigerators they face a severe transport challenge. Their peripheral location has always presented them with high transport costs. Refrigerators are low in value and product density making transport costs a high proportion of sales price even in the best location. They have overcome these barriers through a unique management organisation and focus on vehicle utilisation. The transport director, who holds their operators licence, also holds patents for the design of their products. From the start of their manufacturing operation they have focused on a producing 100 litre refrigerators predominantly for the commercial market. However, they have also focused on designing the product to maximise the number that can fit inside a 40 foot container. Currently they are able to fit 240 100 litre freezers in a 40 foot container and 276 freezers in a 45 foot, curtain side road trailer. With all but two clients they are able to match order sizes to full loads. They have achieved almost 100% loading factor with their vehicles for nearly 10 years. They are helped in this by the fact that, despite producing other sizes of refrigerator, the majority of their sales are of 100 litre refrigerator.

Transport managers in all companies are faced with trading off transport cost against service standard. In companies where transport costs are a relatively high proportion of sales price the main pressure on transport managers is likely to be to maintain or improve service standards.

Table 15 shows logistics and transport cost as a percentage of sales price for the manufacturers interviewed for this Work Package (where the figures were available). Springs Industries has the highest transport cost as a percentage of sales price for products that are exported from the US. At the other extreme, for Intel, the cost of transportation is insignificant. The largest cost elements of the sales price of a microprocessor are research and development and depreciation. It is important to note that individual company estimates of logistics cost as a percentage of sales price are difficult to compare. Companies do not necessarily include all of the same cost items in their calculations, particularly in the case of logistics costs. Also the sales price may be an internal company price, an ex-works price or a landed export price.
Table 15. Logistics or Transport costs as a percentage of Sales Price

<table>
<thead>
<tr>
<th>Company</th>
<th>Logistics costs as % of Sales Price</th>
<th>Transport costs as % of Sales Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP Chemicals</td>
<td>7-10%</td>
<td>Less than 0.5%</td>
</tr>
<tr>
<td>Elida-Faberge</td>
<td></td>
<td>Not available but high</td>
</tr>
<tr>
<td>Eternit</td>
<td></td>
<td>Less than 5%</td>
</tr>
<tr>
<td>Ferrari</td>
<td>2-3%</td>
<td>Not available but very small</td>
</tr>
<tr>
<td>IBM</td>
<td></td>
<td>4%</td>
</tr>
<tr>
<td>Intel</td>
<td></td>
<td>Not available but high</td>
</tr>
<tr>
<td>Inveresk</td>
<td></td>
<td>4%</td>
</tr>
<tr>
<td>Norfrost</td>
<td></td>
<td>Not available</td>
</tr>
<tr>
<td>Pago</td>
<td></td>
<td>Not available</td>
</tr>
<tr>
<td>Scottish Courage</td>
<td></td>
<td>Not available</td>
</tr>
<tr>
<td>Siemens</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>Springs Industries</td>
<td>7% (US), 15% (export)</td>
<td></td>
</tr>
<tr>
<td>Tasty Foods</td>
<td>6%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

The interviews with manufacturers revealed that maintaining and improving service standards is also the most important pressure on transport managers even in those companies where transport costs are a relatively high proportion of sales price.

In some instances transport costs are just not considered. Ferrari is perhaps a rather extreme example. They only make 3800 cars in a year of which 1000 are for the US market. They suggest that they have not even looked at transport costs in depth because they will not make any trade-offs related to transport. However, even more mundane products are service driven. The logistics manager at Bosch, the power tool manufacturer claimed that ‘transport costs are basically irrelevant; customer service is the over-riding factor’.

This suggests that the strategies to reduce inventory discussed in Chapter 2 are widespread across all industrial sectors. This pressure creates a major constraint on the ability of companies to maximise the utilisation of vehicles both in terms of the size and weight of customer orders and the delivery schedule. These wider supply chain constraints are explored in the next Chapter.
6. Design of Logistical Systems and Supply Chain Configuration

In examining changes in transport requirements at different levels of the supply chain, the analysis needs to consider:
- The transformation of product as it passes along the supply chain
- The assembly of different products into mixed orders
- The types of handling system used to convey these mixed orders

6.1. Transformation of product

The effect of product design on transport operations is complicated by the transformation of products as they pass along the supply chain. They typically undergo processing, assembly, or both, at different points in the supply chain that change one or more of the product attributes listed above and hence the transport requirement. In the interests of minimising the amount of freight movement it is clearly desirable to undertake weight- and volume-reducing activities at an early stage in the supply chain and to delay any final increase in product mass associated with customisation to a point near the final customer. The design of the final product and associated packaging may be inefficient in transport terms, but if it only assumes this form close to market the net effect on the freight transport system may be quite modest.

Broadly speaking, there are five processes that can increase the physical mass of products during their distribution from the main processing or assembly point:
1. Deferred assembly: e.g. of flatpack office furniture
2. Product merging: e.g. addition of an instruction manual
3. Inflation: e.g. injection of air into footballs or bubble wrap
4. Dilution: e.g. addition of water / gas to soft drink concentrate
5. Packaging: at the three levels outlined above.

By performing these processes close to market companies are effectively applying the principle of postponement (Bucklin, 1965). This principle states that companies should delay committing inventory to particular market segments as long as possible. By holding products in generic form and only customising them as they are required, it is possible to minimise inventory levels and dependence on long term sales forecasts, which are notoriously inaccurate. Postponement relates both to the nature of the product ('form postponement') and the location at which it is held ('place postponement'). It has been motivated primarily by a desire to cut inventory levels and to provide a greater degree of product customisation without having to increase inventory. Postponement can also yield transport benefits. As Van Hoek et al. (1998) point out, ‘A high product cube or weight increase through final manufacturing, as in the case of the soft drink industry, favors postponement for reasons of reduced transportation and inventory carrying costs.’ Most of the research on postponement has concentrated on its effects on inventory levels. Very little work appears to have been done to assess its effects on transport efficiency.

6.2. Assembly of mixed orders

The size of customer orders and the time-scales within which they must be delivered are generally the most significant constraints on transport managers’ ability to maximise vehicle utilisation. In many instances manufacturers encourage customers to buy products in quantities that maximise unit-load use or vehicle use. However, changing supply chain configurations are putting pressure on manufacturers’ ability to persuade customers to take full unit-loads. Increasing frequency of delivery is making order sizes smaller. These smaller orders fall below the quantities required for full unit loads, decreasing vehicle utilisation.
Eternit used to transport predetermined full pallet loads of product, such as 40 concrete tiles per pallet. However, competition from other manufacturers and pressure from purchasing cooperatives is forcing Eternit to deliver product in less than unit loads.

A.T. Kearney (1997) have devised a Unit Loads Efficiency Matrix which can be used to illustrate how in-transit space efficiency varies (Figure 12). This space efficiency sharply declines at the point where different types of product in differing sizes and shapes of secondary unit are assembled on a single tertiary unit. A roll cage or pallet with an assortment of products typically has much lower space utilisation than a wooden pallet ‘block stacked’ with a single product. The mixed-product pallet also has a much more irregular profile, reducing opportunities for stacking.

In some sectors, the order picking function is moving back along the chain from regional distribution centres to national distribution centres or factories. This is increasing the average distance that products are moved in mixed-pallet loads and depressing the average utilisation of vehicle space. This trend may be exaggerated by the growth of home delivery services, particularly grocery products, ordered through the Internet.

Companies have a variety of strategies for trying to overcome these problems. Vehicle loading factors can be made into key performance measures. Staff can be measured on achieving minimum levels of vehicle fill translating the cost pressure on the company into an individual target. However, this requires good communication with the production department and advance warning or visibility of orders before they hit the despatch area.

IBM target their export supervisors on the level of vehicle fill they achieve on outbound distribution. They look at the profile or orders arriving at despatch in the next 24 hours and assess multi-drop potential. They have the option to move small shipments to groupage or less than truckload. Fulfilment and marketing work together with large business partners to try and get orders that suit the outbound logistics.

Bulky, low value supplies can be sourced locally to reduce total tonne kilometres.
Mitsubishi’s, video recorder plant in Scotland (now closed) sourced all of its packaging, casing, printer matter and other low value bulky parts from within Scotland. Digital Equipment (now merged with Compaq) made the same point. Ironically, Eternit’s decision to manufacture a new type of tile in only one of their four factories may result in longer average length of haul in an industry that is characterised by local sourcing.

Companies use different service providers for full load and part load traffic.

Elida-Faberge use seven different hauliers for direct delivery to retailers RDCs. Full pallet load traffic is also sent through Pallex, a company specialising in shared user, palletised delivery. Small shipments move through Chronopost, a parcels carrier. They also make use of customer backhaul opportunities. Their traffic splits approximately 56% full pallet, although direct delivery is a mixture, and 40% layered pallets through Pallex.

However, where transport is outsourced the issue of vehicle utilisation is often seen as the responsibility of the carrier.

BP Chemicals are actively encouraging their transport suppliers to take responsibility for filling road tankers. Inveresk are trying to move to a system where their sole transport provider, WRM, is able to have visibility of orders coming from all four of their Scottish Mills and can maximise vehicle utilisation through route and load planning. Siemens ICN are not concerned about vehicle utilisation. They have passed responsibility onto the carrier completely by negotiating freight rates based on weight not on vehicles.

6.3. Handling systems

In Chapter 2 it was suggested that supply chain management raises important questions for the freight transport system. These were:

- How should responsibility for transport be divided between members of the supply chain? This has traditionally been determined by the terms on which the goods are sold (ex works, FOB etc.), but does not necessarily allocate transport responsibility to the firms with the most efficient delivery system.
- How does the choice of handling equipment used at different levels in the supply chain affect vehicle utilisation and how is this choice made?
- To what extent do production and distribution cycles across the supply chain permit the rescheduling of deliveries?
- What opportunities exist for backloading and the shared use of vehicles?
- What role can logistics service providers play in improving transport efficiency across the supply chain?

In trying to answer these questions the sheer variety of different configurations and consequent complexity of relationships, even amongst just thirteen manufacturers, is overwhelming.

Figure 13 below gives an indication of the geographical extent of the market served from particular manufacturing locations. Companies in different industrial sectors share superficially similar configurations. These may be a reflection of broad logistical trends particularly the concentration of production and inventory...
Figure 13. Extent of Market Area and Manufacturing Locations

Table 16 gives an indication of the major marketing channels for these companies. The superficial similarity disappears when looking at the nature of individual company’s supply chain relations.

Table 16. Marketing Channels

Table 16 only provides a view at a slice through the supply chains of these companies, looking towards the end-user. Inbound deliveries are rarely coordinated. At IBM vehicles used for outbound deliveries arrive empty and those used for inbound deliveries depart empty. There are instances of coordinated inbound and outbound flows. Inveresk imports paper pulp in bales. The bales are delivered to the mills in vehicles that are then cleaned and made available for outbound movements. This is made possible through the use of one transport provider in Scotland and because the original shipper’s responsibility ends when the paper pulp is unloaded from vessels in port.
Several of the companies interviewed are looking at backloading or shared user network opportunities. Amongst manufacturers that outsource their distribution there is a division between those that believe that backloading and shared user distribution are the responsibility of the ‘transport professionals’ and those that believe they should bear some of the responsibility flows of products that complement their own.

Norfrost has had remarkable success in backloading their vehicles. Located in the far North-East of Scotland until recently they had been able to get prices for backloads that covered the cost of distributing freezers for approximately 75% of their loads. This figure has now dropped to 50% because of increasing competition depressing the market rates. They also found the hidden costs of backloading, such as cash-flow, were difficult to handle. Currently they are looking at distributing by rail since they already bring in some raw materials by this mode.

The reduction in inventory levels across the supply chain through the application of JIT, quick response (QR) and efficient consumer response (ECR) has often had the effect of depressing average consignment size and vehicle load factors. This has given rise to a series of supply chain initiatives designed to counteract the effect of inventory reduction strategies on transport efficiency. ECR Europe (2000), for example, has identified a series of measures that trading partners can take to optimise their transport operations. In the UK, the Cold Storage and Distribution Federation, with the support from the UK government, has promoted the benchmarking of transport operations across the food supply chain against a standard set of key performance indicators and encouraged inter-company collaboration to improve transport efficiency (McKinnon, 1999).
7. Conclusions and Recommendations

7.1. Conclusions
In the introduction it was suggested that companies attach insufficient weight to transport when looking at logistical trade-offs and, consequently, these trade-offs are systematically biased against the transport system. In the case of product and packaging design it was unclear whether companies attempt to trade-off design issues against transport costs. In the course of this work package deliverable these issues have been explored through primary and secondary research. It is possible to draw a number of conclusions.

First, despite appearances to the contrary, in general, companies are being rational when not considering transport in the design of products. Functionality and aesthetics dominate product design. Trends towards the use of lighter materials and miniaturisation can indirectly contribute to an increase in transport efficiency. Retailers are forcing manufacturers to develop space efficient products with indirect benefits to transport efficiency. Transport or logistics management has very little input into product design or even product re-design. Where transport costs are a small proportion of product sales price it is unlikely that manufacturers will take them into consideration when designing new products. The exceptions to this are where some attribute of the product, such as its fragility, value or hazardous nature, forces manufacturers to consider how the product will be transported.

Second, perhaps because of this rational behaviour there are few examples of manufacturers adopting the principles of 'design for logistics'. While there are numerous models of new product development in the management literature in practice the processes are informally, or poorly, defined in many companies.

Third, the increasing interest in logistics since the 1960s has been stimulated by a desire to reduce inventory and reduce ‘time-to-market’. This has continued with the adoption of supply chain management techniques. The consequence of these developments is that service has become the dominant issue for transport management, even in those companies where transport is a relatively high proportion of final sales price. Against this background logistics management is ‘adapting’ to change rather than ‘driving’ it.

Fourth, the design, or re-design of packaging appears to include a much greater role for logistics management. There is a greater potential to improve vehicle utilisation through the effective design of packaging. This requires the adoption of a holistic view of packaging to consider the ways in which partial efficiencies can be improved at each level of the packaging hierarchy. However, sales and marketing considerations are still paramount, particularly in consumer products. Sales promotions can have a high transport and handling penalty that is rarely subject to a rigorous trade-off against actual sales.

Fifth, there are conflicting trends within the design of packaging which may have both benefits and penalties for transport efficiency. Attempts to reduce the weight of packaging may decrease tonne-kms but it may also make loads less stable and hence decrease vehicle utilisation.

Transport management is therefore operating within a hierarchy of constraints, some of which are technical but many of which are organisational. Attempts to make general assumptions about strategies for managing these constraints must face the enormous variability between companies. These constraints are dependant on a wide variety of factors such as value density, product cube, position in the supply chain, geographical location with respect to markets, etc. Although there appears to be an average decline in the average density of freight this is a ‘net’ effect of the interaction of many trends.

External influences also exert an influence on these constraints. The underlying increase in road freight costs can encourage efficiency by forcing companies to focus on their strategies for reducing cost.
However where this encourages outsourcing of transport it may be a double-edged sword. Transport costs may be reduced but at the same time it reduces awareness of, and interest in, vehicle fill. This reduces the likelihood that product or packaging can be designed, or re-designed, to promote transport efficiency.

7.2. **Recommendations**

Faced with these conclusions what options are available for policy makers? It is possible to split the possible options into four areas:

6. **Advice on packaging design.** There has been much effort put into persuading companies to reduce or eliminate packaging waste, either through regulation or education. It may be possible to complement this work with an understanding of the way in which the hierarchy of packaging affects freight transport volumes and vehicle utilisation.

7. **Education and the promotion of best practice.** Many companies do not have an explicit policy on vehicle utilisation. Vehicle load factors are the outcome of a range of inter-related decisions made in different functional areas. Transport managers are given the job of maximising vehicle productivity within the constraints imposed by the production, marketing and sales departments. Firms producing and distributing low value, bulky products often insist that vehicles are despatched full. Some set minimum threshold levels of loading that can only be breached under certain circumstances. Many other firms, however, have not systematically measured or compared vehicle utilisation and therefore had not yardstick against which to set management targets. This situation now appears to be changing, with increasing numbers of companies assessing the efficiency of their transport operation against standard KPIs. Industry-wide initiatives, such as that of ECR-Europe (2000), are providing advice and encouragement to companies on transport optimisation. Full implementation of the recommended measures will, however, require a change in management culture and structure in many businesses.

8. **Promote use of technical tools for examining loading efficiency.** In the course of the interviews it became clear that there are a number of software tools available that help companies optimise packaging, particularly at the unit load level. The widespread promotion of these tools might encourage more companies to examine the trade-offs that are being made at this level.

9. **Legislation.** Given the complexity of interacting trends discussed in this deliverable it appears to be impossible to work out the effects of any form of direct regulation. Policy-makers should consider the effects of other policy initiatives on product design and packaging, and hence vehicle utilisation, for example the effects of packaging regulations and health and safety regulations. In Germany new legislation for beverage packaging has been under debate recently; this may well have a negative impact on vehicle utilisation. Policy-makers should also consider the impact of internalising the environmental costs of road freight transport. For the average manufactured product the increase in transport costs would be unlikely to induce much product re-design. However, it might have a greater effect on packaging and handling and hence a significant impact on vehicle utilisation.
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Annex 1: Questionnaire Used in Company Interviews

Company details

Organisational structure:

- Position of transport and logistics management within the organisation
- Representation of transport and logistics at company board level
- Nature of the links between transport/logistics and other functions, particularly Research and Development, Production, Marketing and Sales.

Nature of the products, packaging and handling equipment

- Types of products manufactured and distributed.
- Nature of the primary, secondary and tertiary packaging.
- Typical handling equipment used at different levels in the supply chain
- Average length of product life cycle

Nature of the product development process

- Average time taken to develop new product (from inception to launch)
- How has this product development time changed over the past 5 years?

Nature of the transport operation

- Relative use of different transport modes
- Main types/weight classes of road vehicle used
- Transport costs and logistics costs as a % of sales revenue
- % of road transport budget outsourced.
- Are the main pressures on the transport management to:
  a) Cut costs
  b) Improve the standard of service
  c) Both in equal measure

Vehicle utilisation

- Proportion of loads constrained by a) weight b) floorspace and c) cubic volume.
• Average road vehicle load factor by weight and/or number of pallets.
  (i.e. ratio of actual load to maximum possible load)

• Relative importance of factors limiting the utilisation of vehicle capacity:
  1....... Size / weight of customer orders
  2....... Delivery schedule
  3....... Nature of the handling equipment
  4....... Nature of the product
  5....... Promotional activity
  6....... Other

• Opportunities for relaxing these constraints

• Extent to which vehicle utilisation could be improved

• How much resistance would there be within the company to these changes and from which department(s)

**Inter-departmental relationships**

• On a scale of 0 - 5 (5 = high), indicate the extent to which transport managers are consulted and b) allowed to influence decisions in the following areas:

<table>
<thead>
<tr>
<th></th>
<th>consulted</th>
<th>allowed to influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production scheduling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice of handling system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marketing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales</td>
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<td></td>
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</tbody>
</table>

How much consideration is given to the transport operation when decisions are made in the following areas (again using a scale of 0 - 5):  

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of facilities</td>
<td></td>
<td></td>
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<tr>
<td>Sourcing of supplies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials handling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice of marketing channel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extent of the market area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After sales support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycling / reverse logistics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Has the transport / logistics department attempted to estimate the transport cost implications of the decisions made in these areas?

• To what extent does the company explicitly trade-off the cost of transport against other costs and revenues?
• If there is little or no evidence of this happening, what is preventing it?
  a) Nature of the accounting system
  b) Inter-departmental rivalry
  c) Little importance attached to the transport function
  d) Other (please specify)

• To what extent has the development of logistics / supply chain management increased / reduced the amount of importance attached to transport?

• What could be done to increase the amount of consideration given to transport in decisions relating to the following factors:

<table>
<thead>
<tr>
<th></th>
<th>comment</th>
</tr>
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<tbody>
<tr>
<td>Product development</td>
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<tr>
<td>Packaging</td>
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<td>Location of facilities</td>
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<td>Sourcing of supplies</td>
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<td>Production system</td>
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<td>Materials handling</td>
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<tr>
<td>Choice of marketing channel</td>
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<td>Extent of the market area</td>
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<td>After sales support</td>
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<tr>
<td>Recycling / reverse logistics</td>
<td></td>
</tr>
</tbody>
</table>

• In what ways might the following be changed to reduce the transport requirement:
  a) Product design:
  b) Nature of the packaging:
  c) Nature of the handling equipment:
  d) Staging of the processing / assembly operations across the supply chain:
  e) Location of the order picking operation within the supply chain:
  f) Monthly order payment cycle:
  g) Nature of sales promotions