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

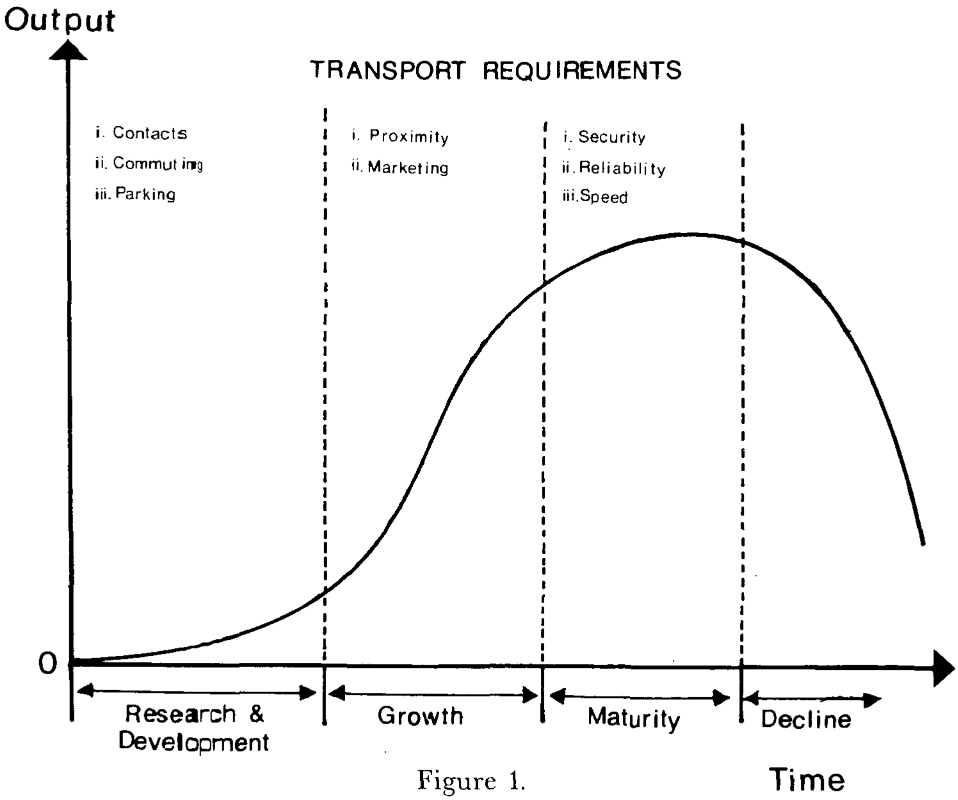

Figure 1.

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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