THE IMPACT OF NEW INFORMATICS TECHNOLOGY ON EUROPEAN TRANSPORT

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New technology and informatics in transport is becoming a subject of great importance to Europe and will have a considerable impact on transport economics and techniques. While Ireland is not a prime mover in these innovations, it is important that firms should be aware of developments and poised to avail of the new technology. The word informatics embraces both the computer and telecommunications systems but this article does not cover applications of computers which are exclusively within the firm — such as salary payments, accounting, invoicing, etc. These applications have existed for many years and indeed the widening use of informatics has not been brought about by any revolutionary developments in technology but rather by a gradual extension of existing techniques to outside the firm and to embrace the field of inter-firm communications. This has been driven by the falling costs of computers themselves and by competitive pressures, particularly in Europe, from countries such as the United States and Japan. This in turn has provoked a realisation that the abolition of artificial barriers within Europe, to the development of an economic market capable not only of withstanding the challenge from Japan and the USA, but also of presenting a reverse challenge to them, can and must be accelerated.

Those far seeing people who drafted the Treaty of Rome envisaged that the abolition of international tariff barriers would create a vibrant growing single market within the Community. They were partly right. The economic growth, and with it the growth in trade, has been quite phenomenal since 1958 and in spite of the problems caused by the two oil shocks in the 1970s that impulse for growth has continued and has been strengthened by the accession of new Member States.

What the original founders did not foresee, or at any rate provide for, was the ingenuity of the national administrations of the Member States to find

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other means of raising revenues and of protecing national interests. So, a vast complex of taxes, duties, phyto-sanitary controls, and other constraints has been built up (including in particular the control of inter-State road transport) to the point that it is now estimated that the movement of goods internationally within the Community can require as many as 70 different forms. It has recently been shown that for road haulage, six to seven driver documents, about 12 freight documents and 27 vehicle documents have to presented and checked for customs clearance (Aberle, 1985). The frustration which this creates at the frontiers was demonstrated in dramatic form by the lorry drivers' strike of February 1984 at the Alpine crossings, which had the effect of pushing the national administrations to move on propositions of the European Commission on the streamlining of frontier facilities. It is estimated that the cost of frontier controls and the delays caused thereby, add upwards of 5% to the finished cost of goods.

The most significant of the measures agreed was that relating to the introduction of a Single Administrative Document (S.A.D.), combining in one document all the information necessary to move goods across the Community. This will be introduced in January 1988 and should make life much easier for transporters. It is important to note that the S.A.D. is structured to be used easily with computers.

While work on the S.A.D. was going on, other forces were at work to investigate the potential of computers in streamlining the movement of goods. In early 1984, the Commission submitted a proposal to the Council of Transport Ministers related to the implementation of a long term programme for the use of telematics for Community Information Systems concerned with imports or exports and the management and financial control of agricultural market organisations. This has become known as the CADDIA project.

This was followed in January 1985 by a further communication on the coordinated development of computerised administrative procedures. Known as the C.D. project, this is being undertaken within the overall framework of CADDIA. This project aims to coordinate and link the customs procedures of the Community countries, not only for intra Community trade but also for trade with third countries. The C.D. project has laid down a programme up to 1992 to link fully the customs Authorities of each of the Member States. Not that the Member States themselves are idle. For example, France and the United Kingdom already have such facilities in place, while Belgium, the Netherlands and Denmark are introducing computers to handle customs procedure in the very near future. One aim of the C.D. project is to move the frontier controls on goods to the point of destination of the goods, but to do this an efficient information transmission system is necessary, particularly between customs authorities. However, the linking of computers raises serious problems of compatibility not just of the machines, but of the software and the language and communications protocols which are used.

The 1992 target of the C.D. project has increased in significance during the past year following the publication in July 1985 by the Commission of its White Paper on the Completion of the Internal Market. This paper commits the Commission to introduce legislation which by 1992 will dismantle all remaining obstacles to the internal trade of the Community. It goes further than the issue of border controls, and also embraces a wide range of issues such as the harmonisation of taxation levels between Member States.

The European Commission is addressing itself to this problem through its ESPRIT programme, and has adopted the standard of OSI (Open System Interconnection) which has been accepted by European Computer Manufacturers. Effectively this means that machines with the defined system of machine architecture can be linked irrespective of company or country of manufacture.

For telecommunications, the X-25 System has been adopted by the European P.T.T.s as the standard, and work is now progressing on a file transfer system developed by the Commission, called the Multi File Transfer System (MFTS). For different telematic systems to be able to co-operate in carrying out data processing transactions, it is necessary that the systems recognise not only the data that has been exchanged but also the instructions that indicate how the data are to be processed and displayed. For this to occur the functionality of the different systems must be identical, the European standardisation organisations (CEN/CENELEC) and the Conference of European Posts and Telecommunications (CEPT) are involved in a programme for the preparation of Functional Standards for all the main data transfer and intercommunication functions. This involves not just the EEC States, but also those from EFTA. Thus, the basic building blocks are being established and the C.D. projects's aim of linking the computers of the individual Member State customers, so that information on the flow of goods can be transferred easily from one community country to another, is being facilitated on the technical side.

There are other problems, of course, in the transfer of information, relating to questions such as the format of the message and the words used (syntax). These also have to be standardised and here the C.D. project is proposing the adoption of International Standards Organisation (ISO) standards for messaging and formatting. Allied to this, one major industrial group — the European vehicle manufacturers, who buy and sell from each other — have been looking at ways and means of cutting costs and standardising their messages, invoices, etc. Clearly, it would cut costs to use computers to automatically transfer the information from one company or factory to another. The thrust in the world automobile industry, pioneered and led by the Japanese, towards Just-in-time (JIT) inventory management has been under way for some time, and is being extended into the broader logistics field. The four largest US automobile manufacturers are now so committed to electronic data interchange that they have demanded that their suppliers be able to communicate with them electronically by 1988, and they foresee an estimated saving of $200 per car [Lallande, 1986].

The European automobile manufacturers recognised the problem of standards at an early stage, since it has a particular significance in Europe, and their project, which is code named ODETTE, is hoping to adopt the same standards as the C.D. project. This will have a dramatic impact on transportation, because the companies will in future be looking at the total logistical system, from raw material input to the finished product at the customer's door, rather than just the distribution/transport element in isolation as has tended to be the case in the past. The use of computers with standard formatting, messaging and telecommunications will allow the transfer of data and the control of physical goods to be done much more easily and in a synchronised and co-ordinated way. Once data are input in a standardised form they can of course be added to, transferred, and manipulated as appropriate at each stage of the operation. This has immense implications for both production and transport.

For illustration, at the main Volvo plant at Göteborg the stock of car seats is now equivalent to only two hours' production needs. This low lead time has been achieved by the extension of MRP principles back into the physical procurement chain, by the achievement of a high degree of control over suppliers, and particularly by a carefully designed and integrated information and logistics management system. For Volvo this means that the volume of working capital is reduced substantially, but there is a corollary that the transport companies must provide a service that is absolutely 100% — because if there is any hold up at all then the entire production line is fouled up. This will bring a discipline quite unknown in many areas of business and would bring many changes to transport in Ireland.

The ODETTE system envisages that once an order is filled the information to this effect can be transferred to the customer giving the relevant data of dispatch date, time of arrival etc. all from a single original data entry. Thus, goods leaving France for say Germany would be known by customers long before their actual arrival, which is quite the reverse of many current transactions, where the goods arrive before the documents. Other industries in Europe — for example electronics and chemicals — are currently examining the implications of the ODETTE approach with a view to designing similar systems in their own sectors.

What about road transport itself, which is subject to many restrictions — quotas, authorisations, and other prohibitions of one kind or another, which are man made and predictable, and other types of hazards such as the weather, and road congestion, which are extraneous in origin? Where can new technology help in these cases? The main ideas currently under examination are:

— Route planning
— Up-to-date en route information provision
— Market Information
— Smart Card Technology

All of us setting out on a journey have an idea of which route we will follow — what we do not know are the blockages on the way, road works, traffic conditions, accidents etc. For most of us as private drivers on relatively short journeys the cost is largely our own frustration, but in the case of the carriage of goods over long distances these delays cost money. Therefore it is necessary to have up-to-date information available to the route planners. Nowadays in some countries this is being done by a central computer which will respond to requests for the optimum route between points A and B. This comes in the form of a printout showing the routes to be taken and even detailed onscreen maps showing the destination within a city's street system. The next stage of that development is to have a display unit on board the vehicle which will give the same information. Such a system is already in use in Holland using a compact disc with a digitalised map of every route in Holland, and it is currently being expanded to the Benelux countries and eventually to EURO 12. The drawback of this system is that it is difficult to up-date the information quickly. Even with radio systems it is unlikely that information can be brought to the driver's attention fast enough to allow the appropriate evasive action.

The application of these techniques appears simple at the superficial level, but again the problem of standardisation arises. At a very fundamental level there is the problem of road signs, symbols, and language. Ireland is not currently a participant in the EEC's COST project looking at the application of these techniques, yet while the greatest applications will probably occur in the areas of densest population and traffic, potential economic benefits in the other regions should not be overlooked.

Other systems being looked at include the possibility of video-text systems which would give information on road conditions, position at borders, etc. This could be available on TV screens along the main European routes e.g. at motorway service stations which would be accessible to vehicle drivers. Again the need for standardisation arises. An interesting project has recently begun in Sweden, called ARISE, involving the integration of various components of computer technology to give a comprehensive vehicle on-board traffic information system covering both route planning and the supply of real-time information on traffic conditions, en route services, etc.

One of the greatest costs in transport is that of empty running and with the regulatory constraints on road transport in particular this is a major cost estimated to run into hundreds of millions of pounds. It it were possible to reduce empty running everyone would therefore benefit. Consequently, a number of systems have been introduced whereby transporters can key into a central system and find out if shipments are on offer which would be of interest, and they can also enter information on what they have on offer. Such systems are already in use in several countries, for example the TRANSPOTEL system in Germany. The coming of cellular radio also offers possibilities for information systems in this application area, but again standardisation is the important thing.

Much is also happening in shipping and rail transport. There is quite a lot of development in controlling the movement of containers through the ports, for example Rotterdam and Antwerp, where the larger companies have always had good information on their own throughputs. Now a system is being planned in Rotterdam, called INTIS (International Transport Information System), which will provide for large and small companies (using a variety of personal computers, mini computers, or larger computers using batch processing) which will provide all relevant information to customs and shipping companies and at the same time provide a transport management system.

Recently, a group of major shippers, forwarders and carriers in Europe agreed under the chairmanship of SITPRO to undertake a project, called DISH (for data interchange in the shipping industry). This will involve the electronic exchange of information between carriers and their customers in deep sea liner shipping. Trials of the system are expected to be underway before the end of 1986. In this connection also it is appropriate to mention a current study of the European Commission on the potential use of satellites in the control and monitoring of the movement of dangerous cargoes.

The International Union of Railways (UIC) is developing a system called HERMES, which so far has been accepted by six railway systems but unfortunately not by all. It is not clear yet whether HERMES will be compatible with the standards referred to earlier. Part of the system involves a detailed plotting of wagon movements, which if successful would result in a considerable increase in efficiency.

At the Economic Council for Europe in Geneva (ECE) there is considerable interest in the introduction of the "smart card" to replace the TIR Carnet used in the international movement of goods traffic by road. Again the technology itself is not new but the application is, and it would have large benefits in the reduction of paperwork and vehicle delays. The smart card has the appearance of a normal plastic credit card, but has the ability to carry a large amount of computerised information, which can be read, updated, and transmitted by special card readers, which in the transport context can be placed along routes at key interchange points such as transport junctions, terminals, and customs points. It can also be used for bank transfers, for the payment of duties, VAT, and many other en route expenses, with the transactions occuring real-time and effected independently of location and cash.

Two problems currently remain regarding the application of smart card technology. One, ironically, is the lack of standardisation and is familiar to those using plastic cards for banking facilities, and the other concerns the introduction of infrastructure to process the cards. In relation to the latter there is the complication that the installation of smart card infrastructure at borders could become a reason for maintaining border controls, the abolition of which by 1992 the Commission is now committed to.

A further general problem regarding the use of technology in the international context described in this paper is emerging from the viewpoint of the legality of electronically produced documents. The receipt of a document on a computer screen without an authenticated signature can, as will be appreciated, pose problems in terms of traditional legal conventions. The Commission is now considering the implications of this in some detail.

This brief article has attempted to convey a broad picture of the thrust of new technology in the transport sphere in Europe. The cost of many of the developments is initially high, but it is foreseen that with increasing volumes of usage the unit costs will fall rapidly and the benefits will be substantial to individuals, firms, and the Community in general. We must be wary however of being bamboozled by technology and alert to the risk of over-ambition. There are risks in having large computer data banks, from viewpoints such as privacy, fraud, system breakdowns, and diseconomy in the case of small countries. Nonetheless it seems clear now that in the field of industrial logistics, and customs control of raw material and product movements, there is much that can be done to improve flows and eliminate bottlenecks, and that the risks are small and controllable compared to the size of benefits accruing from a properly integrated and competitive European industrial base.

The principal consideration for Ireland is firstly to be aware of what is happening, and secondly to be prepared to draw from the latest developments those that can offer lasting economic benefits to the country.

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THE ROLE OF TRANSPORT IN HIGH TECHNOLOGY INDUSTRY

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The late 1970s and 1980s have witnessed major shifts in the nature of industry in most developed economies — shifts which cover both the manufacturing and service sectors as well as the balance between them. This technological transformation has seen the retreat of the traditional heavy industrial base (involving, for example, steel, rubber, textiles, etc.) and the advance of knowledge-intensive industries. Considerable research has been conducted into the specific requirements of high technology industries, in particular their labour and skill needs [e.g. Hampshire County Council, 1984; Braun and Senker, 1982; and Breheny *et al.*, 1985], the role of defence contracts, land availability, and specific managerial problems of running such companies. Relatively little attention has, however, been paid by researchers to either the transport needs of high-technology firms or the position that the logistics dimension now holds in the internal management of such organisations.

This article addresses the relationship between transport and high-technology production, and the extent to which high-technology industry has different transport needs compared to its low-technology counterparts. The general conclusion is that transport, in its widest sense, is far more important to high-technology management than shows up in conventional economic analyses.

High-Technology Industry

While some efforts have been made to use standard indices, such as the Standard Industrial Classification, to conduct quantitative studies of the high-technology industries [e.g. see McQuaid and Langridge, 1984; and the US Congress Office of Technology Assessment, 1984], no agreement has been reached concerning the boundaries of the high-technology sector. Such indices also hide wide variations in the types of activities embraced in each classification and, because of frequent updatings, are

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of only limited use in time series studies. Because of both the inadequacy of statistics and the definitional difficulties there are therefore difficulties in measuring the size of the high-technology production in most countries.

There are, however, a number of commonly agreed trends. In particular, high-technology activities tend to be found in geographical concentrations, e.g. Boston's Route 128 and Silicon Valley in the USA, the M4 Corridor in England, and Silicon Glen in Scotland. There is also evidence [e.g. Breheny and McQuaid, 1985] that more careful examination of each of these concentrations reveals local product specialisations.

Traditional Perspective

Some of the analyses of the location decisions of high-technology firms have concluded that transport is of relatively little importance [e.g. Premus, 1984], and suggests that various of the static attributes of alternative sites, rather than the costs of moving people, raw materials, and output, have a key influence on the concentration of high-technology industry at specific locations. This ties in with traditional theory of industrial location, that the industries most affected by transport costs are those which rely heavily on raw materials and which produce goods with a low value to weight ratio. Clearly, high-technology industry does not fall readily into this latter category — it produces high value products with low unit transport costs, requires resources from a diverse range of sources, and supplies a geographically diffuse market. High-technology industry has, therefore, come to be viewed as "footloose" and attracted to specific locations by mainly labour market factors, the quality of local environment including financial incentives, local input prices, and access to appropriate research facilities.

This view has been reinforced by a wide range of questionnaire based studies, expecially in the USA. For example, the Joint Economic Committee of the US Congress (1982) found that 89% of high-technology firms surveyed indicated that labour skills and availability were significant or very significant in deciding upon which region to locate in, with 96% reporting the factor to have had a significant effect on more detailed intra-regional location decisions. Indeed, some econometric studies have even suggested an inverse correlation between the quality of transport provision and the geographical shifts in high-technology industry [e.g. Glasmeier *et al.*, 1984]. Equally, studies of high-technology industry in Britain have found the existence of a pool of professional and skilled labour to be the major attraction of a specific location [Breheny and McQuaid, 1985].

This approach and the accompanying empirical work, however, would seem to be too simplistic. In particular they tend to ignore important differences between high-technology industry and longer established industries both in the role transport plays in the production process itself and in the way in which management of high-technology undertakings views logistics. Certainly, some of the recent surveys, conducted using more refined questionnaire procedures, have revealed "communications" in the wider sense to be an important consideration in the eyes of high-technology management [e.g. Breheny and McQuaid, 1985], but even here there appears to have been only a limited effort to really understand the forces at work.

Transport Inputs into High-Technology Firms

Conventionally, transport costs are usually seen as important in moving raw, often mineral, material to a plant for processing and then in conveying the final output to market. The nature of high-technology production means that while transport still performs this basic function it does so in a somewhat different way. Additionally, transport performs a number of other functions which have been of little or no importance to traditional low-technology industries.

Although there is some academic controversy about the validity of the product life-cycle theory [see Rink and Swan, 1979], it does provide a useful basis upon which to examine the role of transport inputs in high-technology production. The idea of the product life cycle is now thirty-five years old and in its simplest form, the theory argues that any product goes through an initial inception and development phase, followed first by a growth phase to maturity, then by a large-scale production phase, followed finally by a decline phase. Figure 1 provides a generalisation of the most frequently cited form of the cycle (a bell-shaped curve) relating output to time.

The key point is that while all productive industry follows a path not unlike the one depicted in the diagram, the relative importance of each stage in the path differs as between different industries [Mahassani and Toft, 1985a, and Toft and Mahassani, 1985]. There are also significant differences in the overall lengths of cycles and the various stages within them. High-technology industry exhibits an expensive and rapid *inception and development phase,* involving considerable scientific research and engineering expertise. US surveys show that some 55% of personnel employed in what may be broadly defined as high-technology industries in Texas are in the professional, scientific or technical occupational categories, compared with less than 22% in the standard sectors. Similar analysis of high-technology employment along Boston's Route 128 reveals

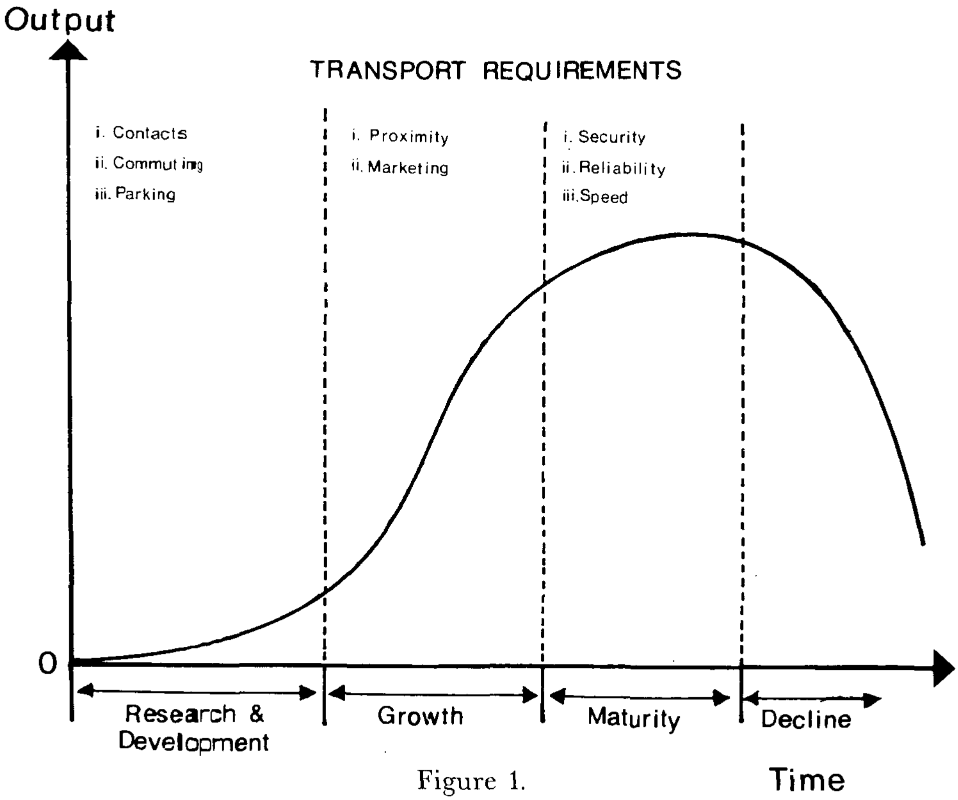

Figure 1.

nearly 50% of the work to be in the professional or technical para-professional occupational classes. The ability of any firm to compete at this phase of the cycle is central to its subsequent success in the market. Transport is relevant here partly because it permits ready access to pools of skilled labour and partly because it extends lines of communication. Local transport quality is important at the micro-level in the siting of laboratories and R&D facilities because scientific and engineering expertise is at a premium, and lengthy commutes or poor access to recreation areas affects *its* location choices [Shanis *et al.*, 1985]. Good intra-urban person transport seldom plays a part in the thinking of low-technology management but it certainly features in that of high-technology industry.

At the national level, good access to airport facilities, in particular, seems to be important to permit the international mobility required for research personnel to function effectively [Rosenberg, 1985]. Despite the advent of telecommunications (itself an output of the high-technology revolution), researchers appear inherently conservative and still seek regular face-to-face contacts with their peers to develop new ideas and refine existing ones. Scientists and engineers worry that they are no longer at the cutting edge of research if they do not regularly meet with their peer group. A US survey of industry in Austin, Texas, for example, found that employees in firms specialising in R&D revealed a proclivity to make 8-12 monthly air round-trips, while employees of undertakings simply concerned with manufacturing made between 0.07 and 0.25 monthly air trips [Mahmassani and Toft, 1985b]. It is no accident, therefore, that the major agglomerations of high-technology firms are within easy reach of airport facilities and this would seem to be particularly so for the R&D sections of firms with geographicaly divided development and production sites. Air transport is thus important in virtually all high-technology location decisions although possibly more as a means of retaining R&D initiatives than actually being the prime reason for adopting an initial site.

Just as survey work may underplay the role of transport in the development phase of the cycle, so also inappropriate questions may be asked at the *growth and commercialisation phase.* Here, expert management, finance, and marketing, become important. Once more management is time conscious and ease of commuting is important. Green-field sites with ample parking space offer both the type of transport infrastructure management seeks and the physical environment it increasingly desires. Of more importance for success at this stage, however, is access by the firm to finance, because it is during this part of the product life-cycle that cash-flow problems arise and venture capital plays a vital role if critical thresholds are to be crossed.

There are advantages at this stage in locating in areas with an established high-technology base — this in itself being a transport cost minimising option. Proximity to other producers normally means access to an experienced and responsive venture capital market — possibly involving sources of local public finance [see Rosenberg, 1985]. It also means that more conventional agglomeration economies may be exploited to reduce set-up costs. In terms of marketing, a geographical identity is acquired. Not to be overlooked is that it is generally possible to poach management personnel from longer established undertakings.

The growth phase also involves the investment from innovation to the development of production itself. Many high-technology products either form components for existing producers or themselves require inputs from established high-technology producers. While the products involved in this intra-high-technology industry trade are not normally bulky or inherently cumbersome, they do pose transport problems in that they are of high value and, frequently, relatively fragile. Thus, high speed transport is sought to keep inventory costs low while, given the relatively small portion of total costs attributable to *direct* transport considerations, a premium is willingly paid for security of transport. Once again, these costs tend to be minimised by locating close to other high-technology firms.

The *maturity into large-scale production phase* of the cycle involves a somewhat different perspective of transport needs. Indeed, because of this, the production phase may be located at sites well away from those featuring in the earlier phases. Generally, high-technology products have a very short life before being superseded by a more advanced or specialised product. This means that production delays associated, for instance, with labour acquisition and training, need to be minimised if the highest return is to be earned. Equally, production itself normally entails the use of relatively skilled workers, especially when mistakes in the production process can be expensive. Locations adjacent to existing firms engaged in large-scale production (although not necessarily in either the development or commercialisation phase of the overall production process) are thus attractive although, once more, local transport facilities are important. Reliable, high quality transport, often air freight services for wider markets, but in many cases also good road infrastructure, is sought both to bring in components where necessary and to take the output to final markets. Where there is geographical separation between the development/commercialisation phases of the cycle and the site of large-scale production, good transport links are essential in co-ordinating management and control of the different activities of the firm. It is also important for ensuring that vital feedbacks take place.

These latter internal lubricating functions of transport are often adequately served by road transport in smaller countries, but where the separation is on a large scale air transport once more plays an important role.

Good quality international transport links are becoming increasingly important as modularisation of many high-technology products necessitates, for lowest cost production, the bringing together of modules from wide-ranging geographical sources. Standardisation of many components in the electronics field also means that economies of scale in production are best achieved through a high degree of international specialisation.

Thus, from the perspective of the product life-cycle transport plays a number of important roles in management decisions, especially with regard to location. Simple analysis of conventional statistics relating, for instance, the ratio of direct transport costs to selling price have ignored the importance of both transport in the cost of other input prices and the non-financial aspects of transport inputs (e.g. service quality). Equally, industrial surveys, by structuring questions in an excessively simplistic way, have tended to generate responses which are likely to subsume many transport related influences on business behaviour under other headings.

The Importance of Logistics

The different role that transport plays in high-technology industry not only requires a somewhat different approach on the part of outside analysts (interested, for example, in industrial planning) but also on the part of management itself. Traditionally, transport has played a relatively minor role in overall managerial decision-making. Firms have usually been content to accept the transport arrangements in operation and only to respond (e.g. by seeking more efficient alternatives) at certain crisis stages in their development (e.g. when serious bottlenecks develop). Transport cost minimisation has not been central to the decision-making of firms and the positon of the transport manager in most companies has not been a central one. [In his autobiography, Lee Iaccoca (1984, p.99) offers some interesting insights into upper management's general lack of interest in transport in low-technology industries other than at times of emergency.]

In some countries this situation may be explained by the high degree of regulation of the transport industry, whereby the options open to management appear restricted and the search costs involved in pursuing a cost minimisation strategy outweigh any potential savings. Certainly this situation prevailed in the US until the late 1970s and still persists today in many European countries. It also applies, albeit to a lesser extent, to firms in countries such as the UK and Ireland which are involved in wider EEC markets — the Common Transport Policy is only gradually becoming truly competitive.

Changes in the level and nature of regulation of transport in the US and the freeing of transport markets from entry and pricing controls have widened the opportunities open to user firms (Schneider, 1985). Significant cost savings, both in financial and in generalised cost terms, where factors such as time, reliability, security, etc. are brought into the calculations, are now possible and the function of the transport manager has become more important. Policy changes within the EEC are also slowly freeing international constraints on road and air transport, both of which are heavily used by the high-technology sector, and while there are still, for example, limitations on the freedom of lorries to move around Europe, the situation is much less restrictive than it has been in the past [Button, 1984].

Within high-technology firms the transport function is also increasingly being subsumed within a wider perspective concerning the whole question of logistics. Logistics is essentially seen as the management of inventories at rest or in motion [Heskett, 1977]. If one focusses on logistics strategies rather than narrower ideas of transport, then the actual role of transport takes on greater significance. Decisions regarding transport affect not simply the question of moving factors of production (including labour) to the place of production and finished products to final markets but to an entire range of other issues, e.g.

- what sort of warehouse distribution system should be used and what pattern of warehouse locations should be adopted?
- what level of inventories (i.e. raw materials, semi-finished production and finished goods) should be maintained?
- what should be the scale of each production plant?
- should different functions within the firm be geographically dispersed or concentrated?
- what forms of transport are best suited to the different functions of the firm?
- to what extent should components be brought in or produced within the firm?

While the development of sophisticated logistics strategies is extending into all forms of industry, they are particularly relevant to the high-technology sector. The high cost of holding large inventories means that efficient management is essential. Additionally, the rapid technological redundancy of most high-technology products (i.e. a relatively short product life cycle) means that not only can high inventory holding tie up large amounts of capital but it can also lead to potentially massive capital write-downs if new, substitute products penetrate the market.

Inventory control is a direct function of transport in the sense that production itself is determined and limited by technical factors. The increased realisation of this, and in particular that the appropriate choice of transport has come to be of central importance, means that transport is likely to be viewed differently within the management structure of high-technology firms. Time considerations and reliability of supply (both of inputs and in the distribution of final product to consumers) are paramount if inventories are to be kept to the minimum. Just-in-time delivery is rapidly becoming the norm for high-technology undertakings [Schonberger and Gilbert, 1983] and , in the USA and to a lesser extent Europe, this has increased the reliance on air transport as a principal mode of transport. The use of own-account road transport is also important in many high-technology industries, mainly to minimise delays between trunk haulage and delivery (either to the production plant or to the final customer).

Logistics is, like high-technology industry, dynamic and ever developing and thus long-term generalisations are dangerous. What is vital from the point of view of assessing the importance of transport factors to high-technology management is that they tend to extend beyond the conventional notions of their role in overcoming physical obstructions to production and distribution, and have begun to embrace central financial management and production control issues.

Conclusions

Transport is often given passing mention when location and production decisions of high-technology industry are discussed, and its importance is normally ranked below labour market considerations. The nature of high-technology industry, however, suggests that transport both plays a more important explicit role in the decisions of high-technology management and has many more implications than these discussions admit. Some of the neglect of the transport dimension originates from the rather crude way in which transport costs are generally treated even in the study of traditional, low-technology industries. The advent of improved management techniques within high-technology firms, spurred on by the competitive and dynamic nature of the industries involved, has made the traditional approach even less relevant.

The appreciation of the role of transport in stimulating the successful growth of high-technology production is also important for national policy-makers. Regional economic policy still places emphasis on traditional, low cost and slow modes of transport (if transport is considered at all), without questioning traditional operating methods and structures. Urban transport debates still focus on social needs, rather than the transport incentives needed to maintain or attract the scientific and research personnel which high-technology industry seeks. Greater attention to the provision of high quality rapid transport systems in towns, for instance, may both offer a policy tool for attracting R&D activities back into inner city areas and lead to some alleviation in the level of traffic congestion, while low fare bus policies seem unlikely to do either. Equally, coherent policies with regard to airport provision and associated high-quality road transport are more likely to influence the location of high-technology firms than efforts to retain rail services. This appreciation of the specific requirement of high-technology industrial needs also has clear implications for the development of appropriate elements in the Common Transport Policy of the EEC.

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