Transport Demands of Scotland's High-Technology Industries

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The nature of U.K. industry has changed considerably over the past two decades. Traditional industries have declined with the advent of high-technology products. Equally, production techniques of the established sector have also been subjected to major change. This paper looks at the role transport now plays in the new industrial situation and the different pressures that high-technology manufacturing industry is placing on transport suppliers. The paper takes, as a case study, the transport needs of the high-technology enclave known as Silicon Glen in central Scotland and examines how a sample of high-technology firms use different transport modes and how transport fits both into their production process and into the way the local labor market functions.

The importance of suitable transport infrastructure in attracting industry to specific locations has long been recognized although the exact nature of the link has been the subject of some dispute. In the United Kingdom, the initial strategic planning of the trunk road system, for example, was to a large extent justified in terms of stimulating economic development and balanced growth (*1*). More recently, though, the link between transport and industrial location has been perceived to be weaker; the Armitage Inquiry (*2*), for instance, places transport costs toward the bottom of the list of influences affecting the location of factories or industrial distribution systems. An oft-cited reason for this view is that the financial costs of transport for modern, footloose firms constitute only a small part of total production costs. In truth, however, it seems more likely that the importance of transport lies somewhere between these extremes.

The changing nature of western economies, with the onset of postindustrialization combined with major shifts away from the traditional industries in the manufacturing sector, means that a better understanding of linkages between modern industry and transport would help future infrastructure planning.

In the specific context of high-technology industry, the role of transport in influencing location has, in the past, proved difficult to isolate. The work that has been done is primarily American. Rosenfeld et al. (*3*), for example, found that in the southern states, while pockets of growth have occurred in rural counties, "new technology industries grew [between 1977 and 1982] predominantly in counties with interstate corridors." In contrast, Glasmeier et al. (*4*), although finding that airport proximity was a significant attribute for an area seeking to attract high-technology firms, also found that the quality of the local freeway network was not. To add to this rather confused picture, while Hummon et al. (*5*) found that 60 percent of high-technology firms in Pennsylvania stated that Philadelphia International Airport was an important variable in their decision making (4 percent said it had no effect); Allen and Robertson (*6*) found that proximity to a commercial airport rated only 16th in order of importance in influencing location choices of high-technology firms and 17th when questions of expansion arose. The most extreme position has perhaps been taken by the U.S. Congress Joint Economic Committee (*7*), "The traditional locational factors of access to markets and raw materials [are] not important factors for high-technology plant location decisions."

The evidence available in the United Kingdom is, to date, much less extensive. There is some general indication (*8*) that proximity, which is not explicitly defined or quantified, to international aviation services and to a good road network is helpful in attracting research and development (R&D) firms to science parks. A more thorough study of the M4 Corridor in Berkshire highlighted the importance of access to Heathrow Airport and to the national motorway system in the decision making of electronics companies (*9*). Some relevant details from this latter study are set out in Table 1.

There are a number of reasons why the work in this area is relatively thin and why the studies that have been completed often generate conflicting results.

First, high technology is difficult to define in a way that generates data suitable for quantitative analysis. Those who have studied the sector, be it in terms of labor needs, transport use, or technology diffusion, have used a variety of definitions, usually based on groupings derived from the official Standard Industrial Classifications (SIC) (*10*) for a comparison of some of the groupings of SIC industrial classes used in empirical work. Sometimes the definition is essentially subjective (i.e., the investigator simply takes

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TABLE 1 INFLUENCE OF TRANSPORT AVAILABILITY ON FIRMS LOCATING IN BERKSHIRE (*9*)

Communications	Percentage of Firms		
	Single Firm Firms	Multi-Site Firms	Total Firms
Heathrow Airport	77	72	75
Other Airports	9	11	10
M4 Motorway	73	50	63
Other Motorways & Major Roads	36	44	40
Rail Network	23	22	23

those SIC industries "felt" to be high technology); while on other occasions, more specific criteria are employed (e.g., the percentage of personnel engaged in R&D or officially classified as scientists, engineers, and technicians). While the latter approach is often claimed to be objective, it in fact requires judgment regarding critical cutoff points. The major problem with all approaches that rely on the SIC categorization is that, even at the lowest level of aggregation, each SIC category contains a mix of high- and low-technology firms, making meaningful analysis difficult.

Second, this problem is linked with the need to decide whether one draws the boundaries of high-technology industry simply around the manufacture of high-technology products or whether the domain includes the high-technology service industries and/or those traditional industries, such as automobile manufacturing and textiles, that have introduced robotics into their production process and computers into their design work.

Third, on the other side of the equation, there is the problem of specifying exactly what constitutes the transport input into high-technology production. Traditionally, analyses of industrial location and production costs have focused on the financial transport costs of distributing final outputs to market and of acquiring necessary raw materials and intermediate goods. High-technology production (setting aside the issue of exact definitions for the moment), it is generally agreed, involves high-value products with short technical shelf lives resulting in concomitantly high inventory-holding costs. Consequently, speed and reliability in transportation are frequently more important than the simple financial costs involved. Additionally, many aspects of producing high-technology goods necessitate employing scarce, qualified personnel; and the ability to attract qualified workers may, to some extent, depend on local access to social and recreational facilities. Specification of the transport variable is, therefore, extremely difficult; and certainly use of accountancy data relating to the direct financial outlays of firms can be potentially misleading.

Fourth, and tied to the above because of the high inventory costs involved, high-technology firms tend to employ more up-to-date management procedures than traditional companies and have relatively sophisticated logistics systems (*11*). Consequently, at the micro-level of analysis, involving case study work, one needs to go beyond the simple transport or distribution management function within a company to study the entire production process. Because of the importance of communications in the sector and the development of ideas and concepts, person movements cannot be ignored.

Finally, high-technology goods, like all products, have a product life-cycle (*12*, *13*) with each product going successively through development, growth, maturity, and decline phases before finally becoming obsolete. With high-technology products, the first two phases are particularly important—indeed, are possibly the major characteristics—and these phases have transport implications somewhat different from those of the late phases. It is, thus, necessary when examining transport needs of high-technology industry to be clear about the exact phase under review rather than to average across entire life-cycles.

This study attempts to circumvent some of these problems by adopting a case-study-oriented approach. The empirical work focuses on a small number of firms located in a limited geographical area. Further, it concerns itself with only producers of high-technology goods and does not attempt to extend analysis to either the service sector or to the use of high-technology products in older industries. It relies on unstructured interviews, questionnaires, and observation rather than on statistical analysis of published data sets, the objective being to incorporate qualitative as well as quantitative factors. While this method may appear less rigorous in the sense that generalizations are less easy to make, it does avoid the potential pitfalls that can occur if one examines only hard numbers and relies on data averaged over a large set of often heterogeneous firms frequently involved in different stages of a product's life-cycle. In the U.K. context, this method also helps minimize the added complication that many high-technology plants are foreign owned and fulfill the role of providing back-door access to European markets by U.S. and Japanese companies. This latter feature of the U.K. industry means there is a wider picture to consider—a picture somewhat different from that examined in studies conducted in the United States.

SILICON GLEN

Silicon Glen in central Scotland and the M4 Corridor in the south of England are generally agreed to be the United Kingdom's two main high-technology production centers. There are, in addition, several major science parks (most notably Silicon Fen or the Cambridge Phenomenon in Cambridgeshire) and smaller geographical concentrations of production. The rationale for focusing on the Scottish high-technology sector is that, unlike the M4 Corridor, the transport system of the area is not totally dominated by

major national transport terminals (e.g., Heathrow Airport) or by the hubbing of the national motorway system. Nor has the area the overriding natural advantage of being adjacent to one of the world's leading financial centers or to a major market for high-technology products. Silicon Glen, like several other high-technology centers, enjoys good transport facilities; but decisions about locations and production require trading these off against other, less advantageous features of the area. It is also worth noting that the Scottish high-technology industry is important in its own right and represents a major growth sector in the Scottish economy. Table 2 is based on a definition of high-technology industry derived from an industrial grouping comprising the 10 industries with the highest ratio of intramural R&D to value added in the United Kingdom. The importance, in employment terms, of high-technology industry to Scotland in the early 1980s is indicated in Table 2. Employment has subsequently remained fairly stable. The output of these same 10 industrial classes nearly doubled between 1975 and 1983, when manufacturing output as a whole fell; and in 1984 there was a further 25-percent rise (Figure 1).

Just as an exact definition of high technology is elusive, so is the location of Silicon Glen. Some previous studies have defined it broadly to encompass the whole east-west corridor across central Scotland (*10*), while others have taken a much smaller area such as Glenrothes, north of Edinburgh across the Firth of Forth (*14*). Certainly the claims of the region around Edinburgh, encompassing the area to the west and north of the city, to be called Silicon Glen seem to be strong. Table 3 provides a breakdown of the U.K. location quotients for some of the sectors often deemed to be high-technology oriented. If one focuses purely on the Scottish high-technology sector, then the Fife region (together with the very north of Scotland) is the only one with a location quotient for R&D employment in excess of 2.0 (*15*). In addition, Lothian and Fife represent major exporting regions contributing a substantial part of the increase in electronics exports, from $593 million in 1980 to $1,300 million in 1983. For these reasons, the region is important for the future of the national economy.

TABLE 2 EMPLOYMENT IN HIGH-TECHNOLOGY INDUSTRY IN SCOTLAND

	1979	1980	1981	1982
High-Technology Employment in Scotland	45400	47900	47500	46200
Share of High-Technology in Manufacture Employment	7.9	9.0	10.0	10.3

(Source: C.M.J.McKay, A Note on High Technology Manufacturing in Scotland, *Scottish Economic Bulletin*, No. 32, 1985, pp.10-11.)

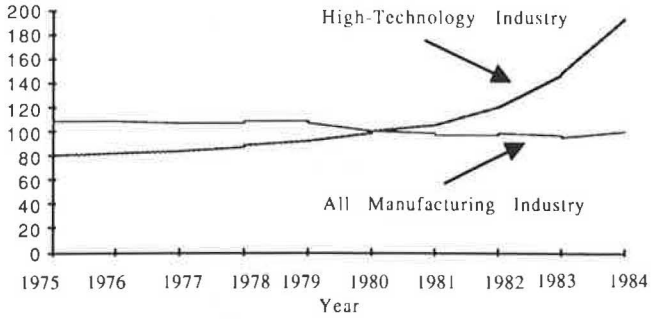

FIGURE 1 Index of production for Scotland (1980 = 100).

The study area has an established transport infrastructure with links to both the main national trunk road network and the intercity rail system. Transport times to major European destinations by road and rail are given in Table 4. There are international air and sea terminals, including container ports at Leith and Grangemouth and airports at Prestwick, Glasgow, and Edinburgh, coupled with a small local airport at Glenrothes. The quality of access also depends on the availability of transport companies operating in the area. Some 30 TIR carriers operate around Edinburgh through 20 roll-on/roll-off points in the United Kingdom, and numerous domestic haulage companies also operate in the highly competitive market place. In addition, a number of international freight handlers, such as LEP Transport Ltd., IPEC, TNT, and MSAS, provide a comprehensive range of services including packaging, customs documentation, and pickup-and-delivery services.

Despite these transport facilities, however, there is still some concern about the access the area enjoys to the national market. Tyler and Kitson (*16*), using an index of transport costs, found less geographical variations between regions than some of the earlier studies did. Nevertheless, the Edinburgh area still showed a transport index of 2.18 for mechanical engineering and of 2.36 for export-oriented activities (the lowest cost locations having the base index of 1.00). The relevance of Tyler and Kitson's study for high-technology industries, however, is uncertain given the industries' particular characteristics and the study's exclusive focus on freight movements.

SAMPLE

The definition of high-technology industry, as emphasized above, is problematic. Indeed, given the heterogeneity of both product and production methods within a single industry, the notion of high-technology industry has been dismissed by some (*17*). There seems to be a general

consensus, however, of what is meant by a high-technology firm (although this may well differ between countries depending on the overall state of economic development), and it is this concept that is favored here. The firms subjected to detailed, case study examination were selected following discussions with area economic agencies, local government personnel, consultants who have been actively involved in high-technology industry, and academics at local research centers. The vast majority of the firms sampled were located in the "new towns" of Livingston (to the west of Edinburgh) and Glenrothes (to the north).

In all, some 16 companies were initially involved, although one ceased to produce in the area in late 1986 and has been excluded from the analysis. Lengthy interviews were held at the firms' plants with transport, personnel, marketing, and production management; and the logistics systems in operation were inspected. Details of the size and ownership of the companies are set out in Table 5. The dominance of U.S. and, more recently, Japanese involvement in the area is apparent. The firms were also relatively large; their primary function was the manufacture of high-technology components or the assembly of finished goods, although, in several cases, they also undertook product development and marketing activities.

Table 6 provides a subjective assessment of the mode of competition of the various firms and offers a general guide to the stage in the product life-cycle in which their particular activities fall (*18*). Innovation is important at the earlier stages of the life-cycle; cost, at the maturity and decline phases. The role of transport is likely to differ according to the firm's mode of competition. Most of the sample firms, mainly foreign-controlled plants, are at the latter end of the product life-cycle (i.e., when customer service and low-cost production become important). One would anticipate from the previous studies of links between product life-cycles and transport (*12*, *18*) that these plants would be seeking reliable transport (for customer service) or economy in movement (for cost leadership).

The length of time the firms had been located in Silicon Glen varied, although 60 percent had been established on their premises since 1980. The newness of the firms, coupled with the high level of foreign ownership, is fairly typical of the high-technology industry in the area. Overall, figures from the New Town Development Corporation

TABLE 4 TRANSPORT TIMES TO EUROPE FROM CENTRAL SCOTLAND

Destination	Days Taken	
	Rail	Road
London	1/2	1
Paris	2	2
Brussels	2	2
Frankfurt	3	2
Milan	3	4
Copenhagen	4	3
Berlin	5	3
Rome	4	4
Oslo	5	3
Dublin	1	1

TABLE 3 LOCATION QUOTIENTS FOR COUNTIES FOR INDIVIDUAL HIGH-TECHNOLOGY SECTORS: 1981 DATA (*9*)

Location Quotient	MLH272	MLH363	MLH364	MLH365	MLH366	MLH367	MLH383
8.0+				Mid-Glamorgan Essex			
7.5-8.0					Berkshire		
7.0-7.5					Hertfordshire		
6.5-7.0		**Fife Region**					Avon
5.5-6.0							Isle of Wight
5.0-5.5	Nottinghamshire West Sussex						Somerset
4.5-5.0	Cheshire	Cleveland Nottinghamshire					Hertfordshire Derbyshire Lancashire Clwyd
4.0-4.5		West Midlands				West Sussex	
3.5-4.0	Hertfordshire	Merseyside	**Fife Region**		Hampshire	**Fife Region** Berkshire	
3.0-3.5			Essex	Hampshire		**Lothian Region** Hertfordshire Essex Dorset	
2.5-3.0	Kent		Bedfordshire Mid-Glamorgan		Staffordshire	Surrey	Gloucestershire
2.0-2.5	Merseyside		Wiltshire West Sussex			Kent Hampshire	Dorset Surrey

List Headings: 272 - Pharmaceuticals; 363 - Telegraph & Telephones; 364 - Radio & Electronic; 365 - Broadcast Sound; 366 - Electronic Computers; 367 - Radio, Radar & Electronics; 383 - Aerospace.

TABLE 5 CHARACTERISTICS OF SAMPLE FIRMS

Employees	Number of Firms	Ownership
11-50	3	UK(1); France(1);Japan(1)
51-100	3	USA(2); Japan(1)
101-400	3	UK(1); USA(1); Japan(1)
401-600	3	USA(2); UK(1)
601-1000	2	USA(2)
1001+	1	UK(1)

TABLE 6 MODES OF COMPETITION ENGAGED IN BY SAMPLE FIRMS

Mode of Competition	Number of Firms
Product Innovation	6
Consumer Service	4
Cost Leadership	5

show that in Livingston 41.9 percent of employees work in externally owned, mainly foreign multinational companies; and in Glenrothes, 37 percent.

The companies interviewed were also typical of those in the region in that they were predominantly from the electronics sector. They were, however, chosen so as to encompass the main high-technology activities within this sector, ranging from silicon wafer circuiting to the production of video machines and from the manufacture of computers to the production of technical ceramics. Those interviewed confirmed that their use of transport was much the same as that of similar companies in the area; indeed, several of the personnel had previously been employed by other local companies.

In terms of factor and goods movements, the foreign-owned firms tended to bring inputs from the United States and Japan (with smaller flows from continental Europe), process them in combination with U.K. inputs, and then distribute them to the U.K. market and continental Europe, especially the European Economic Community (*19*). The U.K.-owned firms served mainly the domestic market; defense equipment was a dominant feature of their production. This picture fits closely with an earlier study by the Scottish Development Agency which showed that 80 percent of foreign-owned electronics multinationals in Scotland were selling more than 20 percent of their output overseas compared with only 41 percent of Scottish-owned firms.

SIMPLE ANALYSIS OF TRANSPORT USED

A simple questionnaire approach, asking transport managers about the transport modes used to bring inputs to the plants and those used to distribute the final products to markets, yielded the results seen in Figures 2 and 3. This form of analysis has, in the past, been widely used in the study of transport utilization in the production process. As one can observe, air transport plays a central role and appears to be more important than is generally the case with traditional industries—a reflection of both the physical nature of the materials involved and the international orientation of the firms located in Silicon Glen. The contrast with other industries in the area is clear if reference is made to a recent study of the transport demands of a mixed group of local firms carried out in conjunction with the planning of the Edinburgh City By-Pass (*20*).

The usefulness of such analysis is, however, questionable. It is clear that many of the companies make extensive use of forwarders and have very limited knowledge of the forms of transport actually used, while others tended to respond to the questions excessively in terms of the dominant, usually trunk haul, segment of a trip. For this latter reason, shipping emerges as important to many firms; their transport movements involving roll-on/roll-off ferries are classified as "by sea" rather than "by road." In some instances where, for example, a manager thinks a consignment is going by air (because it has a flight number), it is actually taken by road; Scotland to/from London "flights" are often of this nature.

Responses to questions on the importance of transport considerations in decisions regarding plant location were bland. No factor emerged as central, although given the predominance of overseas involvements, it is unlikely that such decisions would be taken in the United Kingdom anyway. Indeed, discussions with the main planning agencies in the region suggest that, in their experience, the availability of suitable sites is generally a dominant factor influencing the location of footloose firms, although there must be at least a reasonable access to markets. The availability of government grants was also a force attracting firms to the area.

There was a general view, however, that the transport in the area met satisfying criteria in the sense that while Silicon Glen seldom offered a cost-minimizing location it did, in general, at least meet necessary threshold conditions. Many firms perceived attributes of the transport system as exceeding these thresholds. In particular, the customs facilities for international movements were felt to be more expeditious than those at London air terminals, while the pressure of competition ensured high-quality but low-cost public road haulage. The ability to bring inputs from the Far East and the United States through Prestwick and, to a lesser degree, Glasgow airports; to move them by motorway directly to Livingston and Glenrothes; and then to export to European markets through Edinburgh and England's east coast roll-on/roll-off ports was commented upon favorably by most of the firms interviewed.

Given the rather limited use such information has for transport planning and policy development, however, a more extensive series of interviews was conducted with both personnel employed by the high-technology firms and those providing transport services.

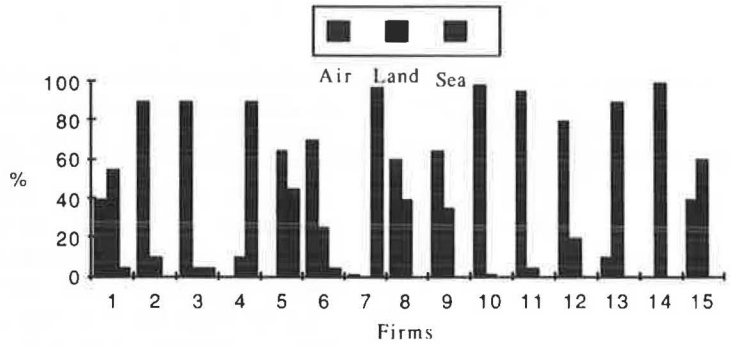

FIGURE 2 Transport employed for inputs to sample firms.

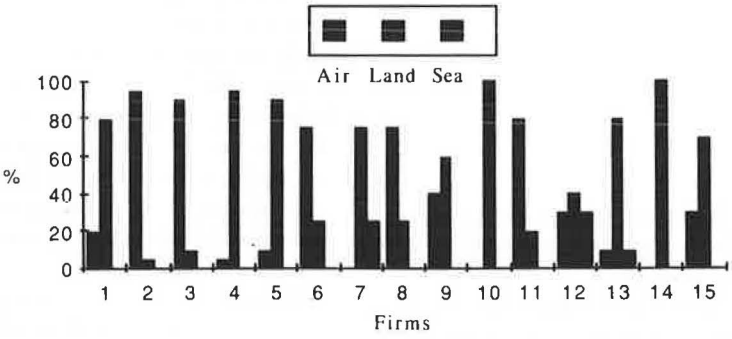

FIGURE 3 Transport employed for outputs of sample firms.

TRANSPORT OF FACTOR INPUTS

Cognizance of the inventory costs involved in handling large stocks of components, raw materials, and final products has led to the development of "just-in-time" production techniques; that is, parts and raw materials arrive at the production plant just as they are needed in the manufacturing process. This technique yields a number of potential benefits:

- Reductions in the amount of cash tied up in idle inventories,
- Stimulation of suppliers and dispatchers to greater efficiency,
- Reduced risk of being left with obsolete stocks, and
- Reduced wastage and improved quality in the production process as workers are forced to solve problems as they occur rather than to draw on inventories and leave difficulties unresolved.

While just-in-time techniques are not unique to the high-technology sector, the nature of its products and the speed of technical progress has encouraged its adoption by many firms. Its employment means that transport needs to be considered as part of an integrated production process with production management closely linked to the logistics side of the business. There must be fine-tuning of the production process coupled with liaison between production management, transport management, and the independent suppliers of transport services.

Of the 15 firms sampled, 10 claimed to be operating just-in-time management techniques and all were certainly aware of the concept although to varying degrees (perhaps not surprisingly, the Japanese and U.S. multinationals seemed to exhibit the most comprehensive analytical grasp of its meaning). Detailed examination of the actual procedures, however, revealed important differences in ways just-in-time operations are practiced and, indeed, suggest that many of the firms not claiming to have adopted the technique, in practical terms, pursue it more rigorously than some that do! Certainly, several of the plants surveyed were responsible for manufacturing at least two different products—usually one associated with high technology, the other not—and the levels of inventory-holding differed markedly between the lines. Management explained this in terms of purchasing attitudes of customers in the traditional sector where there is a tendency to place bulk orders intermittently and thus inventory-holding is pushed the full length of the production chain.

Even where just-in-time techniques are practiced, they are seldom pursued to the fullest extent. Table 7 provides a breakdown of the explanations offered by companies for not embracing a comprehensive just-in-time approach.

Interestingly, while the companies particularly concerned with improving their overall inventory handling consciously seemed to be seeking ways to improve the

TABLE 7 REASONS FOR NOT FULLY ADOPTING JUST-IN-TIME PRACTICES

Concerns	Firms*
Fear of damage to goods/inputs in transit	6
Possible delays for customers	2
Inappropriately designed factory	4
Poor quality of components affected continuous production	1
Lack of complete coordination between the transport function and the production	1
The particular needs of one-off,specialized products	2
The demands of some customers buying 'ex-works' leading to scheduling problems	1
Possible customs delays	2
Experimental and small size of plant	1
Economies of scale in bulk buying or carriage of inputs	2

*Several firms had more than one reason for not full adopting just-in-time procedures.

reliability of their transport usage and to reduce damage to consignments, only one had any substantial own-account fleet. This finding contrasts markedly with an earlier, more general study of the U.K. scientific and industrial instruments and systems industry; this study found that more than 70 percent of firms possessed their own transport facilities (*21*). The explanation may lie in the frequent need for specialized vehicles. In some cases, Silicon Glen firms had firmly tied themselves to a particular forwarder or hauler, one firm giving long-term contracts to allow special-purpose vehicles to be purchased to meet specific loading requirements, while another had a joint enterprise to develop a computerized inventory control and accounting system. More generally, the abundant supply of transport services meant that the high-technology companies regularly used a number of different transport firms and haulers to reap the price and service benefits generated in a competitive market place. Even where own account operations were still practiced, they were relatively long standing and were coming up for review.

Despite the problems in fully adopting just-in-time practices, the general movement was clearly in the direction of extending this type of operational approach. The longer-term impacts on the transport system are already emerging. Warehousing, in the traditional sense, is little used by the companies sampled or by the freight forwarders interviewed; major transport terminals themselves are used by the high-technology firms as consolidation points. Where warehousing is practiced, it is in highly automated facilities, again usually adjacent to major transport interchanges. From a public policy perspective the traditional warehousing facilities in the inner city areas or at ports are inappropriate for the needs of the industry.

Many of the firms were particularly concerned about the customs difficulties sometimes encountered. The problems stemmed more from uncertainty about the length of time a consignment would take to clear customs than from the actual process itself. The largest firms with substantial and regular flows of both imports and exports had arrangements for bonded areas at their factories with clearance done there. The medium and smaller concerns found customs clearance the greatest impediment to their operations.

Again, from the public policy perspective, there was concern that many of the factories available were ill equipped to deal with rapid loading and efficient intrafactory handling. While there are clear implications for publicly financed advanced factory design, the complaint was voiced by one plant manager with respect to a company-designed and built factory.

Modal interchange points also posed difficulties for many of the firms concerned with reliability and safety in their transport operations. Nearly half of the companies interviewed spoke of forwarders explaining delays or damage as being due to problems of interchange facilities. Road/air interchange posed particular problems because it is here that the damage to the more highly valued products tends to be greatest. Many companies had developed specialized packaging or had modified existing packaging in general use in plants in other countries to meet this particular problem. In a slightly different context, one major multinational user of road transport had been forced to develop more protective containers for its components because of damage incurred in transit from U.K. ports despite the adequacy of standard packaging for movements across continental Europe.

EXPRESS PARCEL SERVICES

High-technology products, especially those manufactured by the electronics industry, are frequently small items that require rapid delivery. The need for transport systems to meet this demand extends into the R&D activities of companies and the shipment of documents, spare parts, and samples. In the United States, express parcel services have grown to fill this niche in the market (e.g., the industry grew by some 38 percent between 1984 and 1985), and there is now a prospering 24-hr delivery service. The use of express parcel services is also growing in Europe although with something of a lag attached to it. A recent survey of 61 U.K. firms revealed that some 24 different operators were providing express parcel delivery, although Datapost, TNT Overnite, and Securicor Parcels in aggregate held more than 50 percent of the market (*22*).

With one exception, all the firms interviewed in Silicon Glen had used express parcel services in the preceding 3 mo. Some used the same carriers on a regular basis (Table 8), although many companies seemed to have no preferred

TABLE 8 EXPRESS PARCEL SERVICES USED BY SAMPLE FIRMS

Service	Firms
Pandair	1
TNT	5
DHL	3
Red Star	5
Elan	3
No Regular Carrier	5

carrier, and even those that did frequently employed other carriers on an almost casual basis. In several cases, the express parcel services were perceived as backups for regular road haulage operations or air transport. Several large high-technology companies predicted that express parcel services, now extensively employed for transfers of documentation, were likely to be rapidly superseded by electronic transfers of documentation. Further, two of the largest multinationals in Silicon Glen preferred courier services to express parcel service for transporting their sensitive documentation, believing courier service to be not only more secure, but also more cost effective, reliable, and flexible.

PERSONNEL TRANSPORTATION

High-technology industry is often thought to involve considerable numbers of highly qualified individuals. Certainly high levels of technical expertise are required at the R&D stage—the first stage—of the product life-cycle of most high-technology products. In the case of Silicon Glen, however, much of the activity is at later stages in the cycle (most Japanese and U.S. firms maintain their primary R&D units in the home country). The argument that superior international transport is required to keep the region's research personnel at the cutting edge of their fields is, therefore, less valid than would be the case if one were looking at a science park. The area's industry is, however, heavily engaged in the marketing as well as the manufacture of high-technology products. For example, at the time of the survey (summer 1986) five of the companies visited had personnel in Finland, a country striving to develop its own high-technology base. Equally, the multinational nature of many of the firms means there is substantial intracompany travel, particularly between Silicon Glen and the plants and offices in rest of the United Kingdom and in other EEC countries.

The importance of Edinburgh Airport as a gateway to the main international terminals of Heathrow (which, through the Shuttle Service, accounts for about 60 percent of the airport's traffic) and Amsterdam was confirmed by all 15 companies although Glasgow Airport, because of its motorway link to Livingston, also attracted business travel. The Scottish air link to the United States from Prestwick (via Shannon) was felt to be of limited use because the service was restricted and few personnel had final destinations at eastern U.S. gateways. (Prestwick was, however, seen as a useful freight terminal for U.S. traffic.) The range of European flights available from Edinburgh and Glasgow was considered very important by marketing personnel although all felt that high European air fares under the current regulated regime were a disadvantage when contrasted with the much more liberal system in the United States.

Small, special-purpose commuter-style airports located very close to the high-technology centers, such as Glenrothes, were not seen as part of the main transport system. This view stems primarily from the ease of road access at larger, regional facilities, such as Edinburgh and Glasgow airports, and tends to confirm the importance of accessibility, rather than proximity, highlighted in a recent study of Pennsylvania's high-technology industry (*23*). In the particular conditions of the United Kingdom, the low overall volume of air travel also means that smaller airports, close to more substantive alternatives, simply cannot generate enough traffic to offer viable services. In other areas of the United Kingdom where there are pockets of high-technology activity, e.g., in the South West, there are successful small local airports but they are distant from regional facilities.

Local transport is also important for the continued success of a high-technology center. "Burnout" in some of the U.S. centers is feared by some as those with the vital technical skills leave them in search of better living environments. Polls in high-technology centers such as Atlanta, Houston, and the Bay Area have shown that traffic congestion heads the list of perceived regional problems (*24*).

Congestion is relative. Traffic congestion in the Edinburgh region would seem mild to someone used to London or New York traffic, but it is nevertheless perceived as severe by some living and working in the area. One firm in Livingston, for instance, which has a large number of professional employees, expressed serious concern about 5-min delays at a roundabout during the evening peak travel period. Thus, while congestion may be minimal measured against traffic problems in larger cities, at the eastern end of Silicon Glen it is still noticeable. Also, the need to cross the Firth of Forth Bridge (and pay a toll) to travel between Glenrothes and Edinburgh, while not a major time or financial burden, was perceived as a disadvantage to firms in the area.

The observed split in modes of travel to work in the Livingston and Glenrothes areas is not out of line with that reported in U.S. high-technology areas; the car mode dominates, and public transport use is lower than in most comparable U.K. towns. Three of the firms surveyed had, for internal reasons, just looked at the travel-to-and-from-work patterns of their employees. The professional employees, as anticipated, used private motor cars with a limited amount of carpooling. To accommodate these drivers, all the recently constructed factories in the New Towns have extremely generous car parking provision—a point insisted on by the development agencies.

Assembly workers and other blue collar employees, who constitute most of the labor force at the high-technology firms in Silicon Glen, also traveled predominantly by car,

although with a high incidence of carpooling. The companies that conducted the inquiries initially believed that the poor quality of local public transport was the reason so many workers commuted by car. In fact, the companies' objective had been to see if some alternative could be arranged. Indeed, public transport in the areas provides poor service for most high-technology firms. Many of those working in Livingston reverse commute from Edinburgh against a public bus service geared for radial movements into the city. Within Livingston, the Buchanan style of town planning has sited the high-technology plants on estates located at the far corners of the town, whereas the local public transport links housing estates to shopping and recreational areas. There is effectively no public transport for late-shift workers, and several of the larger firms regularly operate a full, three-shift system. The studies by the three firms, however, found little support for a private bus service, especially at night; and there was in all cases a feeling that existing carpooling arrangements worked well. Nevertheless, one of the companies does offer subsidized taxi service at night; the reported usage was small.

CONCLUDING COMMENTS

The work reported here lacks technical rigor in the sense that there is no in-depth, quantitative analysis, but rather an attempt to explore the less easily measured factors influencing the demands high-technology industry places on the transport system. Conclusions must, therefore, be rather tentative, but the case study reported in the body of the paper has provided a number of pointers that may help in the long-term formulation of transport policy.

This study of Silicon Glen in central Scotland has confirmed that good transport by itself is insufficient to attract high-technology industry to an area. Equally, it has shown that adequate transport, of the appropriate type, is necessary to stimulate high-technology production. Not only is adequate transport an important direct input into the production process, but it also plays a vital secondary role in assisting in marketing and in the efficient operation of the local labor market. The generality of these findings must be set in the particular setting of the type of firm found in Silicon Glen. It is unlikely, for instance, that they extend to the science-park type of high-technology concentrations where physical output is much smaller and R&D-related employment much greater. Equally Silicon Glen is dominated by large multinational companies with interests somewhat different from those of most U.K.-owned high-technology companies. The evolving internationalization of production, which is being stimulated by the growth of trade barriers, is likely to see this particular type of geographical concentration of multinational firms grow in number.

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