LOGISTICS AND LAND: THE CHANGING LAND USE REQUIREMENTS OF LOGISTICAL ACTIVITY

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Introduction

Of all the resources required to support logistics operations, land is arguably the one which has received the least attention from academic researchers. A few articles on the subject have appeared in geographical journals (e.g. McKinnon, 1983; Hesse, 2004 and Bowen, 2008), but there has been little discussion in the mainstream logistics literature of the changing nature and scale of logistics-related demand for land. Most logistics modelling simply assumes that there will be enough suitably-zoned land available accommodate all the necessary storage, handling and transport activities in or around optimal locations. Very limited consideration has been given to the total amount of land required by logistics and how this is likely to change in the longer term. This has been the subject of a review undertaken for the UK government's Foresight Programme in a project entitled 'Land Use Futures' (Foresight, 2009). The aim of this project is 't*o explore how land use in the UK could change over the next 50 years… examining society's future needs and values towards land use*.'

This paper summarises the main findings of the part of the project concerned with logistics. It begins with a taxonomy of logistics-related land uses and then focuses on the category with the largest 'footprint' – i.e. warehousing. Recent trends in the demand for warehouse land in the UK are analysed using data from government sources and commercial property companies. Attempts to forecast the future demand for warehouse space on the basis of GDP projections are challenged on the grounds that they ignore a series of developments likely to distort the relationship between warehouse space and economic growth over the next few decades. The paper examines seven of these developments and concludes by presenting an integrated model showing the inter-dependencies between factors likely to affect the future land requirements of logistics in the UK.

Classification of Logistics-related Land Uses

Figure 1 provides a three-level classification of the range of logistical activities requiring land. Collectively, they consume a substantial proportion of land zoned for commercial and industrial use. On the basis of available data, it is not possible to estimate exactly how much land they occupy. Official figures do exist for warehousing, the dominant logistics land use. In 2006, there were approximately 151 million square metres of warehouse floorspace in England and Wales (Dept of Communities and Local Government, 2007). Assuming an average plot ratio of 45% (Roger Tym & Partners et al, 2004), the amount of land on warehouse sites would have totalled 23,500 hectares, equivalent to 0.8% of non-agricultural and forestry land. In addition to storage space in buildings, there is also extensive use of land for outdoor storage of primary products and waste material. Freight terminals also occupy significant expanses of land, some of which is shared with the movement of people. No reference will be made in this paper to land area covered by road and rail networks, mainly because this is used primarily for the movement of people rather than freight.

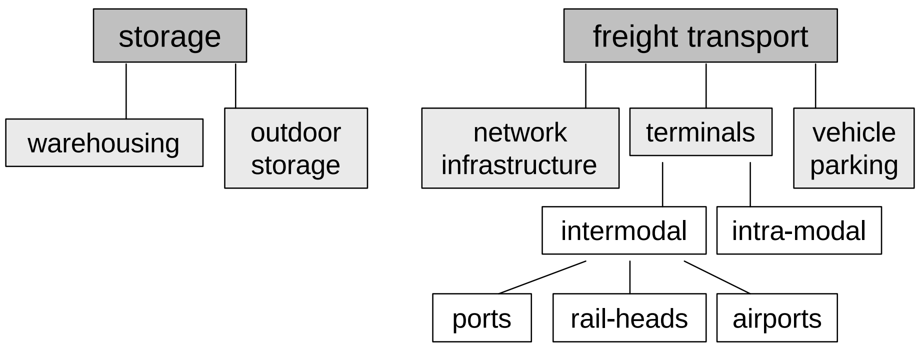

Figure 1: Taxonomy of Logistics-related Land Uses

Recent Growth in Demand for Logistics-related Land.

Warehousing

Between 1998 and 2004 warehouse floorspace in the UK grew steadily at an average rate of 2.5% per annum, roughly in line with the growth of GDP (Dept. of Communities and Local Government, 2007) (Figure 2). The relationship between GDP and warehouse floorspace is, however, more complex than this close correlation would suggest. It can be split into two key ratios, GDP to inventory and inventory to warehouse floorspace, which can vary independently. Between 1986 and 2004 the ratio of manufacturing, wholesale and retail sales to inventory (i.e. the 'stock turn' rate) increased from around 7.2 to 12.1 (Dept for Transport, 2006)[1]. This means that companies are holding smaller amounts of inventory relative to output and suggests that there should be some decoupling of GDP from warehouse floorspace. Net changes in the second ratio, of inventory to warehouse floorspace, appear to offset this trend. One might expect the amount of warehousing floorspace to be related to the value of inventory in the economy as warehousing is essentially the physical accommodation of this stock. Overall, however, the ratio of inventory (expressed in monetary terms) to warehouse floorspace appears to be declining. This means that the amount of floorspace per £ billion of inventory is increasing. Further research will be required to explain this trend, though it is likely to be influenced by a series of developments, some increasing the inventory : floorspace ratio, others having the opposite effect:

1. The 'value density' of inventory (i.e. ratio of cubic volume to value) changes through time.
2. Inventory is also stored in other types of building (mainly shops and factories), in outdoor locations and in transit. It is not known what proportion of total inventory is held indoors in warehouses.
3. Warehouse space is not simply used for storage. Most warehouses perform other functions such as goods handling, order picking, product customisation and recycling, all of which occupy space.
4. Warehouse floorspace is a 2-dimensional measure, whereas storage capacity is essentially cubic. Warehouses, and their internal racking systems, have been getting taller, distorting the relationship between floorspace and inventory-holding capacity.
5. The amounts of vacant warehouse space (both speculative new-build capacity and older premises) vary significantly through time, in line with both the general level of economic activity and commercial property cycles.

The trend in warehouse floorspace has sharply diverged from that of factory floorspace since the late 1990s. Factory floorspace rose slightly between 1999 and 2001 and then fell back to its 1998 level (Figure 2). Superficially, these divergent trends seem to reflect the switch from a manufacturing-based economy to a service-driven economy relying on high levels of import penetration. Hunt (2006) bemoans Britain's evolution from the '*workshop of the world*' to the *'warehouse of the world*' with '*mushrooming acreage of mega-sheds and depot centres undermining civic life and our manufacturing base*'. He asserts that, '*the liberalisation of world trade and the influx of manufactured goods from India and China mean that Britain has no option but to erect ever larger warehouses'.*

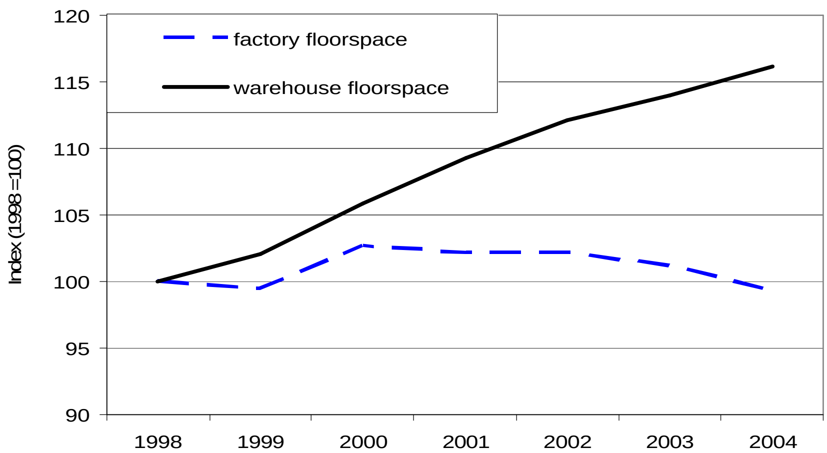

Figure 2: UK Trends in Warehouse and Factory Floorspace, 1998-2004
(Source: Dept of Communities and Local Government, 2007)

[1] Sleeman et al (2003) found that the ratio of inventory to gross value added in the UK economy declined by only 1% between 1992 and 2001, though by 9.6% between 1986 and 2001.

Over the past decade, there has been a strong demand for large new distribution centres (DCs) with floorspace in excess of 10,000 square metres (King Sturge, 2008). Between 1996 and 2008, around 45-50 of these new DCs were set up annually, their average size doubling from around 20,000 square metres to 40,000 square metres. Much of the new development of these large DCs has been speculative. At the end of March 2008, 2.6 m square metres of warehouse in these DCs was vacant or under construction. Since 2004 roughly 60% of the demand for large DCs has come from retailers, with manufacturers' and logistics companies' share varying between 10 and 20%. Not all the growth of warehouse space has been in newly-built DC's with 10,000 sq metres or more of floorspace. Many smaller warehouses have also been built in recent years and many factories / light industrial units have been converted to storage / distribution. For example, Amazon's two DCs in Scotland were previously electronics plants. Sleeman et al. (2003) observed that a '*creeping differentiation (was) taking place in the distribution property market. No longer does one size, the 'big box' fit all'* (p.8).

Other logistics-related land uses

In assessing the overall land use footprint of logistical activities in the UK, consideration must also be given to the other types of premises classified in Figure 1. Quantifying the extent of this footprint is very difficult as there are no national statistical on the amount of land occupied by the diverse range of logistics facilities, other than warehousing. Assessing the logistics land-take at ports and airports is complicated by the sharing of space between freight and passenger operations.

Lorries generally have dedicated parking space at motorway service stations and standalone 'truck-stops'. Trade bodies have complained for many years that overnight parking facilities for the trucks in the UK are lacking both in capacity and quality. The amount of space available along major transport corridors has not increased in line with the growth of lorry traffic.

The sharp decline in the amount of freight moved by rail between the 1960s and late 1990s was accompanied by the conversion of much railway land in and around marshalling yards, goods depots and rail sidings to other uses, such as housing, business services and retailing (Haywood, 1999). These trends have recently been reversed. The growth in rail freight traffic since privatisation in 1996 has increased the demand for land at strategic locations on the rail network for the development of both intermodal terminals and rail-connected warehouses and factories. Details of current terminal development are provided by Network Rail (2008).

Future Trends in Logistics Land Requirements

Forecasting the demand for warehouse space

An attempt has been made to forecast the future demand for warehouse capacity in Greater London (URS Corporation, 2006). Analysis of the historic warehouse growth trend in London revealed a very close correlation between warehouse floorspace and London's gross value added (GVA) (r=0.96). This formed the basis of an extrapolatory forecast to 2025 predicated on the assumption that GVA would grow around 2.5-3% annually over this period (Figure 3). This study also reviewed a series of logistics developments which might influence the future demand for warehousing space but no attempt was made to incorporate these causal factors into the forecasting model.

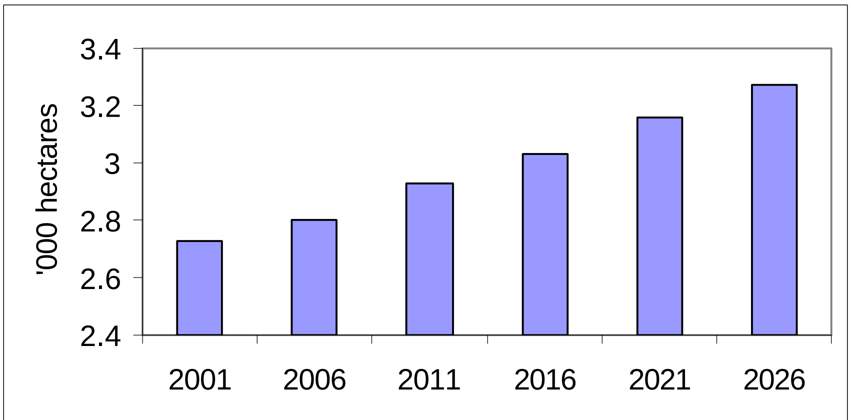

Figure 3: Projected Growth of Warehouse Floorspace in London
(Source: URS Corporation, 2006)

The past relationship between warehouse floorspace and the level of economic activity is likely to be distorted over the next few decades by several developments. Attention here will focus on seven of the most important ones.

- Off-shoring of manufacturing and upstream supply chains
- Increase in the relative cost of freight transport
- Transfer of freight to more environmentally sustainable transport modes
- Growth of online retailing
- Advances in warehouse technology
- Restructuring of the waste supply chain
- Adaptation of logistics systems to the effects of climate change

Off-shoring of manufacturing and upstream supply chains

Over recent decades there has been a massive shift of industrial capacity from developed countries to the low labour cost countries of the Far East and Eastern Europe (Dicken, 2007). Many UK-based companies have relocated manufacturing plants to these countries or been forced to scale down / close their operations in the face of intensifying global competition. When a manufacturing plant is relocated to another country or its output is replaced by imports, the upstream supply chain also moves off-shore and with it the related storage requirements. Manufactured goods are imported to the UK in their finished form, generally through ports. Complex supply chains built around indigenous manufacturing and comprising several storage / handling nodes are then replaced by simple one- or two-tier chains for imported product with much less storage / handling capacity. The development of port-centric logistics, involving the 'de-stuffing' of containers and storage of products in port-based distribution centres, is nevertheless increasing the demand for warehouse land in the vicinity of major ports (Mangan et al, 2007). Tesco, ASDA and B&Q, for example, have set up major new DCs at Teesport. Much of this new space, however, is effectively replacing other warehousing capacity and does not necessarily a net increase in to the country's total warehouse stock. This off-shoring of UK manufacturing capacity and related increase in import penetration, which is reducing upstream warehouse space requirements and shifting demand for finished goods warehousing to the ports, is likely to continue in the short- to medium-term.

It is also possible that warehousing will off-shore to the European mainland. Inventory centralisation, which is now at an advanced stage at a national scale within the UK, has been active at a continental level since the early 1990s. Major companies have been moving from country-based distribution systems to 'pan-European' systems focused on a single warehouse or a few multi-country warehouses. This trend has already eroded warehouse capacity from the UK and increased the quantity of goods supplied to British customers from stockholding locations in neighbouring countries. The UK's island status, the higher cost per mile of transporting goods into the country, its relatively congested infrastructure and customer pressure for rapid delivery will, however, limit the extent to which companies transfer the stockholding function, and its related land-use requirements, to other countries.

Increase in the relative cost of freight transport

The centralisation of inventory, which has been a dominant logistics trend over the past 40 years, may be reversed by rising oil prices, the imposition of environmental taxes and worsening congestion / congestion charges which would inflate the real cost transport and tilt the logistical cost trade-offs between transport, inventory and warehousing back in favour of more decentralised patterns of stockholding (Gosier et al., 2008). This would be likely to increase the ratio of warehouse space to economic output and disperse this space more widely around the UK regions. The prospects of a return to more decentralised warehousing are limited, however, for several reasons:

- Company experience and computer modelling suggest that logistical cost trade-offs are very robust, particularly given the magnitude of the inventory and warehousing benefits that companies can achieve by centralising (McKinnon, 1998). Transport costs would therefore have to rise by a steep margin to induce a return to more localised warehousing.
- The use of local transhipment / break-bulk operations can help companies minimise the transport cost penalty associated with inventory centralisation. Sharp increases in transport costs may be more likely to cause a proliferation of transhipment depots than a decentralisation of inventory. While storage space would remain concentrated in large centralised facilities, additional land would be required for the construction of more small depots across the country.

- Fuel and carbon price increases and congestion will promote a modal shift to rail and water increasing the longer term sustainability of centralised warehousing (Kohn and Huge Brodin, 2008). The wider land use implications of this trend are explored in the next section.

In a recent Delphi survey, 100 logistics specialists were asked to predict a series of UK logistics trends to 2020. They gave the likelihood of inventory becoming more centralised by 2020 a 50% higher weighting than the probability of it decentralising, despite their prevailing opinion that transport costs would rise significantly over this period (Piecyk and McKinnon, 2009).

Transfer of freight to more environmentally sustainable transport modes

The pursuit of logistical sustainability, by government and business, will substantially increase the proportion of freight moved by rail and water-borne modes. Network Rail (2007) has projected a 26-28% growth in railfreight tonnage between 2004 and 2015. The fastest growth of rail freight tonnage is anticipated in the intermodal sectors (Channel Tunnel, Domestic Intermodal and Maritime Container markets). Other sectors, such as Construction and Metals, where railfreight typically originates from industrial premises in railside locations are also expected to experience healthy growth. Overall, the predicted growth of rail's share of the freight market will entail a realignment of supply chains from the road network to rail and water-borne networks and spatial redistribution of terminal and storage capacity. As Haywood (1999) argues, *'the challenge for the future is to integrate the land use and transport planning systems in order to continue to rework the freight railway into the country's industrial and commercial fabric*' (p.276). This would effectively reverse the dominant trend of the past fifty years, which has seen the development of exclusively road-oriented production and distribution systems and disposal of large tracts of railway land. Most of this 'brownfield' land has been converted to alternative uses, mainly residential, retail and business services, which do not generate railfreight traffic.

Much of the new rail-related property development is likely to associated with intermodal services. New terminals will be required to increase accessibility to the rail network and minimise the length of road feeder movements, whose relatively high cost has tended to discourage the development of intermodal services. The land requirements of individual terminals will depend not only on their throughput but also the range of services based at the terminal site. The most basic terminal will provide open 'hard-standing' adjacent to rail sidings for short-term holding and transhipment of intermodal units. Intermodal terminals can also become a strategic location for DCs receiving and / or despatching a proportion of their throughput by rail. As rail's share of the freight market grows, more DCs will gravitate to these sites as property developers prioritise rail-side warehouse development. Several intermodal hubs of this type already exist in the UK at locations such as Daventry, Wakefield and Trafford Park, but not on the same scale as in other European countries, such as Germany with its Güterverkehrszentrum and Italy with its Interporti. If there were to be a major shift of freight trunk hauls from road to rail in the UK, for both domestic and international traffic, the demand would grow for logistics-related land around rail hubs.

Growth of online retailing

In terms of the share of total retail sales, Britain has the largest online retail market in the world and one of the fastest growing. In 2006, online retail sales grew thirteen-times faster than the total UK retail market (Verdict Research, 2007). Some specialists have predicted that once internet shopping's share of the retail market exceeds 15-20%, the viability of large sectors of the conventional retail market will be undermined and the switch to online retailing will rapidly accelerate. The shift from conventional to online retailing has major implications for the logistics property market at different spatial scales. DTZ Pieda (2001) identified four types logistics property development associated with online retailing (parcel hubs, regional DCs, local fulfilment centres and satellite collection points) and attempted to forecast the demand for warehousing floorspace in each type of facility by 2005. It is not known to what extent these forecasts have been realised. At a national scale, online retailing is rapidly increasing the proportion of merchandise channelled through the hub-and-spoke networks of parcel carriers. The number and capacity of both the large central 'sortation' hubs, mainly located in the English Midlands, and local depots will have to expand to accommodate the growth in volume. Upstream of these parcel networks are the warehouses of the online retailers where merchandise is stored and picked at an item level for home delivery. Their land requirements will also increase. To date, the growth of grocery home shopping has consumed very little additional land. The vast majority of online grocery orders are picked in existing supermarkets. Only two of the dedicated 'fulfilment centres' that have so far been set up (by Ocado in Hertfordshire and Tesco in Croydon) remain in operation. If online grocery sales continue to grow at their current rate, order fulfilment will gradually transfer from shops to a new generation of local depots. This displacement of grocery sales from supermarkets may result in a longer term reduction in retail floorspace, or possible conversion of some shops to 'pick centres' for online orders. Small shops, petrol stations and post offices are also being used at present as collection points for online orders of non-food products (Rowlands, 2007). One property company had plans to set up a network of 'E-stops', resembling superstores but specially-designed to act as local collection points for online orders. These have not yet been implemented. To date, only locker-banks have proven to be commercially viable and they predominantly serve the B2B market, providing pick-up points for service engineers and salesmen. As online sales volumes grow, the commercial case for investment in dedicated collection point networks will strength. Their total land-take, however, is likely to be small.

Advances in warehouse technology
One of the main effects of these advances is likely to be the intensification of warehouse land-use, reducing the amount of land required to store and handle a given amount of product. The development of high-bay warehouses, between 10 and 40 more metres high, dramatically reduces the ratio of throughput to floorspace / land area. Most of these warehouses have automated storage and retrieval systems (AS/RS). To date there has been relatively little development of high-bay ASRS warehouses in the UK by comparison with other developed countries such as Germany, Sweden, Japan and the US (Sleeman et al 2003). This can be attributed to several factors, including lower labour costs in the UK, concern that ASRS systems lack flexibility, difficulty of obtaining planning consent for tall warehouses in the UK, the high degree of logistics outsourcing in the UK on contractual periods that do not permit adequate payback for high-bay automated warehouses and a commercial bias against longer-term investment in the UK. The relaxation of any of these constraints in the longer term might result in greater development of high-bay warehouses in this country and corresponding reduction in the warehouse footprint relative to inventory levels and sales. The development and diffusion of more sophisticated warehouse management systems (WMS) will also improve the utilisation of warehouse space, increasing throughput per unit of floorspace.

While warehouse technology will intensify the use of floorspace within the building, the site coverage (or 'plot ratio') is predicted to decline as more extensive yards will be required around the DCs for manoeuvring and parking vehicles. Currently large DCs with floor area in excess of 10,000 square metres generate one truck visit per day per 1112 square metres of floorspace (Baker and Perotti, 2008). Many future DCs will be used essentially for 'cross-docking', have a limited storage function and be characterised by high traffic densities. Already such premises have plot ratios of between 25% and 35%, in contrast to the warehousing average of around 45% (Sleeman et al., 2003). The building footprint may contract but the amount of surrounding land increase, possibly resulting in little net change in overall land-take.

Restructuring of the waste supply chain
The fundamental shift in warehouse management from waste disposal in land fill sites to recycling and re-use is already well underway and gathering momentum (DEFRA, 2007). To meet its targets for the re-use and recycling of waste the UK is having to restructure its waste supply chain. This is having a major impact on the land requirements of 'reverse logistics' operations (McLeod et al, 2008). The amount of new land required for dumping waste is drastically reducing, while much more land is being devoted to the storage, recycling and incineration of waste material.

There has been a particular problem during the current recession in finding sufficient storage space for many forms of waste for which demand has slumped. The current storage 'crisis' in the waste sector is likely to be a temporary phenomenon, however, reflecting the immaturity of the market for recycled product. It is the result of recycling levels rising sharply, delays in the provision of new storage space and the steep economic downturn. As the waste market matures, more land will be required for both the storage (both indoor and outdoor) and processing of waste material.

Adaptation of logistics systems to the effects of climate change
Adaptation to the climate change already 'in the pipeline' will present major logistical challenges over the next few decades. Much of this adaptation will be necessary to reduce the exposure of logistical systems to rising sea-level and the increased frequency and severity of river flooding. It is not known what proportion of logistical facilities are at risk of flooding and may need flood protection or relocation. The centralisation of inventory in a relatively small number of large DCs over the past forty years has

increased the vulnerability of supply chains at these critical points. It is estimated, for example, on the basis of data in IGD (2008), that approximately three-quarters of retail grocery supplies in the UK are channelled through roughly 65 distribution centres. Much of the nation's storage and goods handling capacity is also concentrated in and around ports, which are at inherent risk of inundation should sea level rise by a significant margin and storm surges increase in intensity.

Climatic adaptation will also impose huge new demands on logistical systems. The construction of flood defences, a new energy infrastructure based on renewables, nuclear power and carbon capture and storage, replacement homes and commercial premises for those abandoned in coastal areas / flood plains will require the extraction, movement and storage of vast amounts of building materials. Additional land will have to be provided to meet these new logistical demands, mainly from the construction industry.

Conclusion

Figure 4 identifies the main factors likely to influence future requirements for logistics-related land and maps the inter-relationship between them. The main drivers will be a series of economic trends affecting the rate and composition of economic growth, the relative costs of key logistics inputs such as fuel, labour, capital and space, and the transfer of production and related supply chain activity to other countries. They will largely determine the amount of physical inventory requiring storage and handling. The total quantity of inventory in the economy is partly a function of its geographical distribution. The greater the degree of centralisation, the smaller the amount of inventory required to maintain a given level of product availability. This degree of centralisation will be influenced by future changes in the relative costs of logistics inputs and the evolution of management practices in this field. The amount of floorspace required to accommodate a given amount of physical inventory is likely to reduce as advances in warehouse technology increase the average height of racking systems and generally improve space utilisation. A contraction of the 2D storage footprint may be offset, however, by an increase in the range of other activities performed in and around warehouses which will consume land. An accelerating rate of product throughput will increase in the traffic density and create the need for more on-site truck parking and manoeuvring space. The strengthening flow of waste product moving back along the supply chain for sorting and recycling will also require more external, as well as internal, storage space. As a consequence, plot ratios may increase. The amount of land devoted to warehousing, the dominant logistics land use, will be supplemented by the future land requirements of other logistical activities such as goods handling, inter-modal transhipment, outdoor storage and vehicle parking. The overall demand for logistics-related land is likely to increase significantly and be spatially redistributed towards the rail network and ports and away from areas of high flood risk.

The framework also illustrates how policy intervention in the transport and land-use planning arenas can exert an influence. In practice, central and local government can play a much greater part in shaping the pattern of logistics-related land use than can be shown in this diagram. The amount of land required and its geographical distribution will be sensitive to a broad range of government policies, reflecting logistics' pervasive role in the life of the nation.

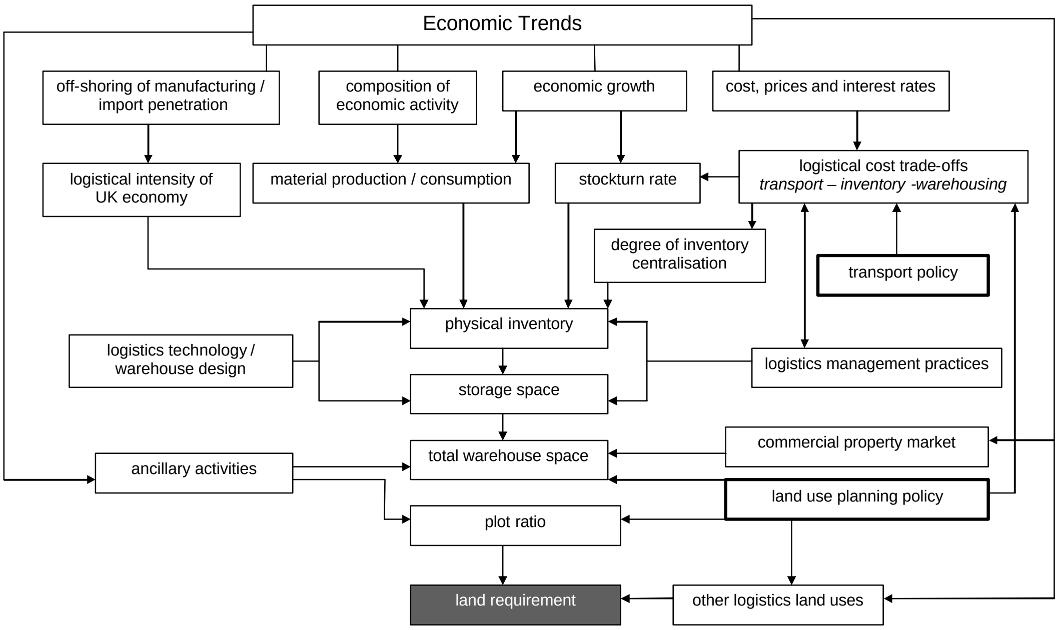

Figure 4: Factors Affecting the Future Land Requirements of Logistical Activity

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