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WAREHOUSING IN THE UK: OPERATIONS, PLANNING AND DECARBONISATION

Briefing Report

Technical Report ENG-TR.033

May 2023

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University of Westminster

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1. Introduction

This briefing report investigates the UK warehousing industry, the role it plays in supply chain management and its relationship with freight transport operations.

Chapter 2 discusses the activities carried out in warehouses and how these have changed over time as the responsiveness of modern supply chains has become increasingly important. Order picking systems, handling equipment and the deployment of automation used in warehouses are also covered. The various terms used to describe warehouses are considered some of which are synonyms while others are used to describe the specific activities carried out in the building. In this report the term warehousing is used throughout for simplicity, despite the existence of these various terms.

Chapter 3 provides an overview of the UK warehousing industry and its importance. It uses data to indicate the size of the industry and the distribution of warehouses by their size, location and the industry sectors they serve. It provides insight into all warehouses as well as those often defined as large (i.e. over 100,000 square feet (sq ft)).

Chapter 4 discusses long-term changes in the size, location and workforce of UK warehousing over previous decades since the 1960s and the reasons for these changes. These include economic, technological and logistics management factors.

Chapter 5 considers the changes in warehouse size, location and demand for warehousing floorspace in the last twenty years, indicating trends over this period.

Chapter 6 reflects on more recent changes in stockholding and the demand for warehousing since the onset of Brexit and the Covid-19 pandemic.

Chapter 7 considers the impact of changes in warehousing and logistics management of freight transport operations, both internationally and domestically. It indicates the growing reliance on road freight transport journeys over ever-increasing distances within the country as warehouses have become increasingly large and more centralised, serving large regional and national hinterlands.

Chapter 8 considers the need for external space at warehouses for logistics-related activities including the loading and unloading of goods vehicles serving them. It discusses this in relation to warehouse plot ratios as well as considering vehicle trip generation rates and the facilities required for visiting vehicle drivers.

Chapter 9 considers the warehousing workforce in the UK and the working conditions in the industry.

Chapter 10 reflects on warehousing employment densities and the traditional views of local planning authorities on permitting warehouse development. It also considers how automation is changing the type of work available and pay rates in warehouses which needs to be taken account of by planning authorities in their decision-making.

Chapter 11 discusses the energy efficiency and energy consumption of warehouses and the greenhouse gas (GHG) emissions associated with their operation. It goes beyond operational activity to consider the GHG impacts of ‘whole-of-life’ warehousing including the materials they are built from, their construction, maintenance and refurbishment and their demolition. It considers steps that can be taken to decarbonise warehousing. It also compares warehousing with freight transport GHG emissions to provide a more holistic insight into the contribution of these allied activities.

Chapter 12 provides conclusions drawn from this review of warehousing.

It should be noted that this briefing report has been based on a review and use of existing publications and data, rather than through the carrying out of new primary research into the warehousing industry. Despite being an imperial rather than metric unit of measure, warehousing floorspace is most referred to in square feet (sq ft) rather than square metres (sq m) in this report as this is the unit typically used in the warehousing industry.

This report has been produced as part of the Centre for Sustainable Road Freight (SRF – EPSRC grant number EP/R035148/1). A slide set and summary report are also available from the SRF website to accompany this report. Further details about the SRF project are available at: http://www.csrf.ac.uk/

2. Warehousing activities and terminology

2.1 History of warehousing

Clay tablets with cuneiform script were discovered in Uruk in modern day Iraq in the 1920s. They dated back 5,000 years to when Uruk was a Mesopotamian settlement on the banks of the Euphrates, among the earliest urban civilisations in the world. Scholars struggled to decode the meaning of these earliest surviving examples of writing that we have. Speculation included that they contained stories of gods and goddesses, hagiographies of kings and queens, tales of wonder and awe or epic poetry. However, when they were eventually translated in the 1970s, it transpired that written language had first emerged to keep count of loaves, jars, crops and animals that were entering and leaving temple storehouses, either for trading, planning or taxation purposes. So, logistics and inventory management were the inspiration for the start of written language. Even prior to the emergence of written language, counting marks, sometimes accompanied by a symbol of a type of product such as a grain of wheat, a sheep, or a loaf of bread, had begun to be inscribed onto clay tokens to keep accounts of goods which were to be traded in marketplaces from approximately 11,000 years ago in Mesopotamia with the emergence of agriculture and settled communities (Harry Ransom Center, n.d.).

A substantial quantity of warehousing is fundamental to the ability to trade in goods on a regular and large scale and thereby to meet the needs of urban societies. The early City of London relied on its port and docks, with its sizeable warehousing facilities, which allowed the City to trade with other countries by sea and to carry out coastal shipping to send and receive goods around the country. This water trade was supported by a domestic land transport system that connected London with other towns and cities by horse-powered road transport. These inter-urban road freight transport businesses to and from London provided regular inter-urban services, which can be traced in written records to at least the mid-15th century, made use of inns and taverns as storage locations, collection and delivery points for goods, and stopping points on long-distance inland journeys for the feeding, watering and stabling of horses (Chartres, 1977, 2002; Gerhold, 2005; Sharpe, 2016).

Despite the importance of warehouses and the functions they perform, little attention was paid to warehousing in 20th century business and academic studies compared with other economic activities such as production, procurement, transport and marketing. Instead, it was thought of as simply involving the storage of goods, and therefore something of an ‘inactivity’, producing no value or profit, and therefore given a low priority within business (McKinnon, 1983). This view began to change during the 1970s and 1980s, with greater appreciation of its role in logistics and supply chain management. It began to be seen as dynamic activity, with one commentator noting that “just as transport constitutes the movement of goods across space, so storage can be considered to be their movement through time” (McKinnon, 1983). Rather than being seen as a store or a repository, the warehouse became regarded as a node in the distribution system through which goods are channelled (Ackerman, 1977). Study of the management of stock gained popularity based on the productivity gains it could lead to and the lost sales it could prevent. Concerns about stock levels and their associated supply chain costs, as well as consideration of using storage space efficiently, gathered momentum during this period with consideration paid to how stockturns could be increased, thereby freeing up working capital.

2.2 Warehousing objectives and activities

The prime objective of most warehouses, “is to facilitate the movement of goods through the supply chain to the end consumer” (Richards, 2014). Whereas, traditionally, warehouses were viewed as places in which to hold stock, acting as a buffer between raw material and component suppliers, manufacturers, wholesalers and retailers/consumers, with high stockholding levels and little stock visibility and information flow along the supply chain, this has changed considerably due to the cost of warehousing space, stock, labour and energy. Views of the supply chain have shifted from a ‘push’ system in which upstream supply chain partners made to order, to a ‘pull’

system driven by end user demand. Many efforts have been implemented since the 1980s to reduce stockholding levels and reduce lead times in supply chains. This has revolutionised the role of the warehouse; “primarily a warehouse should be a trans-shipment point where all goods received are despatched as quickly, effectively and efficiently as possible” (Richards, 2014).

Despite efforts taken by businesses to reduce stockholding in recent decades through these various initiatives (see **section 4**), stockholding remains necessary for products: (i) required on a continual basis so that they are available when customers need them, and (ii) when their supply lead times exceed their demand lead times, so that customer expectations about when they require the goods can be met. Warehouses smooths the variations between supply of and demand for these products (Rushton, Croucher and Baker, 2014).

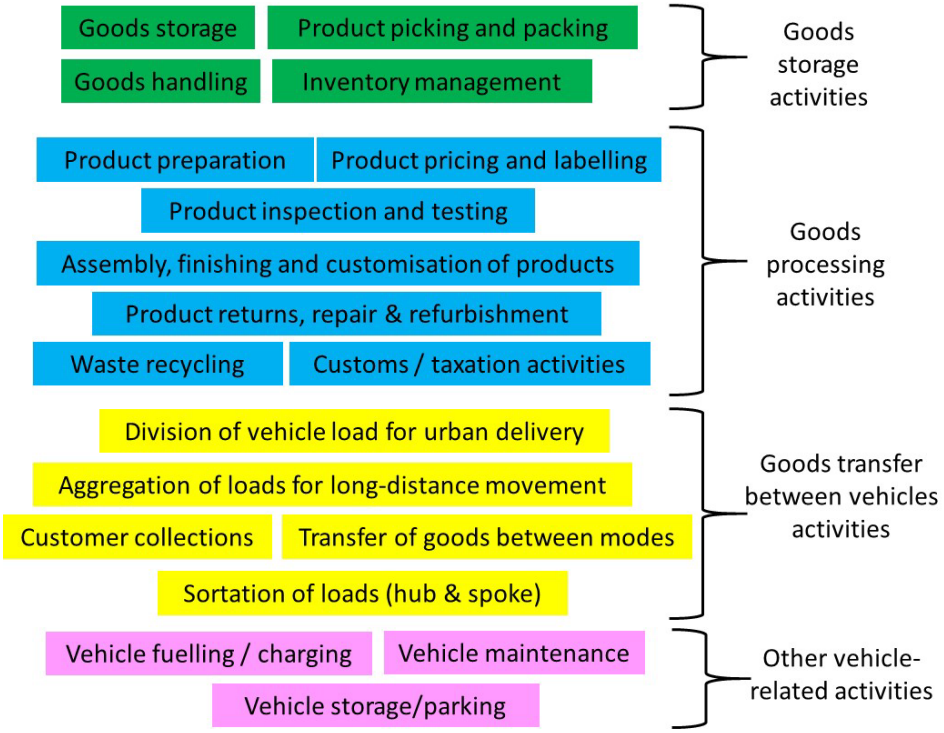
Stock is held for reasons including (Richards, 2014): uncertain and erratic demand patterns, distances between the manufacturer and end consumer, discounts obtained due to bulk buying, trade-off decisions made by businesses concerning transport and shipping costs that justify larger shipments, cover for disruptions to production processes, to provide the ability to increase production runs, to manage seasonal demand for specific products, to cope with peaks in demand at certain times of year (e.g. Christmas), to ensure spare parts are available, to part build products in anticipation of demand (i.e. work-in-progress storage), to hold onto products that are expected to increase in value over time, to store paper documents where a legal obligation to do so exists (such as contracts, accounts, invoices, patient records and legal documents).

The four basic activities that take place in a warehouse are: i) receiving goods, ii) transferring, putting away and storing goods, iii) order picking, and iv) shipping goods (Gu et al., 2007). Receiving goods involves unloading goods from the freight transport vehicle delivering them, updating stockholding records (each item stored in a warehouse is typically given a unique product or stock keeping unit - SKU), and, if necessary, inspecting the goods to determine any quantity or quality inconsistencies. Transferring, putting away and storing goods involves taking the received goods to their storage locations in the warehouse – this may require repackaging goods (for example from full pallets to cases) and physical movements (from the incoming loading bay to another area in the warehouse where they will be stored. Order picking is the major activity in most warehouses – it involves retrieving the correct quantity of goods required for a goods order from their storage location (determining the sequence and routing in which goods will be retrieved from their storage location). Then, depending on the order picking system used, picked goods may need to be accumulated and sorted into individual orders for customers (if goods have been picked in batches for multiple orders at the same time). Subsequently, if necessary, the goods will be consolidated and packed into secondary or tertiary packaging to create unit loads for conveyance in a transport vehicle (such as onto a pallet, or into a cardboard box or packet for online retailing operations). Goods shipment involves transferring the completed orders to the despatching area (a loading dock at most warehouses) where one or more orders are loaded onto a goods transport vehicle which, when loading is complete, departs the loading bay at the warehouse to transport the goods to the next point in the supply chain. Cross-docking takes place in warehouse operations in which the incoming goods received at the warehouse are immediately sorted and transferred directly to goods vehicles on which they are despatched without any storage process at the warehouse.

Beyond its role as a staging and storage point for goods in their journey from producer to consumer (performing stockholding, sortation, order picking, packing and despatch activities), the warehouse also plays many other, often overlooked, roles in supporting the freight transport used to move these goods.

Figure 1 shows diagrammatically the activities that can take place at these logistics sites (referred to as ‘warehouses’ in this report). These include good storage activities, goods processing activities, goods transfer between vehicles and/or modes, and other vehicle related activities including (vehicle refuelling, maintenance and overnight parking).

Figure 1: Activities that may take place at warehouses (i.e. facilities where goods are stored and handled)



In addition to the indoor space at a warehouse required for receiving goods, storing goods, order picking, and shipping goods and the various tasks associated with goods handling and management, warehouses also require outdoor space for some of the activities shown in **Figure 1**, including the manoeuvring and parking of goods vehicles that ship goods to and from the warehouse. Depending on the type, size and location of warehouse these outdoor activities can also include activities such as vehicle fuelling/charging (and therefore on-site fuel storage, vehicle maintenance facilities, vehicle and trailer parking facilities, driver comfort and rest facilities, and outdoor storage.

The total size of the warehouse site therefore includes both the area occupied by the warehouse itself, as well as the land surrounding the warehouse on which vehicle movement, parking, other vehicle/driver activities and outdoors storage may take place. The 'plot ratio' of a warehouse is a metric used to measure the area of building on a warehouse plot of land. The plot ratio is expressed as a ratio of the gross floor area of the building to the total area of the site that surrounds it. Therefore, the higher the plot ratio, the greater the land area of the entire site that the warehouse building covers. The external space and facilities at warehouses and plot ratios are considered in more detail in **section 7.**

As well as the most common roles and activities of warehouses, they are also increasingly used for providing assembly activities for products (an extension of what traditionally took place in factories) and other value-adding activities such as a centre for handling returned products (especially in non-food online retailing supply chains).

Various types of warehouses fulfil the following roles (Richards, 2014):

- raw materials storage – storing raw materials close to manufacturers,
- finished goods storage - storing products ready for sale, providing buffer stock for manufacturers, wholesalers and retailers,

- intermediate, postponement, customisation or sub-assembly facilities - storing products temporarily at various stages in their production, as well as for assembling/customising products before final delivery to the customer,
- transit warehouses and consolidation points - receiving products from various sources and amalgamating them for onward delivery in supply chain,
- transhipment or break-bulk centres - receiving products in large quantities and breaking them down into manageable quantities for onward delivery to numerous locations,
- sortation centres – used by parcel carriers and online retailers to collect products from a wide catchment area, sort by destination address, consolidate and deliver them overnight to depots for final delivery,
- cross-dock centres – receiving goods from multiple sources, consolidating and moving them on within hours to their destination (without longer-term storage),
- fulfilment centres – specially equipped and designed warehouses used by online retailers to quickly pick, pack and despatch orders which often require more space for these activities if involving the despatch of small consignments of fast-moving consumer goods,
- reverse logistics centres - warehouses that specifically deal with returned items, in online retailing and other sectors where specialist reuse and recycling management is required,
- public sector warehousing – warehouses used to support national and local government, the health service, and armed forces, for everyday uses together with one-off humanitarian needs.

Warehouses vary in terms of the type of goods they handle and store, some of which have very specific handling and storage requirements. Some warehouses are used for the storage of ambient goods, goods requiring temperature controlled storage (such as chilled and frozen), bonded goods for import or export that are held in specialist facilities by accredited operators to avoid the need for immediate payment of duties and taxes, hazardous goods that have legal requirements concerning their handling and storage procedures to prevent risks to staff and the wider society, and licensed products such as pharmaceuticals, goods requiring bulks storage such as liquids, powders, gases and agricultural crops, and goods that can be kept outdoors in open storage facilities. The goods handled and stored may be loose items, or contained in secondary or tertiary packaging to assist handling and storage space used (such as boxes, crates, pallets, containers or other type of unit load). The rate at which goods move through a warehouse, the quantities handled and the storage period will vary by product types, supply chain and purpose of warehouse.

Warehouses also vary in terms of their size, location, facilities, handling equipment used and degree of automation, and age of the building (with many larger warehouses being relatively new and located outside urban areas close to the motorway network but some smaller and medium sized ones, especially those in urban areas, being much older).

2.3 Order picking in warehouses and warehouse internal design

The order picking activity in a warehouse involves the process of receiving and scheduling the customer orders, assigning stock which may be held in various locations around the warehouse to order lines, releasing customer orders to warehouse pickers (be they humans or machinery), the picking of the goods from storage locations (using sequencing and routing to determine the order in which goods picking takes place, and the preparation (and packing if necessary) of the goods in each customer order for despatch on a goods vehicle disposal. Many different order-picking systems are used in warehouses, with more than one often being used in each warehouse. Order picking systems can vary depending on the types of goods, the method by which goods are picked (i.e. by humans on-foot, humans using machinery (such as forklift trucks or cranes), or some type of automated machinery). In some picking systems, humans and automated machinery are both used in various tasks of the picking activity (such as conveyor systems used to bring an SKU crate to human pickers who remove the number of items required for the order, with the conveyor system retuning the crate to its storage location and the human picker combined the items picked with other SKUs required for the order and preparing them for despatch. Automated

packaging and labelling systems are used in some warehouse operations depending on the extent of sophistication.

The order picking system used depends on several factors including: the size of orders that require picking, the SKU/product assortment held in the warehouse; the lead time with which the order needs to be despatched from the warehouse; the extent of variation in order picking workload (by time of day, day of week, and time of year); the extent to which orders need to be picked in sequences that reflect the layout of where they will be used (such as in retail stores with specific shelf locations for different SKUs); the extent to which orders need to be picked in sequence to reflect the weight of different SKUs in the order to avoid product damage; and the extent to which the warehouse holds perishable goods (such as time-sensitive foods or pharmaceuticals) for which SKUs need to be prioritised and picked in accordance with expiry dates in the order picking system (Boysen et al., 2021; Van Gils et al., 2018).

The most commonly used warehousing order picking system is the picker-to-parts system which is estimated to be used in approximately 80% of all Western European warehouses. This system involves the order picker walking or driving along the warehouse aisles where SKUs are stored to pick items (De Koster et al., 2007; Boysen et al., 2021). The following types six of order picking systems are used in warehouses serving physical retail shops: i) picker-to-parts systems with vehicle support, ii) fully automated case picking, iii) pick-and-pass systems for large orders, iv) crane-supplied pick face, v) bulk picking and store consolidation, and vi) put systems. In addition to the commonly used picker-to-parts system, the other five are more recent order picking systems which make use of new processes and/or automated machinery and other novel equipment such as robots to improve on the picker-to-parts system (Boysen et al., 2021).

Warehouse design comprises five major decisions: i) determining the overall warehouse structure; ii) sizing and dimensioning the warehouse and its departments; iii) determining the detailed layout in each department in the warehouse; iv) selecting warehouse equipment; and v) selecting operational strategies. There are strong inter-relationships between these five decisions. The overall warehouse structure (i.e. conceptual design) decision determines the goods flow pattern within the warehouse, the specification of functional departments, and the goods flow relationships between departments. Decisions about the overall size and dimensions of the warehouse influence the space allocation decisions for the various warehouse departments. Decisions about internal transportation, storage, order picking and sortation equipment selection determine the level of automation used in the warehouse and hence its size, layout and operations. Operational strategy decisions such as the picking and storage strategies used influence the four decision decisions (Gu et al., 2010).

These five decisions are closely related to the nature of use to which the warehouse will be put, the products it will handle, and goods throughput and storage service level requirements of the supply chain service in which it operates. These decisions will be influenced by considerations about the efficiency requirements of the warehousing operation. Consideration of the costs of warehouse construction, inventory holding, replenishment and materials handling for the warehousing solutions available will also be important in this decision-making.

Warehouses used for online retailing operations vary from other types of warehouse in their design and operation as they require the ability to store very large numbers of SKUs, customer orders tend to be high in number but low in terms of items per order, orders need to be picked a despatched as quickly as possible (given the proportion of orders that need to be fulfilled on a same-day or next-day basis), with picking operations often taking place 24/7 (Boysen et al., 2021). Most types of warehouse operation experience peak periods of operation. In the case of warehouses serving online retailing operations and store-based retailing operations, these peaks tend to occur at particular dates/seasons such as Christmas, Easter, ‘Black Friday’, and other festivities. Online retail warehouses may be busier on Mondays after weekend order placement by customers, whereas warehouses serving physical retail stores may be busiest at the end of week to ensure shops are well stocked for the weekend. Due to these features of warehouses for

online retailing they are likely to make use of sophisticated automated handling technology that speeds up order picking (see **section 2.5** for further discussion of automation in warehouses).

2.4 Storage and handling systems in warehouses

The storage and handling requirements of goods in a warehouse depend on several factors discussed in **section 2.3** that vary depending on the type, size and weight of goods and whether they are unitised on pallets or not. Handling and moving palletised goods in a warehouse are facilitated by a range of equipment including for horizontal movement: hand pallet trucks, powered pallet trucks, tugs and tractors, conveyors, automated guided vehicles, and for vertical movement: stacker trucks and cranes, counterbalanced fork-lift trucks, reach trucks, and narrow-aisle trucks.

Palletised storage systems include block stacking, drive-through racking, satellite racking, push-back racking, adjustable pallet racking, narrow-aisle racking, double-deep racking, powered mobile racking, pallet live storage, and automated storage and retrieval systems (AS/RS). These various palletised storage systems have differing handling equipment requirements, operational heights, floor utilisation rates and hence pallets that can be stored per square metre of floorspace. AS/RS can achieve greater storage heights than other conventional storage systems, achieving up to approximately 95% of warehouse cubic space utilisation. These systems differ in terms of the accessibility they provide to stored pallets, their cost and operating speeds (Rushton et al., 2014).

Non-palletised storage systems are used for products not suitable for palletisation either because of their size (either too small, large or long) or because they require lifting from the top. Storage systems for small items include shelving, mobile shelving and flow racks, carousels and lift modules, and miniloads (a type of AS/RS for small loads). Items can be stored directly on these storage systems or first placed in cartons, tote bins or boxes. In terms of product handling, conveyors can be used to move goods between specified points, larger items can require truck attachments and long items can need specialist storage and handling equipment. Heavy items are often handled using cranes. Automated guided vehicles can be used to move large loads. Specialist hanging garment systems are used for storing and handling clothing on hangers (Rushton et al., 2014).

In terms of picking orders from storage locations, various approaches exist including pick-to-order, batch picking and pick-by-line. The choice of system depends on the product range, order size, the picking equipment needed. Order picking equipment ranges from simple trolleys and roll-cage pallets used by humans picking manually on-foot, to powered order picking fork trucks driven by humans, conveyor systems that bring the goods to the picker, and automated picking systems that carry out picking without the need for humans.

The layout of picking areas in warehouses needs to be well-designed to achieve high levels of order picking productivity. This includes considerations as to whether to have separate reserve stockholding and picking locations for products or to combine all stock in a single location. Picking areas need to be minimised to reduce travelling distances and times taken. Before a picked order can be despatched from a warehouse it requires labelling and packing. This has traditionally been carried out by humans, but machinery is increasingly being developed and implemented (Rushton et al., 2014).

2.5 Technology and automation deployment in warehousing

The deployment of technology and automation in warehouses has been taking place over recent decades. However, most warehouses still use manual order picking systems (De Koster et al., 2007; Boysen et al., 2021). Type of automation used in warehousing include conveyor systems, sortation systems, shuttle systems, guided vehicles and robots to handle and move goods, packaging machinery. Computer systems and Warehouse Management Systems (WMS) control this automated technology and use data to plan and manage warehousing activities, calculate

resource requirements, monitor performance levels, and identify problems. Technology has also been developed and introduced to assist human warehouse workers such as computer screens to assist with the picking process and to reduce error rates, hand-held barcode scanners. Warehouse activities that can be supported or replaced by automation include picking, packing, sortation, batching, vehicle loading/unloading, product inspection and security. Automation can achieve faster, more efficient picking and packing rates as well as the utilisation of more of the entire warehouse volume (i.e. using the full height of the building using high storage racking). Automation is more likely to be applied to larger warehouses given the associated costs and the greater of economies of scale. It is also more likely to be deployed in warehouses dedicated to a single user rather than in shared user warehouses.

Crane-based automated AS/AR were first introduced in the 1960s, initially in warehouses storing pallet-based bulk inventories and later, in warehouses handling smaller loads and order sizes. These latter applications include: i) Single-deep automated storage systems (which consist of racks and automated handling systems such as cranes or automated trucks which can be aisle-captive (usually using cranes) or aisle-roaming (usually using high-bay AGV trucks) for automated storage and retrieval of SKUs; ii) compact storage systems in which cranes with double-deep telescopic forks are used to store loads double-deep in the racks (with such systems especially popular for situations in which the minimisation of storage space is important). These compact systems can also be categorised by the mechanism used for the depth movement that supports the work of the crane with these being push-back rack, a conveyor-based, or a satellite-based systems; and iii) carousels and vertical lift modules – carousels are automated storage and retrieval systems in which shelves are linked together and rotate in a closed loop, vertical lift modules are similar but comprise two columns of trays with a lift-mounted inserter/extractor in the centre (Azadeh et al., 2019).

The throughput capacity of AS/AR systems is constrained because only one crane handles loads at all vertical levels within a given storage aisle. To overcome this limitation, autonomous vehicle-based storage and retrieval systems (AVS/RS), a new generation of automated order picking systems, were developed in the 1990s. AVS/RS have similar costs to AS/RS but can carry out faster operations and have greater flexibility, so have become increasingly popular. AVS/RS systems use shuttles, which can drive in horizontal, vertical or diagonal directions on any level in the aisle, with lifts moving shuttles between the levels (Azadeh et al., 2019).

Shuttle/robot-based compact storage systems are variants of AS/AVR shuttle-based automated compact storage systems and can be categorised into: aisle-based, puzzle-based, and robot-based compact storage and retrieval systems. Aisle-based systems comprise multiple tiers of multi-deep storage lanes, each holding one type of product and use lifts instead of cranes to store and retrieve them. Puzzle-based systems retrieve totes, pallets, or containers that are stored in a grid with only one open spot on the grid, with the system repeatedly moving the open locations until the required item is brought to the open spot and can be retrieved. In robot-based systems, items “are stored in a very dense storage block with a grid on top. In each cell of the grid, bins that contain the items are stacked on top of each other and form the storage stacks. The workstations are located at the lowest level next to the storage stacks. Robots in this system are positioned on top of the storage block on the grid. The robots have lifting capabilities, and can extract bins from the storage frames and transport them to the workstations” (Azadeh et al., 2019).

In robotic mobile fulfilment systems (RMFS) robots that can lift and carry movable shelf racks (known as pods) retrieve these shelf racks and transport them to human pickers, which increases the productivity of the human pickers compared to the latter having to travel to the shelves themselves. The human pickers work in ergonomically-designed workstations where they carry out picking and packing activities. This system suits online retailers with large assortments of small products. System flexibility means that more robots and shelf racks can be added to increase throughput capacity to cope with peak periods (Azadeh et al., 2019).

As discussed in **section 2.3**, warehouses used for online retailing operations vary from other types of warehouse in their design and operation as they require the ability to store very large numbers of SKUs; customer orders tend to be high in number but low in terms of items per order; orders need to be picked a despatched as quickly as possible (given the proportion of orders that need to be fulfilled on a same-day or next-day basis), with picking operations often taking place 24/7; and extremely high peak periods are experienced such as at Christmas, 'Black Friday', and other festivities. In addition, if warehouses serving online retailing need to be located in urban areas this involves high land values and rental prices. All of these features of warehousing requirements for online retailing lend themselves to the implementation of automation, with such automated facilities being able to be accommodated in smaller buildings than their human-operated equivalents.

The use of automation in warehousing is having several effects of warehousing and warehousing employment: it is increasing the demand for large warehouses, it is reducing the requirement for warehouse operatives (as they can be assisted or replaced by technology), and it is changing the types of warehouse jobs (with automated warehouses requiring a far higher proportion of professional and skilled staff (i.e. managers and engineers who maintain and repair the technology) than non-automated ones (where operatives who pick and pack goods and load/unload vehicles predominate in the labour force) (see **section 8** for further discussion of employment densities in warehouses). Technology and automation are also resulting in more value-added tasks such as labelling, pricing, assembly and finishing taking place in warehouses than in the past. Some larger warehouses are also being designed with more office space than previously to facilitate business and warehousing operations to be accommodated on one site.

Although technology is being developed to further automate warehousing activities, many warehouses do not currently make use of these automated systems but uptake of automated systems is likely to increase over time. However, humans will still be required to do some of the work in warehouses, interacting with and working alongside this automated machinery. Questions remain about which tasks should be left to humans to achieve optimum joint performance with machines, how to ensure that humans have a good working environment when collaborating with automated machines, and how to remove the tasks most associated with human worker injury, discomfort and boredom. In addition, little research has been carried out into the environmental impacts of the various automated technologies being developed for and used in warehouses.

The best-known user and designer of automated warehousing in the UK is Ocado, the online grocery retailer, which makes use of highly automated warehouses using AI forecasting and control systems and RFMS robots for order picking. Ocado claims that a 50-item order can be picked in five minutes using this approach in a dedicated warehouse, compared to over an hour in a physical supermarket using only humans (Ocado, 2022a). In addition, Ocado also develops website and app technology, routing systems, and AI-based customer service and fraud detection systems. The Ocado picking system is not entirely carried out by robots and computing – humans are responsible for packing into bags the items picked by robots, although Ocado uses robots to also carry out this task in some of its facilities (Ocado, 2022b). Ocado is currently developing far smaller automated fulfilment centres (approximately one quarter size of their other automated picking facilities) but which retain the picking rates of their larger ones so that they can locate their fulfilment centres on smaller sites within urban areas in order to complement the larger ones and to extend the customers to which it can sell products (Ocado, 2022c).

In April 2023, Ocado announced that it would cease operations at it Hatfield fulfilment centre later in 2023 with this being due to relocating these activities to other sites, including its new Luton fulfilment centre, that have higher productivity and smaller warehouse sizes due to their level of automation compared to Hatfield. The Hatfield site, which was Ocado's first fulfilment centre, currently handles approximately one- fifth of the 400,000 customer orders the business receives per week. The Hatfield fulfilment centre is 1.2 million sq ft and employs 2,300 workers, whereas the new Luton fulfilment centre has approximately 350,000 sq ft and has been let on a 20-year lease. Ocado stated that its latest generation of automated fulfilment centres achieve over 200

units picked per labour hour, compared to around 150 for its Hatfield centre, and are also better suited to providing same-day deliveries (Helps, 2023; Thomas, 2023).

However, the automated warehousing technology that Ocado is developing is not without its difficulties and hazards. The company has been subject to two major fires caused by automation in the last three years. In 2019, the 220,000 sq ft Andover fulfilment centre that was just being completed burnt down due to an electrical fault in a robot battery charging unit. The fire burned for 4 days and was estimated to have cost £100 million (Jolly, 2021). In 2021, a fire took place as a result of a collision between three robots picking groceries in its 560,000 sq ft fulfilment centre in Erith that serves customers in east London. The fire took 100 firefighters 12 hours to deal with (BBC News, 2021).

A 2020 European survey of occupiers of logistics land carried out prior to the Covid-19 pandemic asked respondents to rate the importance of various technologies with respect to their potential impact on logistics operations over the next three years (see **Table 1**). The results indicate that occupiers of logistics land expected automated picking systems, warehouse robotics and warehouse/transport management software to have the greatest impacts (CBRE, 2021).

Table 1: View of occupiers of logistics land about the impact of various technologies on logistics operations over the next three years

Real estate factor	Percentage of respondents mentioning this factor
Enhanced automated picking systems	61%
Warehouse robotics	60%
Warehouse /transport management software	48%
Artificial intelligence and machine learning	37%
Driverless HGVs / platooning	34%
3D printing / additive manufacturing	30%
Electric vehicles	30%
Voice technology	29%
Drones	22%

Source: CBRE, 2021.

A 2021 survey of 174 European logistics experts asked them which building design features they thought would be very important in warehouses in the next 3-5 years. The most commonly cited features were ‘use of smart technology’ (58% of respondents), ‘use of automation and robotics’ (49% of respondents), ‘focus on sustainability requirements’ (45% of respondents), and ‘focus on worker wellbeing (40% of respondents) (JLL, 2021a).

2.6 Warehousing terminology

Many different terms are used to describe freight facilities where goods are stored and/or transferred between vehicles and modes. These include:

- Warehouse
- Distribution centre
- Sortation Centre
- Fulfilment Centre
- Depot
- Depository
- Delivery depot
- Store
- Barn

- Shed
- Terminal
- Returns centre
- Cross-docking facility
- Transhipment centre
- Consolidation centre
- Logistics hub

Many of these terms are used interchangeably by those referring to freight transport and logistics. Some have specific functions, such as those defined above, while others are general terms.

Warehouses are either operated directly by a manufacturer, wholesaler, retailer or other user, or are operated on their behalf by a third party (such as a specialist goods handling and storage business, freight transport business or logistics operator).

Warehouses can be operated on a dedicated or shared user basis. A dedicated warehouse is operated for a single user (either operated by the user themselves or by a specialist third party on their behalf), whereas a shared user warehouse contract is typically operated by a specialist third party for more than one user. Shared user warehouses are mostly used by manufacturers, retailers or wholesalers with insufficient goods throughput to warrant a dedicated warehouse.

Growth in online retailing has led to a major new function for warehouses in the last twenty years. This sector is using both large warehouses close to motorways. In recent years, especially since the Covid-19 pandemic, this has also led to the opening of small fulfilment centres and delivery depots close to residential delivery catchment areas in urban areas (especially when same-day delivery is provided). A small number of micro delivery hubs in central urban locations are also being established at which parcels can be transferred to electric vehicles (vans, bikes and on-foot walkers with powered trolleys) for local delivery.

The rise in online meal platforms has led to a rapid growth in so-called ‘dark kitchens’ in urban areas, while instant grocery services established since the Covid-19 pandemic have led to the appearance of so-called ‘dark stores’ – fulfilment centres from which grocery orders are despatched typically on mopeds and bicycles. New operations such as these ecommerce food preparation and grocery retail services (which are often located in former industrial buildings), together with warehouse buildings that are increasingly being put to non-logistics uses including as data centres and filming locations, are expanding and challenging the definition of what is a warehouse.

3. The importance of warehousing in the UK

3.1 The warehousing industry in the UK

Warehouses are operated by a range of different types of businesses including specialist goods handling and storage businesses, freight transport and logistics operators, retailers (food and non-food) and manufacturers of a wide range of industrial, commercial and retail goods. In 2021, there were 4,725 registered UK businesses that specialised in warehousing and storage services (SIC code 52.1 Warehousing and storage). Of these, 1,310 of them were micro businesses with no employees, while 2,965 did employ staff. A breakdown of the number, employment and turnover of these registered warehousing and storage businesses by employee band is provided in **Table 2**. Although large warehousing and storage businesses only accounted for 2% of all businesses in the sector in 2021, they accounted for 77% of the sector's employment and 65% of its turnover. In addition, there were 700 registered UK businesses that specialised in cargo handing in 2021 (SIC code 52.24: Cargo handling) (BEIS, 2021a).

Table 2: Number, employment and turnover of registered warehousing and storage businesses in the UK in 2021

Size of business	Businesses		Turnover	
	Number	%	£ million	%
Micro (1-9 employees)	2,130	72	1,818	8
Small (10-49 employees)	595	20	2,218	10
Medium (50-249 employees)	190	6	3,880	17
Large (250+ employees)	50	2	14,951	65
All employers	**2,965**	**100**	**22,867**	**100**

Note: SIC code 5210: Warehousing and storage.
Source: BEIS, 2021a.

The warehousing and storage sector has experienced strong growth in the UK over the last decade. UK Government data shows that among businesses with employees, their number grew by 52% while their turnover grew by 106% (see **Table 3**). The growth in the number of warehousing and storage businesses, and their growth in turnover was far greater than that for all UK businesses between 2010 and 2021.

Table 3: Number and turnover of registered warehousing and storage businesses with employees in the UK, 2010 and 2021, and comparison with all UK businesses with employees

	Number of businesses	Turnover (£ billion)
2010	1,950	11.1
2021	2,965	22.9
% change 2010-2021		
Warehousing & storage businesses	+52%	+106%
All UK businesses	+19%	+38%

Note: SIC code 5210: Warehousing and storage.
Source: BEIS, 2010, 2021a.

The number of business premises operated by all UK businesses classified as 'transport and storage' (of which warehousing and storage businesses are a subsector) was 88% higher in 2021 than it had been in 2011, and 21% higher than in 2019). This growth in business premises was greater than in all other business sectors and compares with an increase in the number of business

units across all UK businesses of 26% between 2011 and 2021, and just 1% since 2019 (ONS, 2022a).

In terms of the warehousing workforce in the UK, government data shows that, in 2020, employment among all warehousing and storage businesses (SIC code 5210) and cargo handing businesses (SIC code 5224) were 352,000 workers and 10,000 workers respectively (ONS, 2022b).

In addition, many warehouse workers are employed by businesses with a main function other than warehousing (including retailers, manufacturers and freight transport and logistics operators). UK Government data from the Annual Population Survey shows that in September 2021, there were 632,000 workers who described their occupation as relating to warehouse and stock control work. There were made up of 'managers and directors in storage and warehousing' (code 1162), 'stock control clerks and assistants' (code 4133) and those in 'elementary storage occupations' (code 9260). These groups accounted for 17%, 12% and 71% of the total 632,000 people engaged in warehouse work in September 2021 (ONS, 2022b).

In a 2018 survey of occupiers of its buildings carried out by the warehouse provider Prologis, 66% of warehouse workers were male and 34% female. Prologis surveys of its occupiers in 2010 and 2014 found that 88% and 89% of workers, respectively, were in full-time positions. In the 2018 survey, 78% of workers were full-time and 22% part-time (Prologis, 2019a). By comparison, UK Government data shows that in 2020, 89% of those working in warehousing and storage businesses and cargo handing business worked full-time while 11% worked part-time (ONS, 2021b).

3.2 Warehousing provision and leasing in the UK

Warehouses are built and provided by the commercial property market, but their construction requires the provision of planning consent by local planning authorities. Property developers construct and rent warehouses to retailer, manufacturers, wholesalers and other users. Most warehouses are rented rather than owned by the occupier. Ownership of the warehouse and land is either retained by the property developer who earns a return on their investment from the annual rent paid by the occupier or the developer sells the warehouse or builds it on behalf of investors that include pension, life and investment funds, private equity and sovereign wealth funds who then receive the rental income. Warehouses accounted for 12% of all non-domestic buildings and 34% of all non-domestic floorspace in England and Wales in 2022 (BEIS, 2022a).

Research indicates that the growing demand for warehousing and other logistics space globally (related to increases in international trade and domestic online retailing, and improvements in customer service levels) has led to ever-increasing levels of investor demand in warehousing. Whereas investment in logistics real estate (warehousing and other logistics space) accounted for approximately 10% of investment in all real estate in 2007, it has grown annually and accounted for 20% in 2020 (JLL, 2021a).

UK warehousing lease durations (along with other commercial property leases) fell rapidly following the 2008 economic recession, then gradually rose again from 2011 due to strength in the sector but experienced further falls in 2018 onwards due to Brexit and in 2020 due to the Covid-19 pandemic. From 2002 to 2015 average rental lease durations for warehouses were shorter than for retail and office leases in the UK. However, due to the strength in the warehousing market, since 2016 average lease durations have been longer than in these other sectors. In 2019, the average duration of an industrial (warehousing and manufacturing) lease in the UK in 2019 was 6.7 years compared to (over the period 2002-2019) a high of 7.3 years in 2002 and a low of 4.6 years in 2011. Unweighted average industrial lease durations were 8.4 years for larger occupiers and 7.3 years for SME occupiers (with less than 250 employees and 50 million euro turnover). Lease durations on a rent-weighted basis are higher than unweighted ones "which is partly a function of the longer leases associated with larger tenants and the need to capitalise

tenant installation costs". In 2019, industrial rent-weighted lease lengths were 9.4 years. This was well above its historic low over the period 2002-2019 of 8.0 years but well below the high in 2002 of 12.0 years (MSCI and BNP Paribas Real Estate, 2019). Warehouse leases are typically longer for larger business occupiers given the adaptations to the warehousing space they may make given the costs of such adaptations as well as the costs associated with relocation to another suitable site. Such adaptations can include the installation of expensive internal layouts, docks, automated handling equipment and upgrades to public utility provision such as the electricity or gas grid connection. The longest warehouse leases are usually not more than 25 years.

Warehousing lease arrangements often favour the owner (i.e. landlord) rather than occupier (i.e. tenant). The warehouse contracts that are entered into when an occupier decides to rent a warehouse typically require the occupier to keep the building in good repair and well decorated both during the lease and at the end of it. At the end of a lease, occupiers who carry out repairs and decorations themselves can sometimes find it difficult to get the owner to approve the work carried out as satisfactory, while some occupiers end up carrying out work that is unnecessary. Alternatively, occupiers who pay owners to carry out repairs and decorations on their behalf can sometimes find themselves facing excessive cost demands for work that the occupier should have done under the lease. Some such demands include work that was not required to be done by the occupier so the occupier must check this carefully. In addition, the owner can include work in such a cost demand that they do not later choose to carry out, but this is permitted. Leases usually require occupiers to pay for the cost of the building surveyors used by the owner. Depending on the terms of the contract, the occupier can be charged for compensation by the owner for the unlettable period after the lease ends while repair work is carried out by the owner. Some leases include the requirement for the occupier to pay a service charge to the owner. Some contracts permit the owner to use these service charges to get the occupier to pay for improvements to the building from which the occupier gets limited benefit due to the length of their lease. Occupiers may be able to negotiate a contract at the start of the lease in which they are not responsible for repairs and decorations. This may be advisable on leases of less than 5 or 10 years given the costs these can result in but, even if such a negotiation is successful, the occupier will have to pay a higher rent to reflect this. When entering a warehouse contract, occupiers need to take care not to take responsibility for repairs that were outstanding at the start of the lease. Rent reviews often take place during the period of the lease and typically assume that the occupier has carried out repairs and decoration even if this is not the case. Break clauses in leases are usually weighed in favour of the owner and can result in major costs for an occupier that has to terminate the warehouse contract if they do not follow the contract notice period and other requirements. As a result of the above, costly legal disputes over warehousing leasing contracts between owners and occupiers are relatively common.

Traditionally, warehouse owners (property developers, pension funds and other investment funds) have dictated terms concerning warehouse leases and have been resistant to occupiers making changes to the structure of the building, major changes to the fixtures and fittings inside it, and the parties that can use the building, with such changes requiring permission from the owner. This limits the flexibility of the occupier to alter and upgrade the use of the warehouse to their specific and changing needs (such as the need for installing mezzanine floors and automation, improving energy infrastructure and performance, and sharing warehouse space with other businesses). In addition, in most warehouse contracts the owner retains ownership of the fixtures and fittings which is a major deterrent to occupier capital investment in warehouse upgrades. This is especially problematic for third party freight transport and logistics operators who typically have three to five year contracts with their retailer and manufacturer customers, but usually have warehouse leases with durations that exceed this. They are forced to try to predict their future needs and make decisions about the warehouse design and fixture and fittings they require at the outset of their leasing of the warehouses, with potential legal, financial and operational implications if these warehouse design, layout and equipment change over time. Requirements for occupiers to obtain permission from the warehouse owner to make changes and the lack of the occupier's ownership of assets installed are major sources of inflexibility in the use of warehouse space and a key deterrent to the investment in technology and automation that can improve warehouse efficiency

and their decarbonisation (such as upgrading energy infrastructure at buildings for electric vehicle recharging and installing solar panels of roof space).

Contracts may state that the occupier is responsible for ensuring that the warehouse complies with statutory obligations. In this circumstance, the occupier rather than the owner will be liable for the cost of any works required by government legislation to improve the insulation and/or energy efficiency of the building. At the end of a lease, warehouse contracts often require the occupier to reinstate the warehouse as it was at the time they first rented it. This can involve them having to pay to remove equipment, technology and energy infrastructure that they installed. Such infrastructure may well be required by the subsequent occupier if the building is re-let by the owner as a warehouse, so is a gross waste of resources that imposes environmental impacts in its removal and subsequent reinstatement by the next occupier.

The limited warehousing capacity that currently exists in the UK has "led to a significant increase in the number of contract terminations by storage providers as unprofitable longer term arrangements are ushered out in favour of immediately available and potentially more profitable business. Termination without reasonable notice can have a devastating impact on supply chains, particularly where, as in the current market, immediate like for like capacity may be limited elsewhere" (Cradick, 2023). This has led some warehouse occupiers to reconsider the termination arrangements in their warehouse contracts so that notice periods, and implications of termination clauses are clearly stated. The economic and logistics problems arising from the Covid-19 pandemic and concerns about major weather events has also led to some businesses reconsidering force majeure provisions in their warehousing contracts to take better account of circumstances which should trigger a force majeure event, which party should bear the risk, the consequences of a force majeure event happening, and whether there should be any continuing contractual obligations following a force majeure event.

3.3 Warehousing size, location and type in the UK

Important changes have taken place in the size and location of major warehouses operated by large retailers, wholesalers and manufacturers in the UK over recent decades (see **section 4**). Many have opened large warehouses, often referred to as National or Primary Distribution Centres, in central locations in the UK well positioned for receiving both domestic and international supplies and to benefit from the economies of scale that such large facilities can offer. Depending on the type of products involved, they have then either supplemented these with so-called Regional Distribution Centres or urban depots (which receives supplies from the National/Primary Distribution Centre) for the provision of goods to their customers or have made customer deliveries from their centrally located warehouses.

An analysis of warehousing in England in 2018 indicates there were approximately 40,000 warehouses with a total floorspace of 1.7 billion square feet (sq ft) (see **Table 4**). Therefore, the average warehouse floorspace was approximately 40,000 sq ft (calculated from CoStar data in Turley, 2019). Warehouses up to 100,000 sq ft accounted for 92% of these properties and 60% of this total floorspace, while warehouses over 100,000 sq ft accounted for 8% of these properties and 40% of this total floorspace. To provide a sense of the scale of floorspace in a warehouse, a typical football pitch has an area of approximately 70,000 sq ft, so a 100,000 sq ft warehouse has an area of approximately 1.5 football pitches.

Table 4: Warehouse numbers and floorspace in England by size of warehouse, 2018

	Properties		Floorspace	
Unit Size (Sq ft)	**Number**	**% of total**	**Million sq ft**	**% of total**
< 50,000	32,710	81.6%	700	42.2%
50,000 - 100,000	4,330	10.8%	297	17.9%
100,000 - 250,000	2,340	5.8%	345	20.8%
250,000 - 500,000	510	1.3%	169	10.2%
500,000 - 750,000	120	0.3%	74	4.5%
> 750,000	70	0.2%	73	4.4%
All properties	**40,080**	**100%**	**1,657**	**100%**

Source: calculated from CoStar data in Turley, 2019.

Of those warehouses below 50,000 sq ft, approximately 25% are below 1,000 sq ft, 25% are between 1,000-2,500 sq ft, 20% are between 2,500-5,000 sq ft, 15% are between 5,000-10,000 sq ft and 15% are between 10,000-50,000 sq ft (calculated from data in BEIS, 2022a).

Table 5 provides the breakdown of warehouse numbers, total and average floorspace in England in 2018 by region for warehouses of all sizes. This indicates that the West Midlands and North West accounted for the greatest proportion of warehouse properties and floorspace.

Table 5: Warehouse numbers, total and average floorspace in England in 2018, by region

Region	No. of warehouses (%)	Warehousing million sq ft (%)	Ave. floorspace per warehouse (sq ft)
North West	16%	17%	43,968
West Midlands	16%	17%	42,746
East Midlands	10%	13%	52,300
South East	13%	12%	37,406
Yorkshire & Humber	10%	11%	46,115
East of England	10%	10%	39,467
London	10%	9%	35,533
South West	8%	7%	33,631
North East	5%	5%	37,379
TOTAL	**100%**	**100%**	**41,448**

Source: calculated from CoStar data in Turley, 2019.

Table 6 shows the regions of England in which warehouses with a floorspace over 100,000 sq ft were located in 2021. This indicates that approximately 40% of these large warehouses were located in the east and west Midlands in 2021, located centrally in the UK, close to the motorway for distribution across the country. London and the South East (which is also supplied by many of the large warehouses in the Midlands) also accounted for approximately 20% of the floorspace of these large warehouses in 2021. It is possible to estimate that the average floorspace of these warehouses in England is approximately 220,000 sq ft (calculated from CoStar data in Turley, 2019; and VOA data in GL Hearn et al., 2022). The average floorspace of these large warehouses was greatest in the East Midlands (approximately 260,000 sq ft) and least in London (approximately 165,000 sq ft) (calculated from VOA data in GL Hearn et al., 2022). **Table 6** also compares the warehousing floorspace for those warehouses over 100,000 sq ft and resident population per English region, together with warehousing floorspace per head. This indicates that there is little relationship between warehousing floorspace in these large warehouses and regional population levels. Any relationship between warehousing and population that may have once existed has weakened over time as warehouses have become larger and increasingly centralised serving large hinterlands beyond their regional boundaries. Locations chosen for these

warehouses are based on its transport connectivity and accessibility rather than its immediate residential catchment.

Table 6: Distribution of floorspace among warehouses over 100,000 sq ft and resident population and sq ft of floorspace per head of population in England in 2021, by region

Region	Floorspace in (% of total)	Population (% of total)	Sq ft of floorspace per head of population
East Midlands	22%	9%	23.7
West Midlands	16%	11%	13.9
South East	15%	16%	9.0
North West	15%	13%	10.9
Yorkshire and Humber	12%	10%	11.4
Inner M25	7%	16%	4.3
South West	6%	10%	5.7
East of England	4%	11%	3.7
North East	3%	5%	6.3
Total	**100%**	**100%**	**9.6**

Source: Calculated from data in UKWA and Savills, 2021; ONS, 2022c.

Table 7 shows the type of occupiers of warehousing space over 100,000 sq ft in Britain in 2021.

Table 7: Warehousing over 100,000 sq ft by type of occupier in the UK, 2021

Warehouse type	% of total warehousing floorspace
Freight transport/logistics	19%
Retail (high street)	16%
Retail (food)	12%
Retail (online)	11%
Manufacturing	8%
Food service	6%
Automotive	3%
Wholesale	3%
Parcel/mail	3%
Other*	20%
Total	**100%**

Notes:
* 'Other' includes waste management sites, data centres and film studios.
Only includes warehouses over 100,000 sq ft.
Source: UKWA and Savills, 2021.

All warehousing is road-connected and the vast majority of inland transport to and from warehouses in the UK takes place by road. However, some warehousing in the UK is located at rail terminals and ports. It has been estimated that in 2019 there was approximately 32 million sq ft of warehousing floorspace in large warehouses (i.e. over 100,00 sq ft) at Strategic Rail Freight Interchanges (SRFIs) and other rail-connected sites with major warehousing floorspace in England. This represented approximately 6% of all floorspace at large warehouses in England (GL Hearn et al., 2022).

The concept of port-centric logistics (PCL) is defined as 'the provision of distribution and other value-adding logistics services at a port' and has been advanced in the UK over the past twenty years (Mangan et al., 2008). It is focused on containerised movements for the retail and

manufacturing goods imports and involves containers being opened at ports and their contents stored and handled at large warehouses in distribution parks located at the port. Deliveries of these goods are then made directly from these port-based distribution parks to retail outlets (rather than the containers being first transported to retailer distribution centres located at inland locations. Using this approach therefore removes the need for this inland container movements by road or rail to such retailer logistics sites and the costs associated with so doing. However, the application of PCL would require major development of large, modern warehousing facilities at UK ports associated with substantial container flows and the investment associated with such development. It had been forecast by some that the London Gateway container port in the Thames estuary that opened in the last decade and which comprises an adjoining 230 hectare distribution park would herald the arrival of PCL in the UK. However, London Gateway port has "not attracted the expected number of shipping services or logistics property developments, casting doubt on the longer-term impact of PCL on UK retailers' international supply chains" (Mangan and McKinnon, 2019).

Table 8 shows the warehousing floorspace (for all warehouses) and population per English region, together with total warehousing floorspace per head. Similarly to **Table 6**, this indicates that there is little relationship between total warehousing floorspace and population levels, with more remote regions (such as the South West and East of England) and regions with the highest land values (including London and the South East) having far less warehousing per head of population than regions that are centrally located nationally (such as the East and West Midlands) indicating that location choice for much warehousing is driven by additional issues to the size of the immediate residential catchment area, being influenced by factors including transport connectivity and industrial composition. Many large warehouses serve hinterlands beyond the region in which they are situated.

Table 8: Total warehousing floorspace, resident population and warehousing floorspace per head of population in England in 2018, by region

Region	Floorspace in (% of total)	Population (% of total)	Sq ft of floorspace per head of population
East Midlands	13%	9%	44.4
West Midlands	17%	11%	46.0
South East	12%	16%	21.6
North West	17%	13%	37.6
Yorkshire and Humber	11%	10%	33.3
London	9%	16%	15.6
South West	7%	10%	20.0
East of England	10%	11%	26.0
North East	5%	5%	28.7
Total	**100%**	**100%**	**29.1**

Source: calculated from CoStar data in Turley, 2019; ONS, 2022c.

Warehouse location decisions depend on many factors that businesses requiring such space take into account including land, rent and rate costs, road transport accessibility (especially proximity to the motorway network in the case of large warehouses serving substantial geographical areas); suitable local labour availability; travel times to key destinations served; location in proximity to the source of inbound goods (including sea and air ports if relevant); non-road freight transport mode links if required; transport links and services for workers; availability of existing buildings (if not commissioning a purpose-built facility); availability of utilities and electrical infrastructure at the warehouse (especially for electric vehicle recharging); availability of local/regional funding or grants; suitability of the plot ratio[1] of the site and vehicle ingress/egress from site; traffic and environmental impacts of operating from the site (especially if these may lead to planning

[1] Plot ratio is the total gross industrial floorspace divided by the total site area.

problems); existing planning or environmental health restrictions on site operation; and the environmental sustainability of the warehouse (and whether this aligns with company Corporate Social Responsibility targets). The warehouse location decision will also be influenced by the types of product and markets that the business searching for a warehouse are involved in. For instance, parcel businesses and online grocery retailers will have different needs and requirements to businesses involved in the supply of slow-moving, bulky products.

4. Long-term changes in channel and warehouse management and greater reliance on transport

The number, size, location and workforce of warehouses in the UK changed substantially in recent decades due to a number of factors. These include:

- The rise of the service and relative decline of the manufacturing sector in the UK economy from the 1950s onwards (resulting in a growing dependence on the importation of finished goods),

- The growth in the UK retailing sector and market concentration in the retailing market (leading to the reallocation of finished goods away from manufacturers' and wholesalers' depots towards warehouses operated by major retailers),

- The internal rationalisation of stockholding by large businesses (leading to ever-larger but fewer warehouses primarily located on the strategic road network - SRN) and increasing reliance on longer freight transport journeys,

- The development of new warehousing outside urban areas (where much warehousing had previously been located) so as to be in close proximity to a motorway and able to accommodate modern materials handling equipment,

- The reduction in stockholding in many commercial and public buildings in expensive urban locations (including shops, offices, engineering plants, automotive repair workshops) in order to either convert stockholding space into sales areas and other value-added activities and reduce total space requirements and in turn, to place greater reliance on frequent, relatively small deliveries from warehouses by goods vehicles,

- The increase in interest rates in the early 1980s that caused stockholding to become more expensive and which encouraged the adoption of new logistics practices which focused on reducing stock levels through improved stock visibility across the supply chain and becoming more demand responsive,

- The growth in computing technology, material handling equipment and automated picking systems to support efficient warehouse operations and better utilise the cubic capacity of the warehouse building,

- Technological and regulatory change in goods vehicle operations that have led to road freight transport becoming relatively cheaper and more reliable over time resulting in a greater reliance on road freight in order to reduce total stockholding costs.

These factors are discussed in greater detail below.

4.1 Decline in manufacturing, growing dependence on imports and rise in importance of retailing

A relative decline in manufacturing occurred in the UK from the 1950s onwards as a result of poor UK productivity levels and comparative international labour costs. The UK economy restructured as primarily a service-based economy, with financial services and retailing growing rapidly. As a result, the amount of warehousing required to hold manufacturing production (raw materials, works-in-progress and finished goods) became considerably lower than it would have been if manufacturing growth had continued to grow strongly. Much of warehousing that served manufacturing was traditionally located in urban areas, close to the urban factories and production facilities that they served that were in walking distance of the homes of their workers. The process of deindustrialisation from the 1950s onwards led to the offshoring of manufactured products required in the UK and its associated warehousing (i.e. goods were produced and sorted in other countries and then imported into the UK).

Total retail spending in the UK increased by approximately 100% between 1988 and 2020 (at constant prices - i.e. taking inflation into account). This was due to both increases in spending per head and increases in population. Analysis indicates that average retail spending per head at constant prices increased by 79% over this period. Although not all UK individuals will have increased their retail spending at the same rate, with the greatest increases likely to have occurred among the more affluent, the data reflects the substantial average increase in expenditure in nominal terms on retail goods per person. Non-store retail spending (i.e. online shopping) increased by 318% per head at constant prices over this same period reflecting its exceptional growth (calculated from data in ONS, 2022c, 2022d).

This growth in retail spending together with the relative decline in manufacturing has resulted in a growing quantity of goods having to be imported to the UK. As a result, the UK's Balance of Payments (BoP) for trade in goods first entered deficit in the 1970s (i.e. with the value of goods imported exceeding those exported) and this deficit has continued to increase ever since, reaching £156 billion in 2021 in current prices (ONS, 2022e). The current BoP trade in goods deficit is largest in finished manufactured goods, followed by food, drink and tobacco and semi-finished goods. In 2021, China and Germany were the UK's largest import markets for goods, accounting for 12% and 11% of total UK goods imports respectively. In 2020, by value there was an imbalance between the goods imported to and exported from the UK of 60:40 (HM Revenue and Customs, 2022). In 2020, the UK imported 46% of the food it consumed, with 28% coming from the EU and 18% from the rest of the world (DEFRA, 2021).

As UK businesses have become increasingly reliant on the importation of goods and materials from producers in other countries in recent decades this has led to UK retailers, wholesalers and manufacturers having to place orders for these goods well in advance of when they are needed and then retain sufficient stocks of these goods in their warehouses given the relatively long delivery lead times (see Allen and Piecyk, 2023a and 2023b for further discussion of changes in the UK in manufacturing, retailing, goods importation and related freight transport operations in recent decades).

4.2 Retail market concentration and retailers taking control of supply chain

In UK retailing, the rise of large multiple non-food and grocery retailers has resulted in a growing proportion of market share being concentrated in a small number of businesses who opened many retail outlets across the country. In addition to acquiring ever-greater market share of total sales within their sectors, these large retailers have also taken control of the supply chain upstream of their retail outlets, gaining ever-increasing control over goods purchased by suppliers by having these delivered to their distribution centres rather than via wholesalers or direct to store. In the case of major supermarkets, only time-sensitive items with a very short shelf life such as bread, milk and newspapers are likely to be delivered by suppliers direct to retail outlets, whereas a far higher proportion of goods were delivered by suppliers direct to retail outlets a few decades ago.

Achieving greater control over their supply chains provided major retailers with several advantages including (McKinnon, 1989): (i) a strengthening of their negotiating position with suppliers and bulk discounts, (ii) the ability to implement improvements in the efficiency of retail operations especially in terms of labour productivity and cost savings in handling goods in shops from the ability to replace numerous deliveries to their shops by many different suppliers with fewer centralised, consolidated deliveries to their shops from their own distribution centres, and (iii) the ability to ensure that shop stockouts occur far less frequently than when relying on supplier deliveries to store, thereby increasing sales levels and customer satisfaction.

In terms of labour cost savings in shops due to the reduced manual handling of deliveries that can be achieved from receiving relatively few, consolidated deliveries from the retailer's own distribution centre rather than many smaller deliveries from suppliers, a study of a London supermarket in the 1970s showed that 50% of goods supplies were delivered in consolidated form

from a central distribution centre and took 45 minutes to unload. Meanwhile the other 50% of supplies were delivered to the shop by 132 different deliveries made by suppliers and took approximately 25 hours to unload. This work also found that the size of consolidated drops from the supermarket's central warehouse averaged 740 cases as opposed to 26 cases for deliveries received direct from suppliers GLC, 1975 quoted in McKinnon, 1989).

The growth in market concentration in retailing and the greater control this has given retailers over their supply chains, has had the effect of a growing proportion of retail products moving through fewer warehouses and distributions centres (operated by manufacturers and wholesalers) on the journeys to retailers' shops and hence a reduction in the number of times each such product is handled (compared with a supply chain which includes management of storage and distributions by manufacturers and wholesalers).

Much of this increase in retail market concentration (and hence the proportion of products that were handled by retailers' distribution centres rather than manufacturers and wholesalers being responsible for secondary distribution and delivery to shop) took place from the 1970s on. A study of retail sales by product category found that multiple retailers increased the proportion of total sales they accounted for in all categories at the expense of independent retailers and their wholesalers between 1966 and 1982. Multiple retailers increased their share of total retail sales in the UK from the mid-20th century onwards. One source indicates that the market share of all independent retailers fell from 64% in 1950 to 57% in 1961, 50% in 1971 and 39% in 1981, while specially for independent grocery retailers, UK market share fell from 57% in 1950 to 32% in 1981 (Dawson, 1983 quoted in Cooper, 1986). Another source shows multiple retailers increasing their share of total UK retailing from 42% in 1966 to 56% in 1982 (Office of Fair Trading, 1985 quoted in McKinnon, 1986). **Table 9** shows the increase in the proportion of major grocery businesses' products (by value) that they handled through their own distribution centres in 1986 and 1993.

Table 9: Proportion of major grocery retailers' supplies channelled through distribution centres, by value

Retailer	**1986**	**1993**
Safeway	80%	95%
Presto	40-60%	
Asda	10%	78%
Co-op Retail	40-60%	95%
Co-op Wholesale	40-60%	93%
William Low	50%	94%
Morrisons	50%	90%
J.Sainsbury	80%	95%
Tesco	40-60%	95%
Waitrose	80%	90%
Average (unweighted)	**61%**	**92%**

Source: Institute of Grocery Distribution, 1995 quoted in McKinnon, 1996.

The situation was found not to be dissimilar for major non-food retailers in the UK. A survey of fifteen major non-food retailers in 1994 found that eleven of them centralised the distribution of 90% or more of their supplies, while two centralised 80-90% of their supplies (McKinnon, 1996). Additionally, a 1992 survey of 64 of the country's largest retailers (food and non-food) found that they supplied their shops from a total of 240 distribution centres, approximately half of which had been constructed since 1980 (McKinnon, 1996). As well as taking increasing control of the secondary distribution from their large distribution centres to their stores from the 1980s on, some major retailers also began co-ordinating the inbound deliveries of products to their distribution centres, either by using third-party logistics companies to collect these products from suppliers and provide consolidated deliveries to their distribution centres or by using their own vehicle fleets to collect goods from suppliers on their return journeys from shops (McKinnon, 1996).

As a result of the reduction in market share for independent retailers in the UK since the 1950s, this also led to the number of shops operated by independent retailers approximately halving between 1950 and 1981 (from 450,000 to 230,000 shops with a similar rate of fall among grocery and non-food independent shops). These multiple retailers that were increasing their market share were also opening far larger shops than independent retailers, with the size of these multiple retailers' shops also increasing markedly from the 1960s onwards. For instance, the average shop size of multiple retailers and co-operative chains in the grocery sector increased by approximately 175% between 1969 and 1983 (Institute of Grocery Distribution quoted in Cooper, 1986). Despite the total number of shops falling in Britain from the 1950s onwards as a result of the loss of market share of independent retailers, the growth in average shop size (due to the increasing multiple retailer dominance) led to overall increase in retailing floorspace in the UK (with it rising by 15% between 1974 and 1983 (Department of the Environment, 1978; 1984). Independent retailers' grocery stores had been served by small and medium sized rigid vehicles in the 1950s. The shift in market share from independent to multiple grocery retailers in the 1960s led to a related shift in vehicle deliveries towards these retailers' larger supermarkets, however given that at this time food producers were still responsible for supplying goods to shops, this continued to involve many producers making these deliveries in small and medium rigid goods vehicles. However, as the multiple grocery retailers took control of their supply chains during the 1970s, opening their own distribution centres, this led to producers delivering supplies to the distribution centres in large quantities using larger goods vehicles and then retailers operating their own deliveries to supermarkets also using larger goods vehicles (Cooper, 1986).

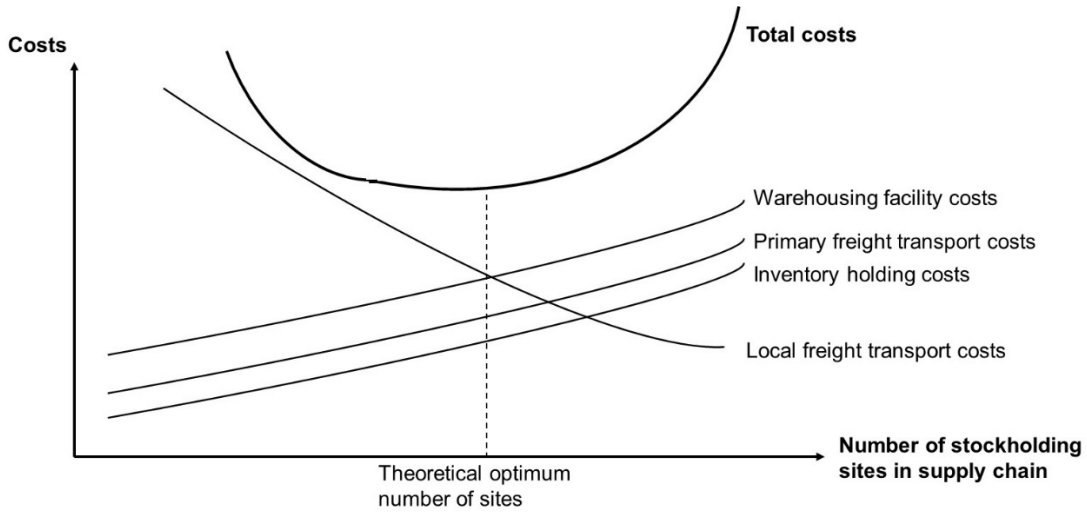
In terms of labour cost savings in shops due to the reduced manual handling of deliveries that can be achieved from receiving relatively few, consolidated deliveries from the retailer's own distribution centre rather than many smaller deliveries from suppliers, a study of a London supermarket in the 1970s showed that 50% of goods supplies were delivered in consolidated form from a central distribution centre and took 45 minutes to unload. Meanwhile the other 50% of supplies were delivered to the shop by 132 different deliveries made by suppliers and took approximately 25 hours to unload. This work also found that the size of consolidated drops from the supermarket's central warehouse averaged 740 cases as opposed to 26 cases for deliveries received direct from suppliers GLC, 1975 quoted in McKinnon, 1989).

4.3 The internal centralisation and rationalisation of stockholding by large businesses

Major non-food and grocery retailers (as well as other large businesses including wholesalers and manufacturers) commenced an internal process of centralising their stockholding into fewer, larger warehouses in a rationalised network. For these retailers, this permitted goods produced in the UK and overseas to be stored in large, central warehouses prior to supply to their shops, rather than holding these goods in many smaller warehouse locations. For example, surveys carried out among large food manufacturers in the UK in 1972 and 1978 indicated that over this six-year period there had been a reduction in their average number of warehouses/depots from 16.1 to 10.6 (which was found to be statistically significant at the 99% confidence level). Twenty four of the businesses that participated in the 1978 survey provided data about their number of warehouses/depots since 1945 – all these participants had reduced their number of warehouses/depots while increasing their sales volume. The data indicates that some of these businesses had begun depot rationalisation in the 1960s, while the majority of businesses carried out their depot rationalisation during the 1970s (McKinnon, 1985, 1986; Thorpe et al., 1973). These ever-larger warehouses (often referred to as National or Primary Distribution Centres) were located away from busy, congested urban areas that were experiencing ever-increasing rental prices and instead purpose-built in locations accessible to the motorway network in more centrally situated locations in the country (especially in the Midlands and Northern regions) where land values were also lower than in urban areas. These larger warehouses served far larger, more geographically dispersed, regional markets than their predecessors (Hesse, 2007, Hesse and Rodrigue, 2004). The decision to situate these warehouses in central locations has meant that they are well located both to receive goods from UK suppliers and those arriving by ship via

seaports and to serve national chains of retail outlets. These large National/ Distribution Centres allow retailers (and other major businesses following this approach) to achieve economies of scale in safety stock holding levels (referred to as the 'square root law' – which states that the total safety stock in a supply chain is proportional to the square root of the number of locations at which a product is stored (Maister, 1976; McKinnon, 2009) and in the deployment of warehouse labour, handling equipment and automation. These locations also tend to have lower land values and worker wage rates than pertain in and around urban areas. For these reasons and others including the reduction of fixed costs, stock damage and loss, improved stock turnover and lower cost of deploying warehouse equipment and technology per unit area in fewer, larger warehouses, the unit cost of physically accommodating and handling stock falls as warehouse size increases. Any increases in road freight transport costs that these retailers experience due to the longer distances over which goods have to be moved between these warehouses and shops are typically more than offset by the benefits these warehouses provide in terms of productivity levels and reductions in total stockholding levels (and the financial costs of holding greater levels of stock (see **section 4.4** for further discussion of changes in road freight transport technology and regulation supporting this shift to warehouse centralisation). **Figure 2** shows the trade-off that exists between warehouse costs and freight transport costs – with fewer warehouses leading to lower total warehousing costs but higher freight transport costs as journey distance increases, resulting in higher freight transport costs).

Figure 2: Trade off-between warehousing and freight transport costs



Source: Adapted from Braithwaite and Christopher, 2016.

Depending on the type of products involved, major retailers and wholesalers that have centralised their warehousing operations in large-scale facilities have then either supplemented these with so-called Regional Distribution Centres or urban depots located closer to their sales markets (which receives supplies from the National/Primary Distribution Centre) for the provision of goods to their customers or make customer deliveries from their centrally located warehouses. The larger National/Primary Distribution Centres are used to hold stock, with the period of time for which each product it is stored depending on the rate at which it sells, while the Regional Distribution Centres or urban depots are essentially transhipment points where goods are typically redistributed to retail outlets within a day or two of arrival. In the case of parcel networks, parcels are redistributed on the same day that they arrive with no storage whatsoever taking place at the urban depot. In the case of very fast-moving consumer goods, they may be supplied direct from supplier to Regional Distribution Centre or direct to store rather than going via a National/Primary Distribution Centre given the speed and frequency of replenishment required and their lack of storage time.

The relationship between the cost of holding stock and the quantity of stock held has also been noted, with stock levels falling considerably after 1980/1 due to sharp increases in interest rates

and the withdrawal of tax relief on stock appreciation. High interest rates typically encourage businesses follow 'low inventory' policies. This interest rate shock in the early 1980s did not lead to stock levels being subsequently increased again from the mid-1980s as rate fell, as had happened in previous economic recoveries. So, this interest rate shock is likely to have facilitated the adoption of leaner logistics systems by many businesses (McKinnon, 1988). This reduction in stockholding levels was assisted by the adoption of computing technology to better manage stock and forecast demand levels.

Warehousing completions grew at a gross average rate of 29 million sq ft per annum between 1982 and 1992, resulting in there being an estimated 1.2 billion sq ft of warehousing floorspace by 1992 (Chesterton, 1992). Much of this growth occurred at a national and regional scale, with many companies deciding to concentrate their production and stockholding at a smaller number of large sites. During this period, the eaves height of warehouses also began to increase from heights of approximately 5 metres until the 1980s to typical heights of 7 to 10 metres by the mid-1990s and subsequently continuing to increase since (with the average eaves height of large warehouses being 14 metres by 2021 – Allen et al., 1996; UKWA and Savills, 2021). This increased eaves height increased the cubic capacity of warehouses which could be made use of with modern handling equipment and automated storage and picking systems, thereby reducing warehouse operating costs per unit area.

Another important development in warehousing during the 1980s was the emergence of the 'distribution park', a cluster of newly-built warehouses and distribution centres operated by various companies all located on one site, typically ranging from 50 to 150 acres in size, in close proximity to the motorway network from which regional and national distribution operations could be conducted. While industrial parks and business parks that accommodated several businesses had existed for many years, the phenomenon of parks specifically for warehousing and distribution facilities was a new concept and a marked departure from the traditional pattern of an individual warehouse on its own site. The rationale behind these distribution parks was that economic and operational benefits can stem from spreading costs among several occupiers, in addition amenity benefits that could be achieved (Allen et al., 1996). By 1994 there were at least 167 distribution parks in Britain that were either operational, in the construction phase or being planned (Distribution Business, 1994).

Total warehousing floorspace had been increasing rapidly in the UK during the 1970s. The interest rate shock and the logistics actions taken by companies to reduce stock levels led to a divergence between warehousing supply and demand in the early 1980s, with a large surplus of floorspace. Much of the spare warehousing was either in older buildings that were unsuitable for the changing logistics operations (such as being too small, having poor layouts, and energy efficiency, inadequate eaves heights, lacking adequate office space and with high plot ratios with insufficient parking and loading space) or were new facilities that had been built speculatively in accordance with anticipated demand (McKinnon, 1988).

4.4 Technological and regulatory change in goods vehicle operations

Since the introduction of motorised goods vehicles technology developments together with regulatory change to facilitate its implementation has permitted the increased carrying capacity of goods vehicles (both in weight and volume terms). The maximum permissible gross weight of the heaviest HGV is approximately 80% greater than in the period 1954-1963, and approximately 40% greater than it was in the period 1964-1982. Further increases in maximum permissible gross vehicle weight occurred in 1983, 1999 and 2001. Lightweighting of vehicle trailers has provided further improvements in weight capacities. The maximum permissible length of HGVs has also increased over time with changes in 1955, 1964, 1968, 1983, 1990 and 1998 (Armstrong et al., 2003). The Longer Semi Trailer (LST) trial commenced by the Department for Transport in 2012 increased vehicle length further, facilitating trailers up to 2.05 metres longer than standard length trailers (of 13.6 metres). The Department for Transport is currently seeking to make LSTs permanently permissible subject to some additional rules to those applicable to conventional

trailers of articulated HGVs (Department for Transport, 2021a). Maximum HGV and trailer width increased by approximately 10% between 1941 and 1964, rising by a further 2% in 1996. The average height of HGV trailers has also increased over time as the use of mechanical handling equipment has made unloading and unloading far easier and the adoption of double deck trailers in some operations (there is no maximum permissible vehicle height in the UK, with it instead being limited by rules concerning vehicle and load safety and the height of road bridges). Speed limits for HGVs of motorways increased substantially between the 1920s and 1967 on the country's fastest roads (70 mph on motorways), following which they reduced in 1971 (to 60 mph on motorways). Most recent changes in 2015, increased the national speed limit for HGVs over 7.5 tonnes on single carriageway roads (from 40 to 50 mph) and dual carriageway roads (from 50 mph to 60 mph) in England and Wales (AECOM, 2020).

These changes in vehicle dimensions and speeds meant that, over time, it became possible for vehicles to carry greater loads and to cover journeys in less time, thereby reducing freight transport operating costs. Based on the relative costs of warehousing and freight transport, together with the financial benefits of operating fewer, larger warehouses, this thereby encouraged greater centralisation of warehousing with increasing reliance on road freight transport.

4.5 The development of new, modern warehousing outside of urban areas

Since the 1960s most warehousing has been developed outside of urban areas due to the land prices and rental values of warehousing in cities, together with the poor transport accessibility associated with many urban sites. As major retailers centralised and rationalised their warehousing networks, each site served a larger catchment area and therefore a location outside an urban area in close proximity to a motorway and able to accommodate modern materials handling equipment became increasingly important. However, there has been a resurgence in demand for warehousing in urban areas since the Covid-19 pandemic and the upsurge in the supply of and demand for online retailing and associated delivery services for non-food and grocery products and meals (see **section 5.1** and Allen and Piecyk, 2023c).

The construction of the M25, the orbital motorway surrounding Greater London which opened in 1980, attracted many warehouses away from inner London locations to sites around and close to it, especially its eastern and north eastern parts where land and rental values were lower and planning policies towards warehousing more favourable (Lichfield et al., 1981).

4.6 Reductions in stockholding in many commercial and public buildings in urban areas

As mentioned in **section 4.4**, major grocery and non-food retailers reduced stockholding levels and storage space in their shops from the 1980s onwards in efforts to increase the sales area and product range and variety and thereby increase market share and sales volume. While this results in a greater reliance of freight transport with more frequent, smaller deliveries of goods required to these urban locations, and hence higher transport costs, these are more than offset by the utilisation of expensive urban land for more value-adding activities and/or sales increases.

Some major non-food retailers (including Boots and Marks & Spencer) established so-called 'common stock rooms' (CSRs) to achieve this, with these CSRs supplying shops in the surrounding area with small, daily or even more frequent deliveries (Murrell, 1988). This approach helped such retailers to increase the ratio of sales area to total floor area from 50% to 80% (McKinnon, 1996). Major grocery retailer took similar steps to reduce backroom storage levels. This strategy, with lower stock levels in backroom stores in shops, required close monitoring of shop sales and stock levels, use of IT systems to provide electronic data exchange and rapid order preparation and delivery from CSRs and regional distribution centres to ensure that shelves were rapidly replenished.

Both in terms of rapidly and frequently replenishing their shops as well as in the provision of goods to their warehouses and distribution centres by their suppliers, major retailers employed what was

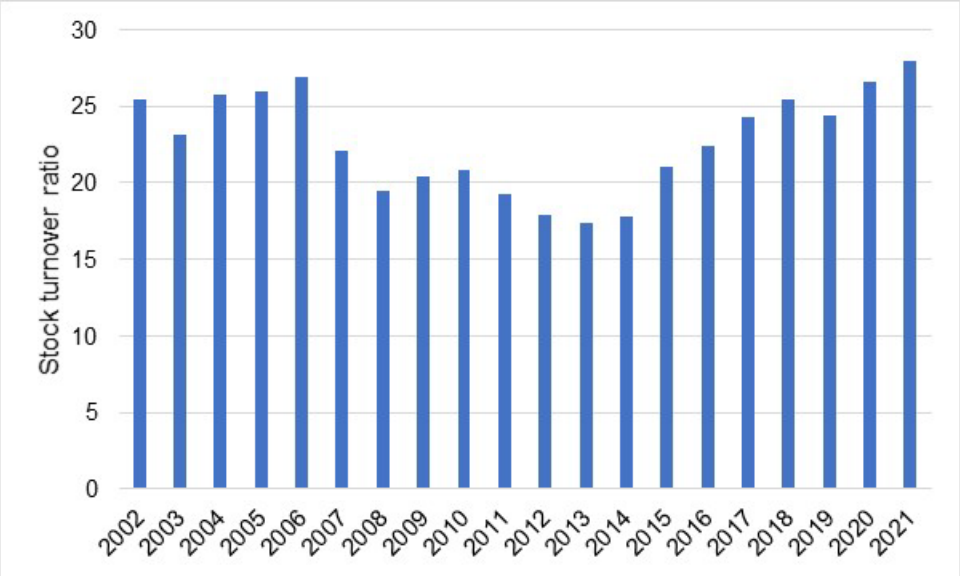
referred to as ‘Quick Response’ (QR). Coined in 1985 by Kurt Salmon Associates in relation to fashion retail, this term referred to reducing the time that products spend either stored as work-in-progress or as finished stock at various points in supply chains, and instead reducing product lead times to that actually required for value-adding activities (Kurt Salmon Associates, 1997).

Similar efforts were made by other businesses to reduce stockholding in offices, factories, car dealerships and many other non-warehousing buildings both to use the space for higher value-adding activities or to or reduce total floorspace requirements in buildings located in urban areas with high rental and land values. First coined in relation to the Japanese automotive sector, in these other sectors, this ever-greater reliance on rapid replenishment of stock with small, frequent deliveries was referred to as a ‘Just-in-Time’ system.

In the early 1990s, major grocery retailers and manufacturers in America including Wal-Mart and Procter & Gamble began focusing on what was referred to as ‘Efficient Consumer Response’ (ECR). This was soon also adopted by grocery retailers in the UK and focussed on reducing stock holding levels by stripping wasted time out of supply chains, improving replenishment rates, standardising handling equipment and the adoption of technology (Fernie, 2014).

In both the retail and other sectors this reliance on rapid stock replenishment by goods vehicles delivering on a frequent basis resulted in the demand for more warehousing space in less expensive locations from where urban shops could be quickly supplied. Goods were held in such locations for far shorter periods of time than they had traditionally, with the number of stockturns achieved within businesses substantially increasing. In the mid-1980s, the order lead time for the delivery of packaged grocery products from suppliers was approximately 5 -7 days. By the mid-1990s many of these products were delivered within two days. In the case of Tesco this approach helped to reduce warehouse inventory by 20% (Economist, 15/4/1994 quoted in McKinnon, 1996). Consequently, Tesco’s stock turnover management ratio (i.e. the cost of goods sold divided by the value of the average inventory level which indicates the rate at which an organisation sells and replaces its stock of goods during a particular period) increased from 15 per year in 1985 to 30 in 1994 (Fernie, 1994). To achieve such fast replenishment of stock, ‘cross-docking’ was increasingly adopted in retail chains with goods received at a distribution centre, sorted by destination and then despatched to shops usually within a few hours of arrival (thereby doing away with the storage of products at distribution centres for such products and therefore the related handling time and costs involved in transferring these goods to racks or other locations and the subsequent retrieval of them). **Figure 3** shows Tesco’s stock turnover ratio since 2002.

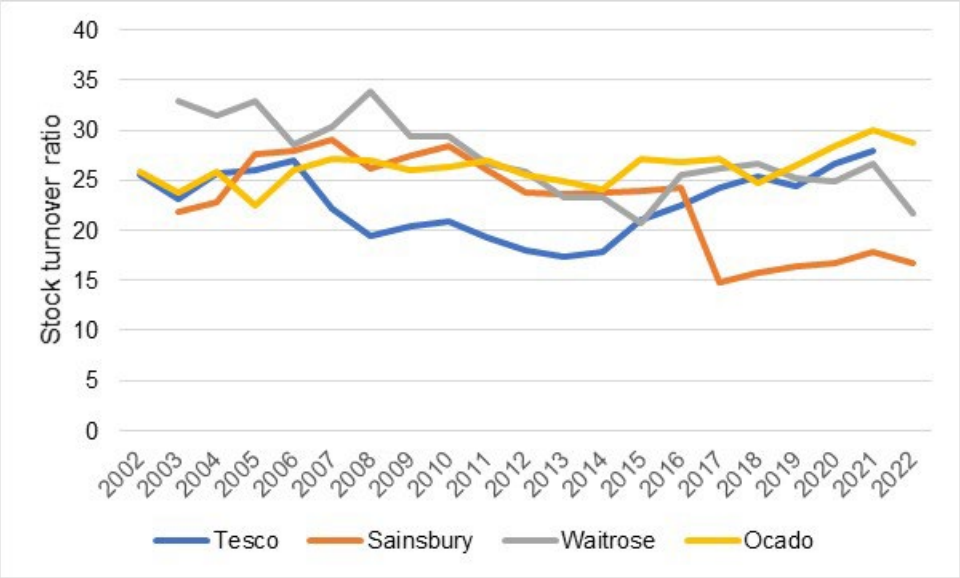
Figure 3: Tesco stock turnover ratio, 2002-2021



Note: data is for February year end each year.
Source: FAME, 2022.

Figure 4 shows the stock turnover ratio over the last 20 years for several leading UK grocery retailers.

Figure 4: Stock turnover ratio for selected UK grocery retailers, 2002-2022



Source: FAME, 2022.

In the year to February 2021, Tesco's stock turnover ratio was 28. Other major grocery retailers also achieve high stock turnover ratios (Sainsbury had a stock turnover ratio of 18 in the year of 2021, Morrison's was 20, Lidl's was 23, Waitrose was 30, Iceland's was 21 and Ocado's was 29) (FAME, 2022). An annual stock turnover management ratio of 30 indicates that, on average, a business sells and replaces its stock of goods every 12 days, whereas a ratio of 20 indicates this happens every 18 days. The annual stock turnover management ratio is obviously far higher for a grocery retailer with many fast-moving consumer goods that are sold and replenished extremely quickly than in many other businesses which sell and replace goods less rapidly. The stock value used in the calculation includes including raw materials, work-in-progress materials, and finished goods. This ratio indicates how well a business is managing its stock - if they hold excessive stock levels relative to sales this results in a very low ratio, whereas low stock levels relative to sales lead to a high ratio. If stock levels are too high this can prove very expensive given all the costs involved in doing so, whereas stock levels that are too low can result in lost sales or impacts on production lines and manufacturing levels. The ratio indicates the relationship between stockholding levels and sales and hence the effectiveness of the stockholding policy – it indicates how well the business is turning its stock into sales, how well stockholding costs (and levels) are being managed, how well the business is selling its goods. Major non-food retailers have lower stockturn ratios - for instance, John Lewis, Marks and Spencer, Currys and Kingfisher had ratios of 16, 15, 9 and 5 in 2021. Oil suppliers BP and Shell had ratios of 11 and 7, respectively in 2021, pharmaceutical manufacturers GSK, Shire and AstraZeneca and had ratios of 6, 5 and 4, respectively, drinks producer Diageo had a ratio of 2 while cigarette producers Imperial Brands and British American Tobacco had ratios of 9 and 5, respectively (Fame, 2022).

Over time, goods vehicles have become an increasingly important part of the supply chain, ensuring that goods are where they need to be when they need to be there. In this sense, goods vehicles have become mobile warehouses.

From the 1980s onwards, many businesses (retailers, manufacturers, wholesalers and other types of businesses in other sectors) reduced their stockholding levels and relied on making ever more rapid deliveries to their stores and buildings in urban areas, replenishing their stock on a regular

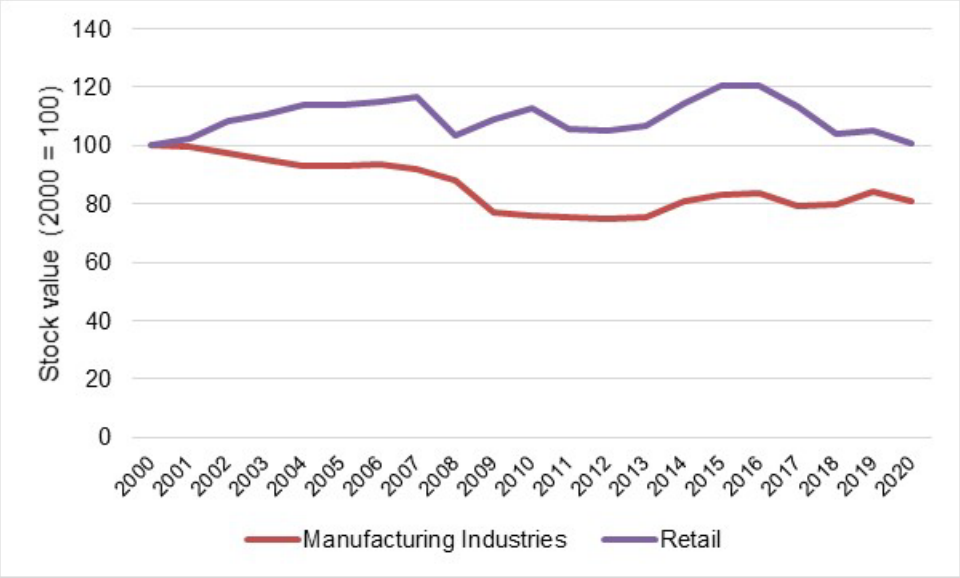
basis with frequent deliveries. However, the supply disruptions that have occurred as a result of Brexit and the Covid-19 pandemic are forcing many businesses to reassess their stockholding levels, as an inadequate availability of goods can lead to lost sales for retailers and wholesalers and can result in manufacturers having to temporarily cease their production operations.

4.7 Changes in stockholding levels in the UK economy

Analysis has shown that the book value of aggregate stocks held in the UK as a percentage of GDP fell over the period 1949 to 1991 (with the brief exception of the early 1970s when, during the economic recession caused by oil price increases, the cost of raw materials rose sharply and finished goods remained unsold). This downward trajectory in stock to GDP values over this period is likely to have been due to improved inventory control together with structural changes in the UK economy away from manufacturing towards a service-based economy (with a consequent reduction in manufactured goods and raw materials and work-in-progress required to produce them) (Waters, 1994).

Stock levels are calculated at the level of the UK economy as a whole (i.e. including manufacturing, retailing, wholesaling, mining and quarrying, utility and other industries) for the purposes of calculating GDP. **Figure 5** shows changes in the value of all stock for the UK retail and manufacturing sectors since 2000. This indicates that while stock values in retailing and wholesaling were higher in real times (i.e. based on constant prices) in 2020 than in 2000, in manufacturing they were lower in 2020 than at the start of this period. This is likely to reflect the rate of growth in the retail sector in the UK compared to manufacturing over this period.

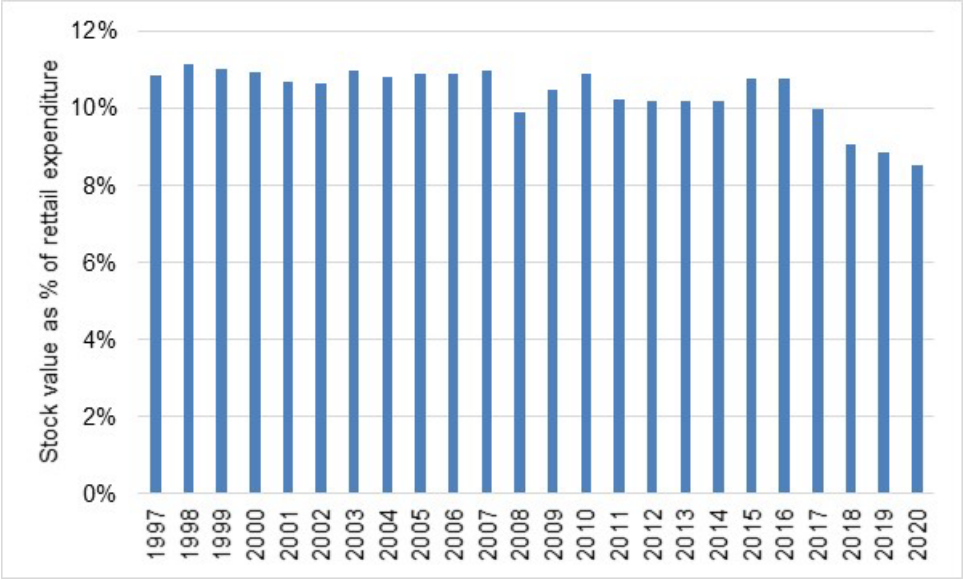
Figure 5: Value of stock by industry in the UK, 2000-2020



Note: includes stocks of raw materials, work-in-progress materials, and finished goods and based on constant prices.
Source: calculated using data in ONS, 2021c.

Figure 6 shows the value of stock held by UK retailers as a proportion of retail expenditure by consumers. This indicates that the value of stock as a proportion of retail sales remaining at approximately 10-11% between 1997 and 2016, since when it has fallen, equalling 8.5% in 2020 (this 2020 figure is equivalent to a stock turnover ratio of approximately 12, which reflects, on average, approximately 30 days of stock for the whole of UK retailing).

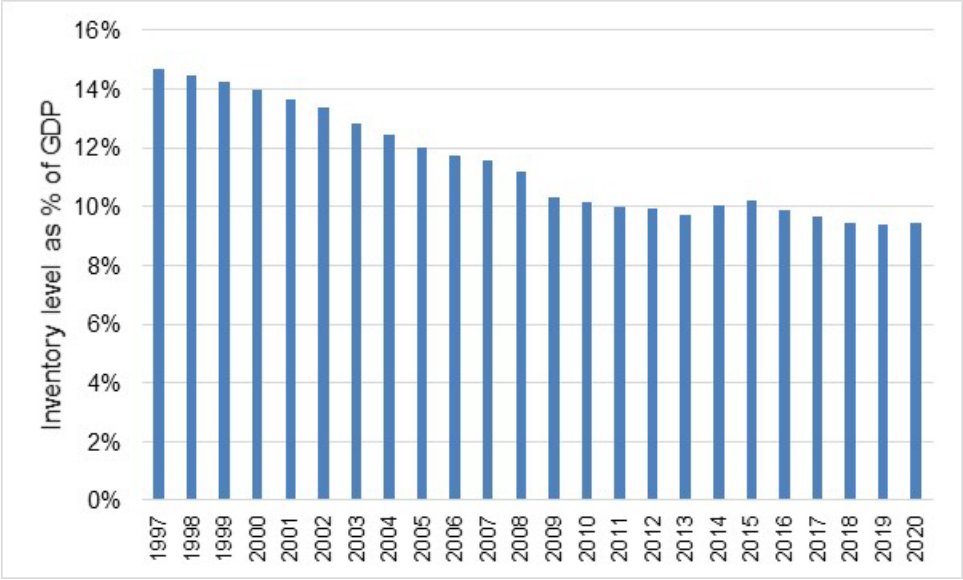
Figure 6: Retail stock value as a proportion of retail expenditure in the UK, 1997-2020



Note: includes stocks of raw materials, work-in-progress materials, and finished goods and based on current prices.
Source: ONS, 2021c and 2022d.

Figure 7 shows the value of stock in the UK as a whole as a proportion of GDP since 1997 (this includes all types of stock: raw materials, work-in-progress materials, and finished goods). This indicates that the value of UK stock diminished as a proportion of GDP between 1997 and 2010, then remaining relatively stable until 2020. The value of stock fell considerably in the manufacturing and quarrying, and gas, electricity and water industries, while rising in manufacturing, wholesaling, retailing and other industries.

Figure 7: The value of stock in the UK economy as a percentage of GDP, 1997-2020 (based on current prices)



Note: includes stocks of raw materials, work-in-progress materials, and finished goods and based on current prices.
Source: calculated using data in ONS, 2021c, 2022d.

The choice of location for these ever-larger warehouses required good access to the motorway network, a suitable available labour supply (but with this requirement diminishing as warehouses

became increasingly automated), and depended on the type of supply chain involved (with occupants requiring the delivery of a large number of small loads to a large number of outlets likely to require a warehouse closer to the delivery market area than those delivering a small number of large loads to a small number of outlets) (Drury, 1982).

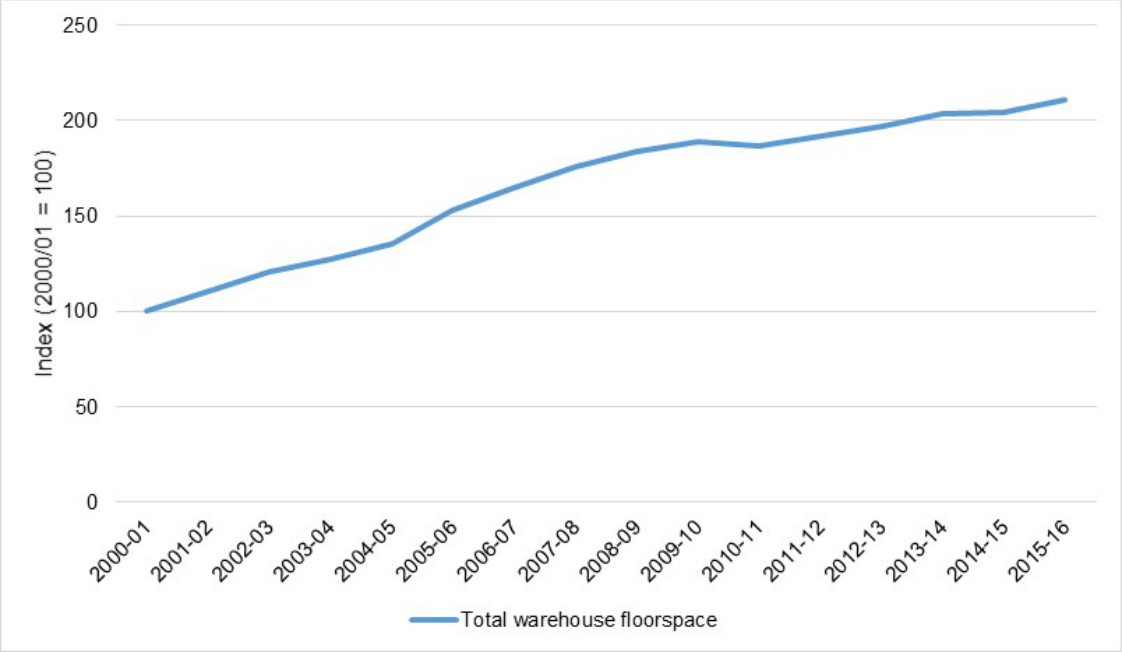
5. More recent changes in warehousing

5.1 Warehousing floorspace and location

The growth in the total amount of floorspace used nationally and in the average floorspace of warehouses, including the increase in large, more centralised warehouses is reflected in various data. Data for the period 2012 to 2018 shows that the total amount of warehousing floorspace in England increased by 6% and the average size of warehouses increased by 3% (CoStar data in Turley, 2019).

Valuation Office Agency (VAO) data provides insight into changes in total floorspace of large warehouses (i.e. over 100,000 sq ft) in England and Wales between 2000/01 and 2015/16 for larger warehouses (see **Figure 8**). In 2015/16 there were approximately 4,000 warehouses in England and Wales in the five VAO warehousing codes analysed with a total floorspace of 370 million sq ft and an average warehouse size of approximately 100,000 sq ft. Over the period 2000/01 to 2015/16, total floorspace in warehouses of this type and size in England and Wales increased by 111%.

Figure 8: Change in total floorspace of large warehouses in England and Wales, 2000/01-2015/16

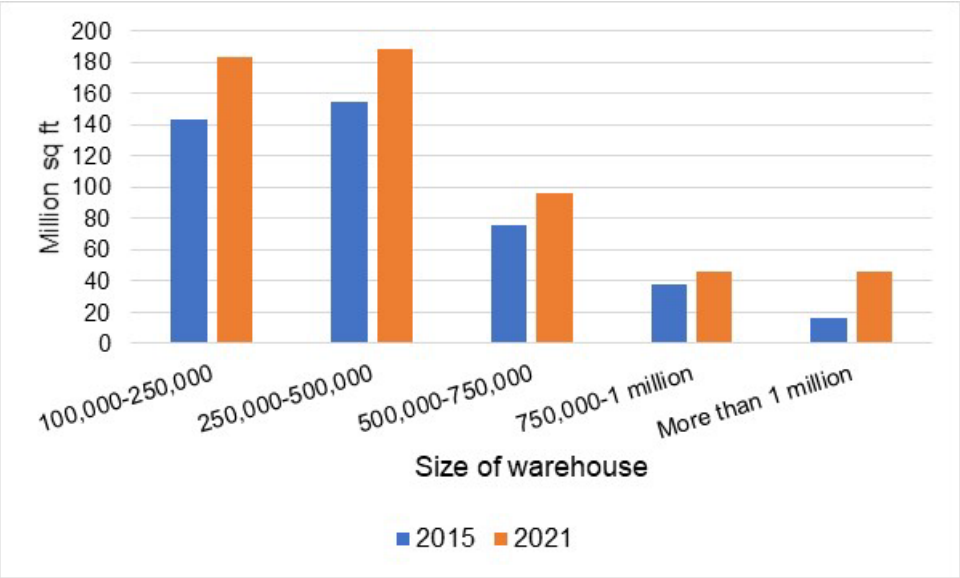


Note:
Data is for five VOA special category codes for warehouses: high tech warehouses (code 129), large distribution warehouses (code 151), storage depots (code 267), wholesale warehouses (code 301) and warehouses within/part of specialist property (code 511).
Source: Valuation Office Agency, 2018.

An analysis of change in total floorspace of warehouses over 100,000 sq ft in England and Wales between 2015 and 2021 indicates that it increased by 34%. The average size of these warehouses over 100,000 sq ft increased from 217,000 sq ft in 2015 to 340,000 sq ft in 2021 (an increase of approximately 55%). **Figure 9** shows the breakdown of these large warehouses in 2015 and 2021 by floorspace. Floorspace statistics only reflect the area of warehouses (i.e. their length and width) and do not reflect their volume, which takes account of their height. The height of large warehouses has also been increasing over time as well as the average are of their floorspace. The average eaves height of warehouses also increased over this period from 11 to 14 metres (i.e. by approximately 25%) (UKWA and Savills, 2021). It has been noted that, “operators are

increasingly attracted to warehouses with a minimum of 21 metres clear internal height to allow for internal stacking and installation of automated machinery" (Turley, 2021).

Figure 9: Warehouses over 100,000 sq ft by floorspace, 2015 and 2021, Britain



Source: produced from data in UKWA and Savills, 2021.

As the average floorspace and height of warehouses increases, so too does the total site area. Regional-scale distribution facilities often have site areas of at least 25 hectares and it is becoming increasingly common for sites to exceed 100 hectares (with sites that include strategic rail freight interchanges requiring approximately 250 hectares) (Turley, 2021).

Table 10 shows the change in total warehousing floorspace for large warehouses (i.e. over 100,000 sq ft) in England and Wales by region over the period 2000/01 to 2015/16. Warehousing floorspace rose most rapidly in the East Midlands (206%) and almost or more than doubled in all regions except the South West (86% increase), the North West (71%) and Wales (34%).

Table 10: Change in total floorspace in large warehouses in England and Wales by region, 2000/01-2015/16

Region	Change (%)
East Midlands	206%
West Midlands	109%
South East	95%
North West	71%
Yorkshire & Humber	107%
London	113%
South West	86%
East of England	113%
North East	114%
Wales	34%
Total	**111%**

Note: Data is for five VOA special category codes for warehouses: high tech warehouses (code 129), large distribution warehouses (code 151), storage depots (code 267), wholesale warehouses (code 301) and warehouses within/part of specialist property (code 511).
Includes data for warehouses over 100,000 sq ft.
Source: Valuation Office Agency, 2018.

Growth in the total floorspace of warehouses over 100,000 sq ft continued strongly over the period 2015-2021 in all regions. Growth was particularly strong in the North East (70%), Yorkshire and Humberside (48%), the East Midlands (45%) and the South West (45%) (see **Table 11**).

Table 11: Change in total floorspace in England and Wales for warehouses over 100,000 sq ft by region, 2015-2021

Region	Change (%)
East Midlands	45%
West Midlands	28%
South East	32%
North West	24%
Yorkshire & Humber	48%
Inner M25	22%
South West	45%
East of England	18%
North East	70%
Wales	12%
Total	**34%**

Source: Calculated from data in UKWA and Savills, 2021.

The greatest increases in new warehousing space over 100,000 sq ft in the UK between 2015 and 2021 by industry sector of occupier were in online retailing (which increased by 52 million sq ft – a 614% increase in online retailing floorspace over the period), followed by followed by freight transport/logistics (which increased by approximately 35 million sq ft – approximately 40% growth over the period). Although accounting for a relatively small proportion of all new warehousing floorspace in units over 100,000 sq ft, wholesale and parcels/mail floorspace also grew rapidly between 2015 and 2021 as a result of the growth in online retailing (increasing by 73% and 51%, respectively). High street retail warehousing floorspace in new units over 100,000 sq ft grew at the slowest rate of all occupier types over the period increasing by only 6% (5 million sq ft) over the period (UKWA and Savills, 2021).

Meanwhile, among second-hand warehouses over 100,00 sq ft in Britain being re-let, online retail increased most between 2015 and 2021 (increasing by almost 8 million sq ft), followed by freight transport/logistics (which increased by almost 6 million sq ft). Conversely, the greatest reduction in second-hand, re-let warehousing space over this period occurred among high street retail users (which decreased by approximately 11 million sq ft), manufacturing (which decreased by approximately 8 million sq ft) and food retailers (which decreased by approximately 3 million sq ft) (UKWA and Savills, 2021).

Demand by non-logistics users for warehouse space has also been increasing in recent years, with especially strong demand for such space for data centres and for filming locations. Demand for data centres was reported to have reached another record in 2021, with London being the leading European urban area for existing data centre space and with the greatest continued take-up (with 98 megawatts (MW) of new supply added to the London market in 2021 with another 50 MW due to be completed in 2022 and 220 MW in the planning stages). Factors in growth of data centre space requirements include the remote working and increased IT expenditure of businesses since the onset of the Covid-19 pandemic (which is expected to continue) with growing demand for cloud-based storage services, together with substantial growth in e-sports and online gaming (JLL, 2022a).

Demand for warehousing space for filming is reported to have never been greater in the UK, with up to 4.5 million sq ft of new development under consideration in order to meet this demand (which is more than the 3.4 million sq ft of current amount of permanent stage space in the UK – in

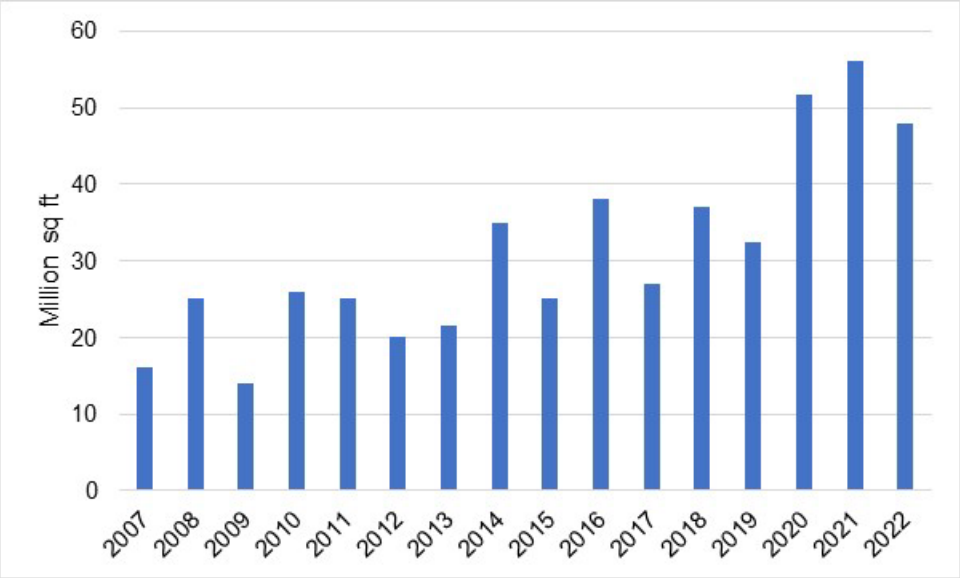
addition there is 1.8-2 million sq ft of temporary stage space). This warehousing space is used to provide stages/studios, ancillary workshops for making the film sets, and offices for project management and administration. The warehouse design for such permanent use includes high eaves heights, the ability to suspend large lighting rigs, and sound proofed walls. This growth in the use of warehousing space for filming is expected to be spread across the UK in relatively close proximity to urban areas as well as around existing studios (JLL, 2021b).

Warehousing land has continued to be relocated from central and inner urban locations to outer urban sites as well as sites beyond the urban area. This is due the affordability and availability of land (with housing and other commercial uses outcompeting warehousing and other industrial uses) as well as relocations to less congested sites with improved transport accessibility and connectivity and policy encouragement to intensity the use of industrial and warehousing land (through the increase in plot ratios, co-location of residential and industrial uses, and vertical developments) none of which suit logistics operations. For example, in London, total warehousing land fell by 9.5% between 2001-2020. In Central London, which was already relatively small in 2001, fell by 34% over this period, while warehousing land in Inner London fell by 43%. By comparison, warehousing land in Outer London fell by far less (by 1.2%) over this period. However, warehousing land fell in all these locations between 2010 and 2020, with warehousing land in Outer London falling by 4.5% over this period, reversing its increase between 2001 and 2010 (calculated from data in AECOM, 2023a). However, demand for smaller urban facilities required for making last-mile deliveries associated with online retailing has been growing in the last few years in urban areas, especially since the Covid-19 pandemic (with facilities located in close proximity to delivery catchment areas for rapid delivery) (see Allen and Piecyk, 2023c).

As discussed in **section 2**, as well as being the main source of the increase in demand for warehousing in the UK in recent years, online retailing has also led to the demand for many smaller warehousing sites and delivery depots in urban areas from which deliveries to customers are made. This has come about due to changes in consumer shopping behaviour over the last decade together with the ever-shortening delivery lead times being offered but has been further exacerbated since the beginning of 2020 by the Covid-19 pandemic, during which online retailing penetration rates have reached all-time highs in the UK. It has been estimated that online retailing accounted for approximately 35-40% of the take-up of UK warehousing space over 100,000 sq ft in 2021 (CBRE, 2022a; JLL, 2022b; Savills, 2022) before falling back to 13% in 2022 (reflecting reduced online retail spending in 2022 compared to 2021 together with substantially reduced warehousing take-up from some of the leading online retailers (JLL, 2023). This growth in online retailing has increased the rate of high street shop closures, especially among department and clothing stores. The demand for warehousing space for online retailing has included both large warehouses outside of urban areas where goods are stored and then picked for despatch as orders are received and smaller urban depots used to transfer parcels travelling on their way to customers between HGVs and smaller vehicles (predominantly LGVs) for the last leg of the journey to the point of delivery. Some online retailers are also developing urban warehousing at which goods can be stored and orders picked in order to meet same-day and instant non-food and grocery orders (See Allen and Piecyk, 2023d for further discussion of the logistics land requirements of online retailing).

In both 2020 and 2021, warehousing space take-up in sites over 100,000 sq ft vastly exceeded the long-term annual average (by 86% in 2021). 2022 was a year of two halves, with record levels of take-up in the first six months followed by 34% less take-up in the second half. However, overall, year-long take up in 2022 totalled 48 million sq ft, the third highest year ever after 2021 and 2020 and 10 million sq ft more than the pre-2020 high. Even the lower second half take-up in 2022 was 22% higher than the long-term second half of the year average (see **Figure 10** - Savills, 2022, 2023).

Figure 10: New leases signed for warehouses over 100,000 sq ft in Britain, 2007-2022



Source: produced from data in Savills, 2023.

The take-up of new speculative building space outstripped new build-to-suit warehousing take-up in 2021 (by 63% to 37%), indicating the pressure on occupiers to acquire sites quickly in response to these supply chain pressures (JLL, 2022b). In 2022, new speculative building take up exceeded build-to-suit warehousing by 53% to 47% (JLL, 2023). This is a very different pattern to the period 2018 to 2020 when take up of new build-to-suit warehouses significantly outperformed speculative new builds, with build-to-suit accounting for 65-75% of all new annual building take up in those years (JLL, 2023).

Second-hand buildings accounted for 14% of the overall take up of warehouses over 100,000 sq ft in 2022 which was an equal record low for the last ten years (with second-hand take up representing 22% of total warehousing take-up in 2021 and 21% in 2020 - JLL, 2023). This may reflect concerns among tenants about high energy prices and the need for well-insulated, modern buildings (Savills, 2023). New orders for the building of warehouses were worth £5.6 billion in 2021, higher than in any previous year (ONS, 2022a).

Overall, retailers (online and in-store) accounted for 57% of take-up of 'grade A' (i.e. those of the best quality) warehousing space in UK sites over 100,000 sq ft in 2021 (41% by online only and 16% by physical and online retailers), followed by businesses providing logistics, warehousing and freight transport services (26%), other businesses (10%) and manufacturers (6%) (JLL, 2022b). In 2022, the proportion of 'grade A' warehousing take-up accounted for by online retailers fell to 13% (down from 41% in 2021), reflecting reduced online retail spending in 2022 compared to 2021 and 2020 together with substantially reduced warehousing take-up from some of the leading online retailers (JLL, 2023). Overall in 2022, businesses providing logistics, warehousing and freight transport services accounted for 38% of take-up of 'grade A' UK warehousing space in sites over 100,000 sq ft, retailers (online and in-store) for 29% (13% by online only and 16% by physical and online retailers), other businesses (17%) and manufacturers (16%). This was the lowest share for warehouse take-up for retailers for five years (JLL, 2023). Another source ranks up-take of large warehouses in the UK in 2022 by activity type as flows (in order of importance): third party logistics, warehousing and freight transport, manufacturing; retailing; ecommerce retailing; wholesale and distribution and post/parcels (Cushman & Wakefield, 2023).

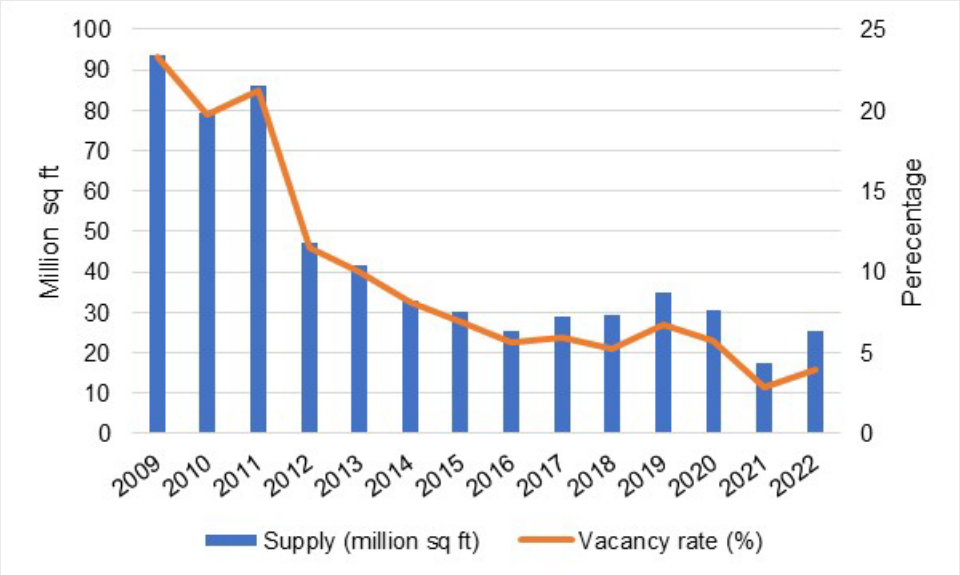
The east and west Midlands accounted for 52% of the take-up of new 'grade A' warehousing over 100,00 sq ft in 2021 (38% in east Midlands and 14% in west Midlands), followed by the South East and London (22%), Yorkshire and Humberside (13%), and the North West (11%) (JLL, 2022b). In

2022, the east and west Midlands accounted for 41% of the take-up (22% in east Midlands and 19% in west Midlands), followed by the North West (20%), South East and London (19%), and Yorkshire and Humberside (10%) (JLL, 2023).

5.2 Warehouse vacancy rates and rental prices

Demand for warehousing has been strong in many regions in recent years, with the level of demand since 2020 leaving very little warehousing floorspace available. One estimate of the floorspace availability for sites in its dataset over 100,000 sq ft at the end of 2021 suggested 5.5% nationally (i.e. the vacancy rate), or only 1.1% if speculative sites under construction were excluded. This rose slightly to 6.4% and 2.5%, respectively, by the end of 2022 (JLL, 2022b, 2023). Another estimate showed a vacancy rate of 2.0% at the end of quarter 4 in 2022 for sites in its dataset (CBRE, 2023). A third estimate put the national vacancy rate at 2.9% at the end of 2021, the lowest ever national vacancy rate on record with exceptionally low rates of 1.7% in the East Midlands, 2.3% in the West Midlands and 2.0% in Yorkshire and the North East (Savills, 2022). This source estimated a national vacancy rate of 3.9% at the end of 2022 (Savills, 2023 - see **Figure 10**). It predicted that vacancy rates will continue to ease back towards the medium-term average given the growing supply of 'grade A' speculative warehouses being completed in 2022 with even more due for completion in 2023 and 2024, unless developers change their planned builds of previously announced schemes (Savills, 2023).

Figure 11: Warehouse floorspace annual supply and vacancy rate for warehouses over 100,000 sq ft in Britain, 2009-2022



Source: produced from data in Savills, 2023.

Table 12 shows changes in vacancy rates for warehouses over 100,000 sq ft by region since 2017. This shows that vacancy rates rose in five regions and fell in three regions between 2017 and 2019. In the UK, as a whole this led to an increase in vacancy rates of 0.7 basis points between over this period. However, vacancy rates fell in all regions of the UK between 2019 and 2021, with the exception of the South West and Wales. This resulted in a decrease in vacancy rates of 3.7 basis points across the UK as a whole. Vacancy rates rose in all regions except East of England and South West & Wales between 2021 and 2022. Given the scale of the decrease in vacancy rates between 2019-2021, over the entire period 2017-2022 vacancy rates fell in all but one region (South West and Wales) and in the UK as a whole (by 2.1 basis points).

Table 12: Vacancy rates for warehouses over 100,000 sq ft by UK region, 2017, 2019, 2021 and 2022 (percentages and change in basis points)

	Vacancy rate (%)				Change in basis points			
Region	**2017**	**2019**	**2021**	**2022**	**2017-2019**	**2019-2021**	**2021-2022**	**2017-2022**
East Midlands	6.2%	5.7%	1.7%	4.3%	-0.5 bps	-4.1 bps	+2.6 bps	-2.0 bps
West Midlands	6.4%	8.5%	2.3%	3.1%	+2.1 bps	-6.2 bps	+0.7 bps	-3.3 bps
London & South East	4.2%	5.0%	2.9%	4.0%	+0.8 bps	-2.1 bps	+1.1 bps	-0.2 bps
North West	9.0%	7.4%	3.1%	3.8%	-1.6 bps	-4.3 bps	+0.7 bps	-5.2 bps
Yorks & North East	8.1%	6.4%	2.0%	2.5%	-1.7 bps	-4.4 bps	+0.5 bps	-5.6 bps
East of England	4.5%	6.5%	3.7%	2.9%	+2.0 bps	-2.8 bps	-0.8 bps	-1.6 bps
South West & Wales*	5.5%	7.5%	9.2%	8.7%	+2.0 bps	+1.7 bps	-0.5 bps	+3.2 bps
Scotland	5.2%	6.1%	3.3%	3.3%	+0.9 bps	-2.8 bps	+0.1 bps	-1.9 bps
UK	**6.0%**	**6.6%**	**2.9%**	**3.9%**	**+0.7 bps**	**-3.7 bps**	**+1.0 bps**	**-2.1 bps**

Note: * South West only not including Wales in 2017 data.
Source: Savills, 2018, 2020, 2022, 2023.

Demand has been outstripping supply and this is having an upward pressure on warehouse rental rates, which rose by 61% nationally between 2011 and 2021, more than double the rate of inflation (CoStar quoted in BPF and Savills, 2022). Increases in rental prices have been especially strong in recent years, rising 18% on average nationally year-on-year between 2020 and 2021 and a further 13% between 2021 and 2022 according to one source (JLL, 2023) and by 22% nationally between 2019 and 2021 and a further 14% between 2021 and 2022, with a 52% increase between 2017 and 2022 according to another (calculated from data in Savills, 2018, 2020, 2020, 2023).

Table 13 provides an analysis of changes in average rental prices for 'grade A' warehouses over 100,000 sq ft over the period 2017 to 2022 by region using data published by Savills (Savills, 2018, 2020, 2022, 2023). This shows that rental prices increased in several regions between 2017 and 2019, with these increases greatest in London and the South East. However, rental values were largely unchanged in Yorkshire and the North East, the South West and Wales, and the West Midlands. Between 2019 and 2021 average rental prices rose in all regions, with these increases exceeding 15% in all regions except the North West, and the South West and Wales. Between 2021 and 2022 average rental prices again rose in all regions, with these increases exceeding 10% in all regions except the South West and Wales.

Table 13: Average rental prices for warehouses over 100,000 sq ft by region, 2017, 2019, 2021 and 2022 (£ per sq ft for grade A warehouses*)

	Rental price (£ per sq ft)				% change***			
Region	**2017**	**2019**	**2021**	**2022**	**2017-19**	**2019-21**	**2021-22**	**2017-22**
East Midlands	£6.50	£6.75	£8.25	£9.75	4%	22%	18%	50%
West Midlands	£7.00	£6.95	£8.75	£9.75	-1%	26%	11%	39%
London & South East	£7.00-14.50	£7.75-20.00	£8.50-25.00	£9.00-35.00	11-38%	10-25%	6-40%	29-141%
North West	£6.50	£7.25	£7.75	£8.75	12%	7%	13%	35%
Yorks & North East	£5.75	£5.75	£7.50	£8.25	0%	30%	10%	43%
East of England	£5.50	£6.00	£7.00	£7.75	9%	17%	25%	59%
South West & Wales**	£7.25	£7.25	£7.50	£8.75	0%	3%	3%	7%
Scotland	£5.25	£5.75	£7.00	£8.00	10%	22%	14%	52%

Notes:
* Typical rental prices per sq ft for grade A facilities (i.e. those of the best quality which would facilitate modern, efficient logistics operations for any business given the eaves height, plot ratio, loading bays, floor loadings, turning circle and other infrastructure and amenities such as security, safety, insulation and lighting. This informal scale also includes grade B and grade C facilities with grade C considered the least modern and well equipped, often not suiting all operations and requiring refurbishment).
** South West only not including Wales in 2017 data.
*** shows range in percentage change for lower and higher rental values where applicable.
Source: calculated from data in Savills, 2018, 2020, 2022, 2023.

It is argued that at the UK national level, warehousing supply and demand are in balance and rents are more stable when vacancy rates are approximately 8% (BPF and Savills, 2022). Rising warehouse rental prices have been leading to a growing level of investment in warehouse property. In 2021 there was approximately £16 billion of investment in UK warehousing, which was double to investment level in 2020, and approximately three times the average annual investment level in 2017-2019 (CBRE, 2022a). Overseas investment in warehouse property has been increasing rapidly and in 2021 accounted for 57% of total investment. Total investment levels were not as strong in 2022 as 2021 but were the second highest on record. However, investment in the last quarter of 2022 were the lowest since 2012 (Savills, 2023). This increasing level of investment in recent years together with rising warehouse construction costs and borrowing costs led to reductions in investor yield rates. These fell to historic lows in the first half of 2022, but reduced levels of investment in warehouse property together with strong rental price increases helped to increase yield rates by the end of 2022. At the end of the year, prime logistics yields were approximately 5.0% in London, 5.35% in the South East and 5.5% in the major regional markets (JLL, 2023). Shortages in the construction labour force as a result of Brexit, Covid-19 and some older workers choosing to exit the labour market together with the high price of construction materials due to supply problems and high energy prices, has meant that new warehousing construction has struggled to keep up with unprecedented levels of demand for warehousing space and construction costs rising faster than rental values up to 2022. However, investment activity in warehousing is likely to remain strong given levels of demand and yield rates compared with other commercial property sectors such as retail and office.

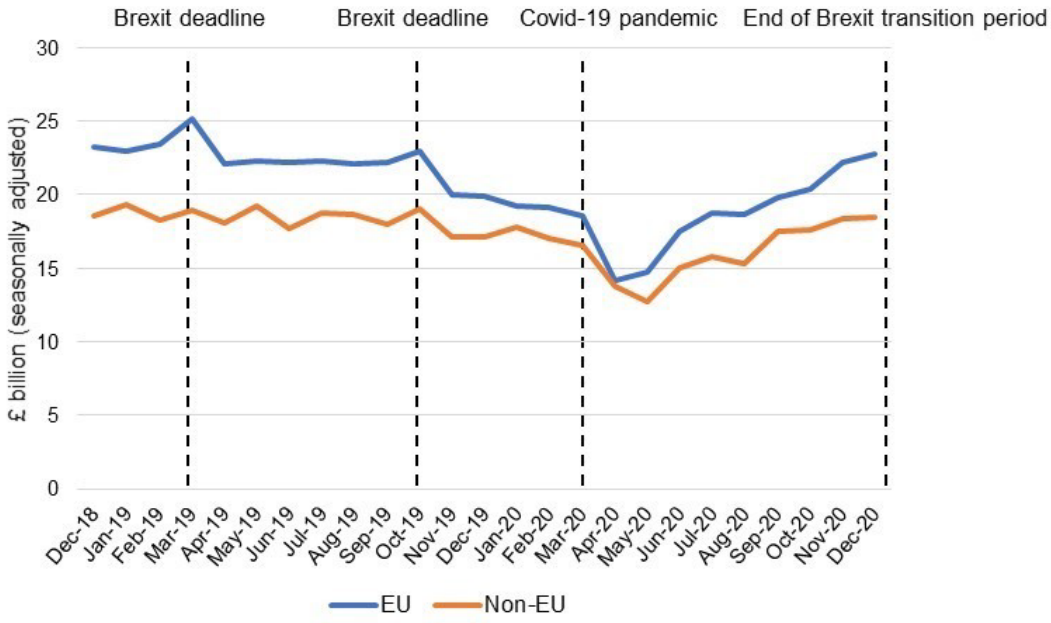
Demand for warehousing space is predicted to be slightly lower in 2023 than in the previous three years, but to remain strong due to lease expiries, changes in supply chain strategies leading to greater use of warehousing, and Environmental, Social and Governance (ESG) requirements of large businesses leading to demand for newer warehousing with lower energy consumption rates (JLL, 2023). Although there may be a small improvement in vacancy rates as planned speculative builds are completed, available supply is likely to remain limited due to on-going shortages in land that is ready and has planning consent for warehouse building, on-going high construction costs and higher financing costs given rising interest rates. These factors may well lead to further rental price rises, even if at lower rates than the last two years. A model of vacancy rates forecasts a rate of 5% in its baseline projection for 2023, with a downside forecast of 7% if warehousing take-up rates should fall due to an economic downturn (Savills, 2023).

The UK Government has carried out a review of rateable values of non-domestic buildings based on 2021 data and began using these new values for calculating the costs of business rates payable for these buildings from 1st April 2023. Up until that point, business rates were based on 2015 rateable values. This review has led to business rates for warehouses and other industrial buildings increasingly sharply. On average, the rateable values for large warehouses have increased by approximately 35% in England and Wales from this date (but with substantial variations by region – rising most in London, the south east and the eastern regions, and least in Wales, Yorkshire and Humberside and the north east). By contrast the rateable values of retail buildings have fallen across England and Wales, while office buildings have increased but by far less than warehouses and other industrial buildings. The majority of rateable values are determined based on changes in rents payable by occupiers over time. There are transitional reliefs from the increase in business rates as a result of these changes in rateable values. In England, buildings with rateable values up to £20,000 have a transitional cap in increases in business rates of 5%, buildings with rateable values up to £100,000 have a transitional cap of 15%, while buildings with rateable values over £100,000 have a transitional cap of 30% (Parker, 2023). Rateable values and business rates have also been increased in Scotland from the same date.

5.3 Impacts of Brexit and Covid-19 on warehousing

As well as the growth in demand for warehousing space associated with online retailing, Brexit and the Covid-19 pandemic have also increased the demand for UK warehousing space in many other sectors due to the shipping and border delays that both have resulted in for goods being supplied internationally with some businesses increasing inventory levels to prevent product shortages in their operations. Brexit-related stockholding is indicated in goods import data presented in **Figure 12** that shows the growth in goods imports ahead of anticipated Brexit withdrawal dates in March 2019 and October 2019, when at that point in time, it was not known what the nature of the UK's exit from the EU would be, and hence the impact of import and exports.

Figure 12: Trade in UK goods imports (excluding non-monetary gold and other precious metals), December 2018 to December 2020



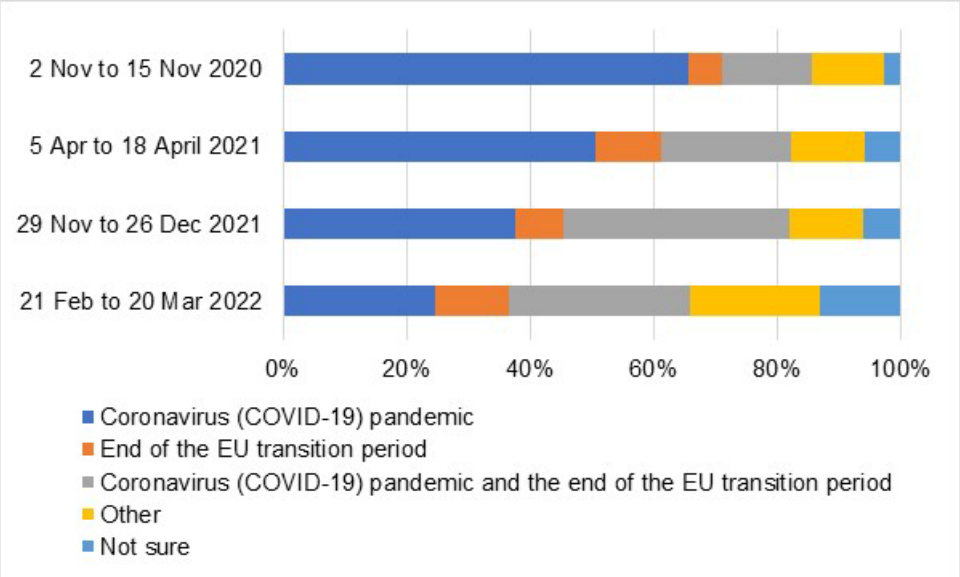
Source: produced from data in ONS, 2021d.

Figure 12 indicates the substantial stockpiling that UK businesses engaged in during these two months as they built of stocks of key goods in case of future trade delays and disruptions (including raw materials, food and drink and medicinal and pharmaceutical products). It also shows the decline in imports during early 2020 until May 2020 as businesses used up these stocks and also as a result of the Covid-19 pandemic that took businesses by surprise and which they had no little time to prepare for. Goods imports can be seen to rise from both geographical sources after May 2020 as goods began to be transported internationally again as Chinese factories and international ports began to reopen, continuing to climb as businesses replenished stock in advance of the end of the Brexit transition period as the UK prepared to leave the EU.

The IHS Markit / CIPS UK Manufacturing PMI survey has shown delays in the time taken for suppliers to make deliveries of raw materials, intermediate and finished goods to UK manufacturers ever since the onset of Covid-19 in early 2020 due to border and port delays and other transport disruptions including HGV driver shortages and the Suez canal blockage, with Brexit also contributing to these difficulties (IHS Markit and CIPS, 2022).

As well as stockpiling imported goods in anticipation of Brexit and the possible disruptions in international trade flows it could result in, some UK businesses also attempted to stockpile goods from UK suppliers as a result of Brexit and Covid-19. **Figure 13** shows that in UK government survey work with businesses since 2020, the extent to which respondents ascribed Covid-19 as the greatest impact on their businesses' stock levels has been reducing, while the number attributing this to both Covid-19 and Brexit increasing.

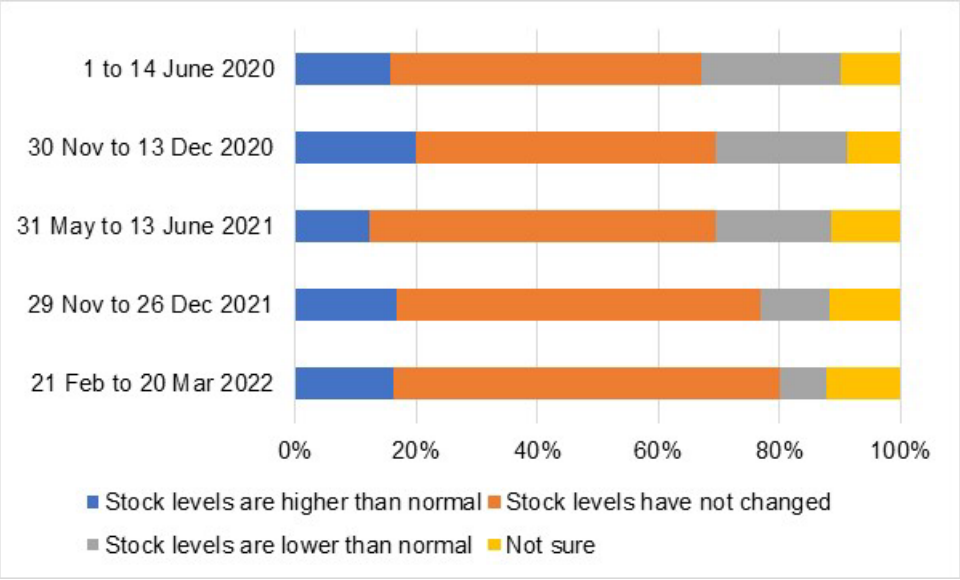
Figure 13: Over the last month, what has had the greatest impact to your business's stock levels? (% of UK businesses citing each factor)



Source: ONS, 2022f.

More businesses with 250 or more employees reported stock levels being lower rather than higher than usual in Government surveys in June 2020 in the early stages of the Covid-19 pandemic (with 16% of these businesses reporting higher than usual stock levels compared with 23% reporting stock levels less than usual) and also in surveys in Nov/Dec 2020 and May/June 2021 (but with a narrowing difference). However, in surveys between December 2021 to Feb/March 2022, more of these businesses reported holding more stock than usual than reported holding less (with 16% of these businesses reporting higher than usual stock levels compared with 8% reporting stock levels less than usual in the latter) (see **Figure 14**).

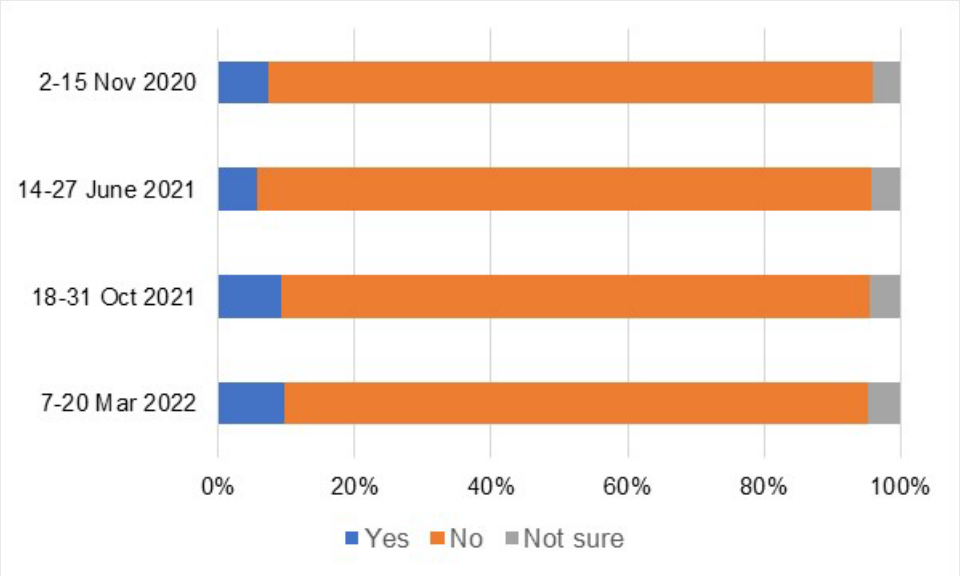
Figure 14: How do your business's stock levels over the last month, compare to normal expectations for this time of year? (% of UK businesses: businesses with 250 or more employees, weighted by turnover)



Source: calculated from data in ONS, 2022f.

Figure 15 shows that the proportion of UK businesses with 10 or more employees that stated that they were stockpiling goods has increased over time since this question was first asked in November 2020. In March 2022, 10% of businesses reported that they were stockpiling goods or materials in March 2022 compared with 7% of businesses in November 2020.

Figure 15: Is your business stockpiling any goods or materials?
(% of UK businesses: businesses with 10 or more employees, weighted by count)



Source: ONS, 2022f.

Since Brexit, the UK Government has unveiled plans for Freeports (secure customs areas, typically at sea or air ports, with alternative tax duties, planning and customs rules to elsewhere in the country), Investment Zones (similar to Freeports but without customs areas) and so-called 'gigafactories' and other innovative manufacturing clusters to produce batteries and other products essential for success in a net zero greenhouse gas future. These will require further, additional warehouse capacity to be made available.

Prior to Brexit, the UK warehousing sector was highly reliant on non-UK workers. The UK Department for Education Employer Skills Survey of 2017 found that 54% of warehousing and transport businesses had recruited or tried to recruit non-UK nationals to hard-to-fill vacancies (Department for Education, 2018). Non-UK EU nationals were more likely to work in warehousing-related activities than in many other UK industries and the UK economy as a whole, accounting for 18% of warehousing workers in 2016 (Labour Force Survey data quoted in REC, 2017). Many of the non-UK nationals working in warehouses were employed via agencies. Brexit has removed the possibility of warehousing workers required in the UK being recruited from outside the country. Since early 2020, the onset of Brexit and Covid-19 has resulted in many warehousing businesses reporting that they are unable to obtain their required size of workforce. This has contributed to the difficulties that grocery and non-food retailers have reported in stocking and replenishing their shop shelves (together with labour shortages in manufacturing plants and among goods vehicles drivers and international supply problems). Brexit has increased pressure on warehouse businesses to increase their rates of pay as well to consider further warehouse automation to reduce labour requirements. The UKWA (UK Warehousing Association) has coordinated a joint campaign with other trade associations (supported by Logistics UK, BIFA, Chemical Business Association, Cold Chain Federation and RTITB) and petitioned the UK Government in December 2022 to add warehousing workers to the Shortage Occupation List, thereby establish a visa quota allowing more skilled warehouse workers to be recruited from outside the UK. The letter cites the reduction in forklift truck drivers and HGV drivers, despite the increase in warehousing floorspace (UKWA, 2022).

5.4 Views about warehousing challenges and difficulties

A 2020 European survey of occupiers of logistics land carried out prior to the Covid-19 pandemic asked respondents about the real estate factors that provided them with the greatest concern for their business' ability to grow (see **Table 14**). The cost/financial terms of logistics facility, the potential need for environmental permits for them, and the inflexibility of lease lengths were most commonly cited. However, respondents from businesses with larger portfolios of logistics land occupation were most concerned about the lack of available suitable logistics facilities (CBRE, 2021).

Table 14: Logistics land occupiers' views of real estate factors they felt represented greatest concern for the ability of their business to grow, 2020

Real estate factor	Percentage of respondents mentioning this factor
Cost/financial terms of logistics facility	27.2%
Environmental permits	19.5%
Lease term/length – inflexible current lease conditions	14.4%
Lack of suitable logistics facilities	12.3%
Long lead time for development of new units	11.8%
Obsolescence of existing logistics facilities	10.3%
Reconversion of logistics space to other land uses	4.6%
Total	**100%**

Source: CBRE, 2021.

In this same survey, factors cited by occupiers as 'important' or 'vitally important' in their decisions about logistics land locations and building included: labour costs and availability, delivery time to customers, proximity to motorways/freight hubs, rent costs and lease options and the quality of local infrastructure. Meanwhile, factors cited as less important in these decisions included: co-location with similar business, proximity to residential areas, environmental implications, building design, and the reputation of property managers (CBRE, 2021).

A 2021 European survey of all stakeholders involved in logistics real estate including occupiers (27% of respondents), investors (28% of respondents), developers (12% of respondents), asset managers (12% of respondents), advisors/consultants (12% of respondents), agents (5% of respondents), and landowners (3% of respondents) asked them to name the single greatest challenge facing the logistics sector (Savills and Tritax Eurobox, 2021 - see **Table 15**). Just over one-third (36%) of respondents cited the lack of supply of new buildings as the greatest challenge, followed by the zoning/permitting system for logistics facilities (i.e. gaining planning approval for warehouses where they are needed – mentioned by 17% of respondents). Together these two responses accounted for more than half of all respondents (53%). Other factors mentioned included achieving the necessary employment for warehouses, managing international trade, increasing rent levels, implementing sustainability measures and power supply issues.

Table 15: European real estate stakeholders' views of the single greatest challenge facing the logistics sector, 2021

Real estate factor	Percentage of respondents mentioning this factor
Lack of supply of new buildings	36%
The zoning/permitting system for logistics facilities	17%
Employment within logistics facilities	12%
Managing changes in international trade (inc. Brexit)	11%
Rising rents of logistics facilities	8%
Implementing sustainability measures	7%
Power supply to logistics facilities	6%
Other	4%
Total	**100%**

Source: Savills and Tritax Eurobox, 2021.

A 2021 survey of 174 European logistics experts asked them which supply chain trends that affect warehouse decision-making they agreed would occur in the next 3-5 years. The most commonly cited trends were 'investment in automation & robotics' (90% of respondents), 'digitization of supply chains' (87% of respondents), 'focus on environmental solutions' (76% of respondents) 'on-demand warehousing' (74% of respondents), 'transparency of supply chains' (74% of respondents), 'increased reshoring' (74% of respondents), 'hold more inventory' (63% of respondents), and 'locate more inter-modal' (56% of respondents) (JLL, 2021a).

The planning system is failing to allocate sufficient land for warehousing in the locations needed to meet current and future. The desire for housing among national and local government is resulting in insufficient land for warehousing and other industrial purposes being made available by local planning authorities (BPF and Savills, 2022 – see **section 8** for further discussion).

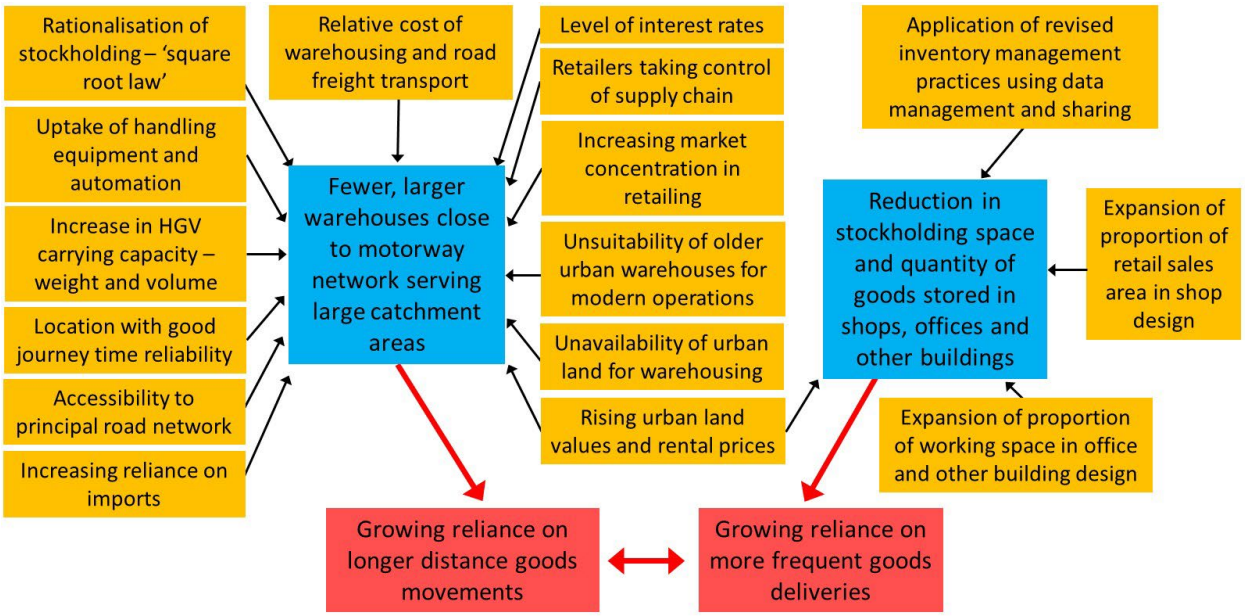
6. Impacts of warehousing trends on road freight transport activity

6.1 Warehousing and logistics management and freight transport operations

The growth in the total amount of warehousing in the UK, together with the trend towards ever-larger centrally located warehouses in close proximity to the motorway network means that most goods flows to and from large warehouses take place using articulated heavy goods vehicles (HGVs). Only approximately 6% of warehousing floorspace in large warehouses over 100,00 sq ft in England is rail-connected (GL Hearn et al., 2022).

The reliance placed on domestic road freight transport has been growing over recent decades due to the developments in warehousing and logistics operations and supply chain management discussed in **sections 3-5** together with the UK's growing dependence on the importation of capital and consumer goods and the growing economic importance of retailing. At the same time, the rising cost of urban land has led to diminishing storage space in many shops and offices requiring more frequent deliveries by HGVs and LGVs (light goods vehicles) to provide them with the goods they require **Figure 16** summarises the key factors influencing the trend towards the use of larger warehouses located close to the principal road network as well as the reduction in stockholding space in urban shops, offices and other buildings that have resulted in goods being transported over longer distances as well as greater delivery frequencies.

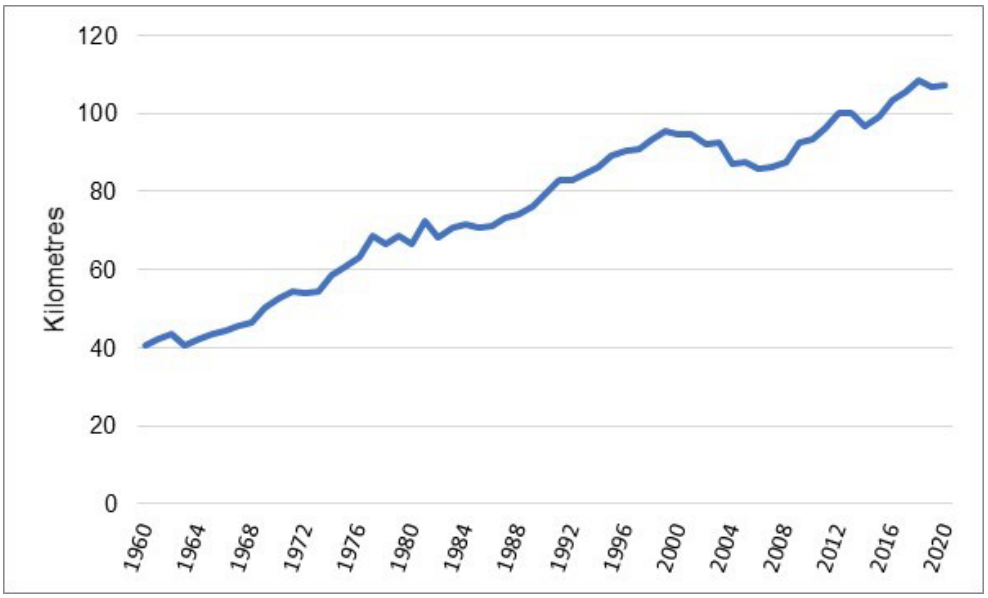
Figure 16: Summary of issues driving change in warehousing and stockholding strategies and their impact on road freight activity in recent decades in UK



6.2 Domestic freight transport serving warehouses

Road transport accounts for approximately 90% of all goods lifted domestically in the UK, compared with 6% by water, 5% by rail, and a fraction of one percent by air (Department for Transport, 2021b, 2021c). Therefore, the vast majority of goods moved to and from warehouses travel by road goods vehicle. The centralisation of large warehouses (discussed in **sections 3-5**) and hence the longer distances over which goods have to be transported from warehouses to shops, offices and other delivery points is reflected in the average length of haul of heavy goods vehicles (HGVs). **Figure 17** shows the average length of haul of HGVs operating domestically in Britain over the period 1960-2020. It increased by 165% over this 60-year period (from 40 km to 107 km). The average length of haul will have to reach a limit at some point given that the geographical size of Britain is fixed, but this has not yet been reached.

Figure 17: Average length of haul for road freight transported domestically by HGVs in Britain, 1960-2020



Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from data in Department for Transport, 2021b.

The change in the average distance over which goods were transported by HGVs over the period 1960-2020 is shown by decade in **Table 16**. This shows that growth in average distance was strongest in the periods 1960-1970 and 1970-1980 when the centralisation of warehousing to fewer but larger buildings began to occur, with continued strong growth from 1980-2000. There was little change between 2000 and 2010, followed by further growth between 2010 and 2020.

Table 16: Average length of haul for domestic HGV journeys in Britain, 1970-2020

Period	% change in average length of haul
1960-1970	30%
1970-1980	26%
1980-1990	19%
1990-2000	19%
2000-2010	-1%
2010-2020	15%
Entire period (1960-2020)	**165%**

Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from data in Department for Transport, 2021b.

Table 17 shows the average length of haul for domestic road freight by HGV, rail and water freight. This indicates the far longer average distances of rail freight and water freight (mostly coastal shipping) compared with HGV operations by road. However, many goods moved by these non-road modes are bulks (liquids and solids) and are not subject to warehousing requirements.

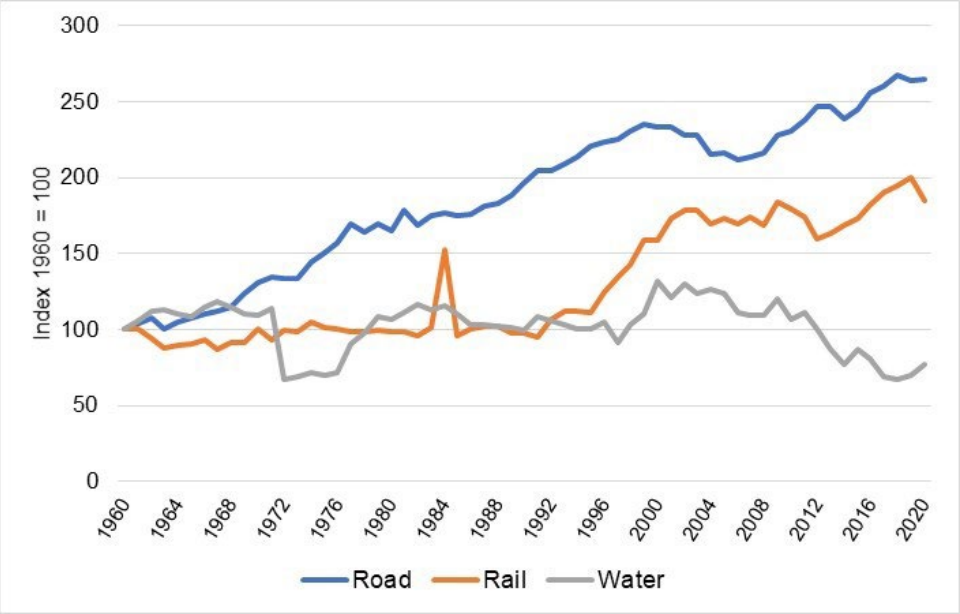
Table 17: Average length of haul of domestic freight transport in Britain, 2020 by mode

Freight mode	Average length of haul (km)
Road	107
Rail	220
Water	284

Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from data in Department for Transport, 2021b.

However, the average length of haul by road has increased far more than for rail and water over the period 1960-2020 (see **Figure 18**). This reflects the change in the distances over which goods are moved by road due to the reconfiguring on warehouse locations in supply chains as well as reflecting the limitations for further growth in average haul lengths for rail and water.

Figure 18: Change in the average length of haul of domestic freight transport in Britain, 1960-2020 by mode (Index 1960 = 100)



Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from data in Department for Transport, 2021b.

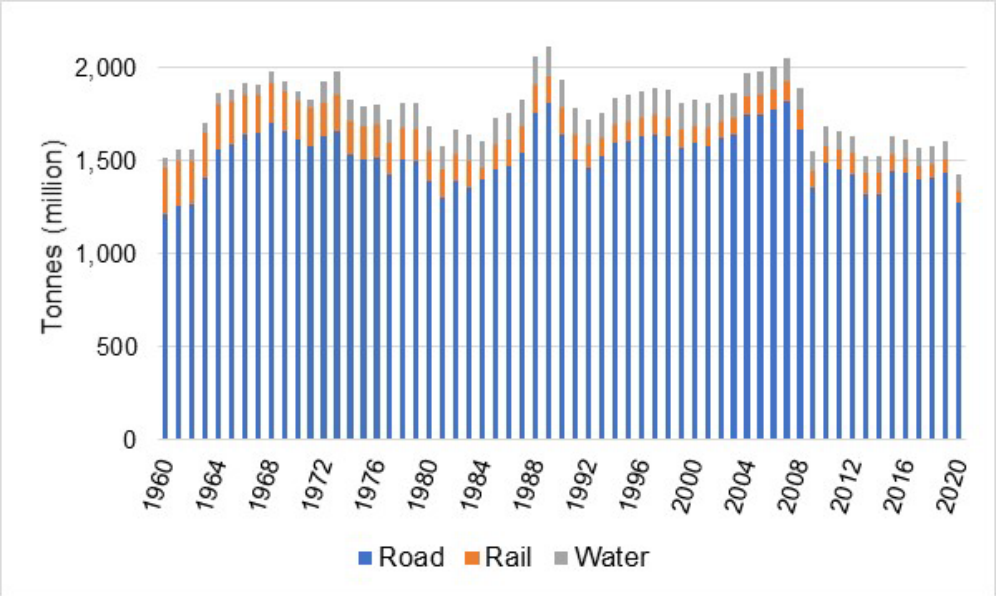
The flexibility and end-to-end capability of road freight transport together with its other cost and service attributes has led to an increasing proportion of freight lifted and moved being carried out by road in Britain in 2020 compared with 1960 (see **Table 18**). **Figure 19** shows the freight modal split over the entire period. Relatively few warehouses are rail- or water-connected so would require road transport at each end of the journey if these modes should be used, adding to the journey time and cost for the goods transported.

Table 18: Modal split in 1960 and 2020 for domestic freight transport in Britain

	Tonnes lifted				Tonne-kms			
	Road	**Rail**	**Water**	**Total**	**Road**	**Rail**	**Water**	**Total**
1960	80%	17%	4%	**100%**	49%	30%	20%	**100%**
2020	89%	5%	6%	**100%**	77%	9%	14%	**100%**

Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from data in Department for Transport, 2021b.

Figure 19: Modal split for goods lifted domestically in Britain, 1960 and 2020



Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from data in Department for Transport, 2021b.

Table 19 shows the HGV road freight activity by English region in 2020 together with warehouse numbers and floorspace and proportion of English population. When compared with warehousing floorspace per region it can be seen that the proportion of HGV road freight activity exceeds the proportion of floorspace in the South West which has relatively little warehousing, much of which is located towards its eastern side, and therefore involves longer journeys than in other regions (either from these warehouses in the South West or ones outside the South West). London generated considerably less HGV mileage (4% of the English total in 2018) than it has warehousing floorspace (9% of the English total). This is likely to be due to the vast majority of this warehousing being located towards the edge of London and therefore HGV journeys delivering goods to these warehouses having short distances to travel within London, while many deliveries made from these warehouses to receivers are made using LGVs rather than HGVs due to traffic and site restrictions in the city (London accounted for 8% of all LGV mileage in England in 2018 but only 4% of all HGV activity). In the South East, the East of England and Yorkshire and Humberside the proportion of HGV activity exceeds the warehouses and their floorspace. This is likely to be due to the volume of HGV trips generated by sea ports and the Eurotunnel that then transits through these regions to their point of delivery (either a warehouse or a final receiver).

Table 19: Warehouse numbers, floorspace, population and HGV vehicle kms in 2018, by English region

Region	No. of warehouses (%)	Warehousing million sq ft (%)	Population (%)	Proportion of HGV vehicle kms (%)
North West	16%	17%	13%	13%
West Midlands	16%	17%	11%	13%
East Midlands	10%	13%	9%	13%
South East	13%	12%	15%	16%
Yorkshire & Humber	10%	11%	10%	13%
East of England	10%	10%	11%	15%
London	10%	9%	7%	4%
South West	8%	7%	6%	10%
North East	5%	5%	5%	3%
Total	**100%**	**100%**	**100%**	**100%**

Note: Does not include freight lifted by non-UK registered HGVs.
Source: calculated from CoStar data in Turley, 2019; Department for Transport, 2019; ONS, 2022b.

The lack of warehousing floorspace relative to population in London is borne out by **Table 18**. There has been a reduction in warehousing floorspace in dense urban areas in London over this period and instead warehousing has been relocated to outer urban locations and locations beyond the London boundary. A similar pattern of warehousing relocation has also been taking place in other urban areas in the UK. Some of this has been due to the increase in manufactured goods imported from other countries and the centralisation of warehousing among large retailers with substantial market shares and a response by businesses to the road traffic and congestion in dense urban areas (discussed above), while some has been due to relative land values and the low profit margins in the warehousing and logistics industry as well as recent policy aspirations that discourage warehousing development (see Allen and Piecyk, 2023c for further discussion of these urban warehousing changes and their effects on road freight transport).

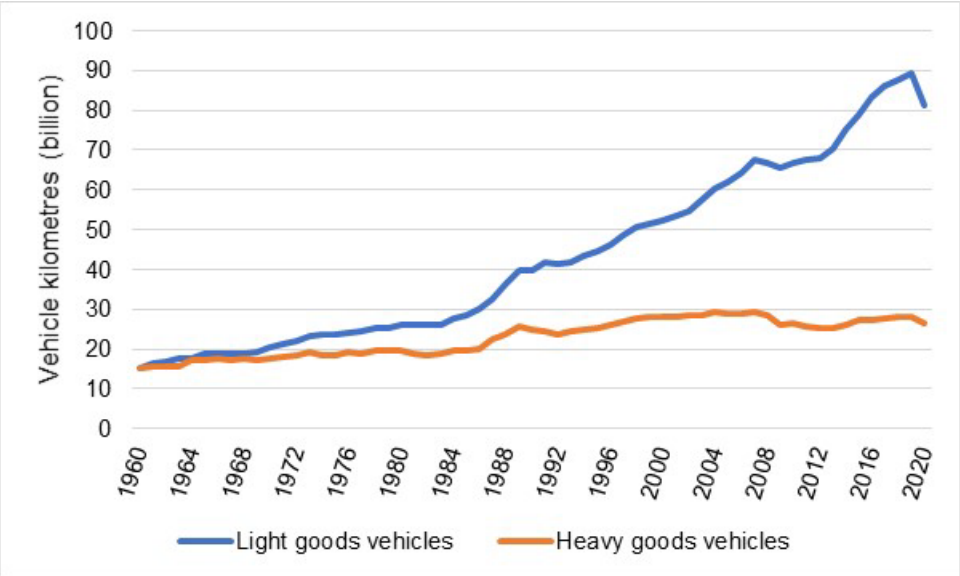
Goods with a non-bulk appearance (i.e. products that are likely to be subject to warehousing unlike solid and liquid bulk products) accounted for 52% of all tonnes lifted by HGVs, 62% of all tonne-kilometres performed by HGVs and 71% of all loaded vehicle kilometres travelled by HGVs in Britain in 2020 (analysed from data in Department for Transport, 2021d). The vast majority of non-bulk products are transported by articulated rather than rigid smaller, lighter HGVs (with articulated HGVs accounting for 76% of all non-bulk tonnes lifted and 85% of all non-bulk tonne-kilometres performed by HGVs in Britain in 2020 (analysed from data in Department for Transport, 2021e).

The importance of articulated HGVs in road freight transport in Britain has been increasing over time. In 1990, articulated HGVs accounted for 42% of all tonnes lifted and 69% of all tonne-kilometres performed by HGVs in Britain. By 2020, this had increased to 66% of all tonnes lifted and 82% of all tonne-kilometres performed (analysed from data in Department for Transport, 2021f). Some of this increase is likely to have been driven by the suitability of articulated HGVs for moving goods that require warehousing over relatively long distances between ports, warehouses and other land uses where they are sold and consumed.

Articulated HGVs travelled approximately 60% of their total mileage on motorways and 24% on trunk A-motorways and trunk A-roads in 2020. Light goods vehicles (LGVs) travelled only 20% and 13% of their total mileage on motorways and trunk A-roads, respectively, in 2020 (calculated from data in Department for Transport, 2021g, 2021h). It should be noted that LGV road traffic has been growing far faster than that of HGVs since 1960 (see **Figure 20** and **Table 20**). However, as noted above, much LGV activity is focused on built-up areas rather than to and from large non-urban warehouses given the carrying capacity of such vehicles. Where LGVs are used for

delivering goods this is mostly focused on collection and delivery activity in urban areas (including the rapidly increasing deliveries of online retail purchases to residential properties). It should also be noted that much LGV activity does not primarily involve the transportation of goods, and is instead concerned with the provision of services, commuting and private use (Department for Transport, 2021i).

Figure 20: Vehicle kms travelled by LGVs and HGVs in Britain, 1960-2020



Source: Department for Transport, 2021g.

Table 20: Change in vehicle kms travelled by LGVs and HGVs in Britain, 1960-2020

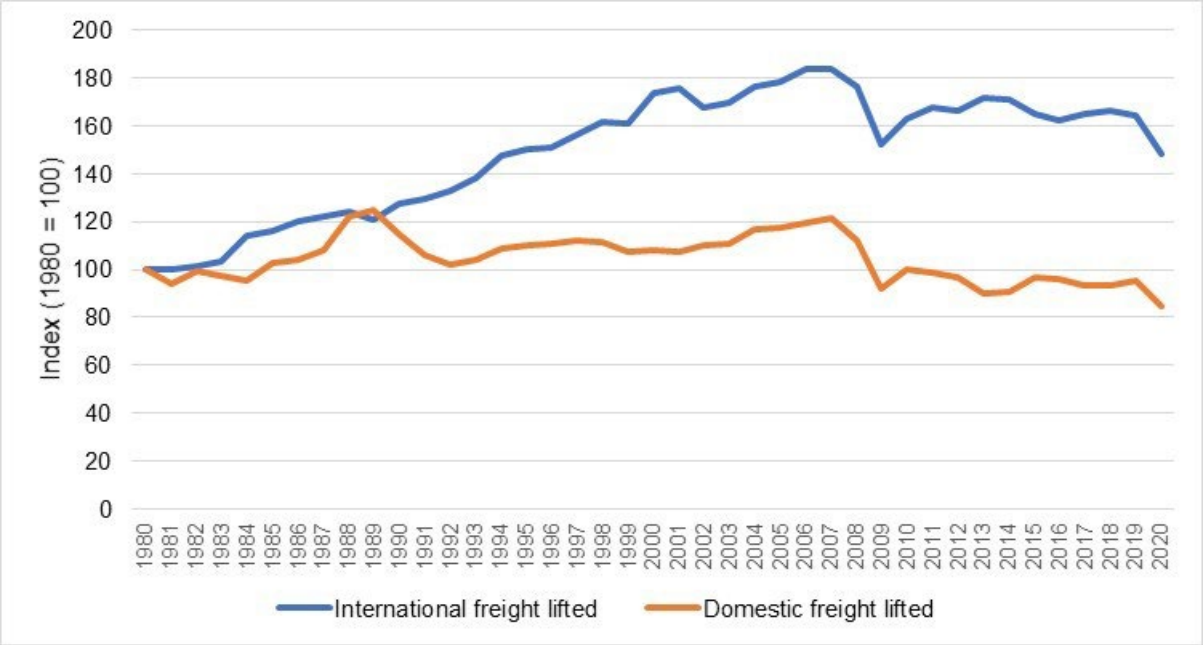
Time period	LGVs	HGVs
1960-1970	35%	15%
1970-1980	29%	12%
1980-1990	53%	26%
1990-2000	31%	13%
2000-2010	28%	-6%
2010-2020	22%	0%
Entire period (1960-2020)	441%	73%
Vehicle kms (billion) in 2020	81.2	26.4

Source: calculated from data in Department for Transport, 2021g.

6.3 International freight transport of goods to UK warehouses

The growing importation of consumer and capital goods into the country over time (see **section 4.1**) has resulted in increasing levels of international freight transport. These goods are transported to the UK via short- and long-sea maritime routes, by rail through the Channel Tunnel and by air. Tonnages of international freight to and from the UK accounted for 26% of the domestic freight lifted annually in the UK in 2020. However, this is up from 15% in 1980, reflecting the increase in the absolute and relative importance of international freight destined for the UK (see **Figure 21**).

Figure 21: Freight lifted to/from UK and domestically within the UK, 1980-2020 (based on tonnes: index 1980=100)



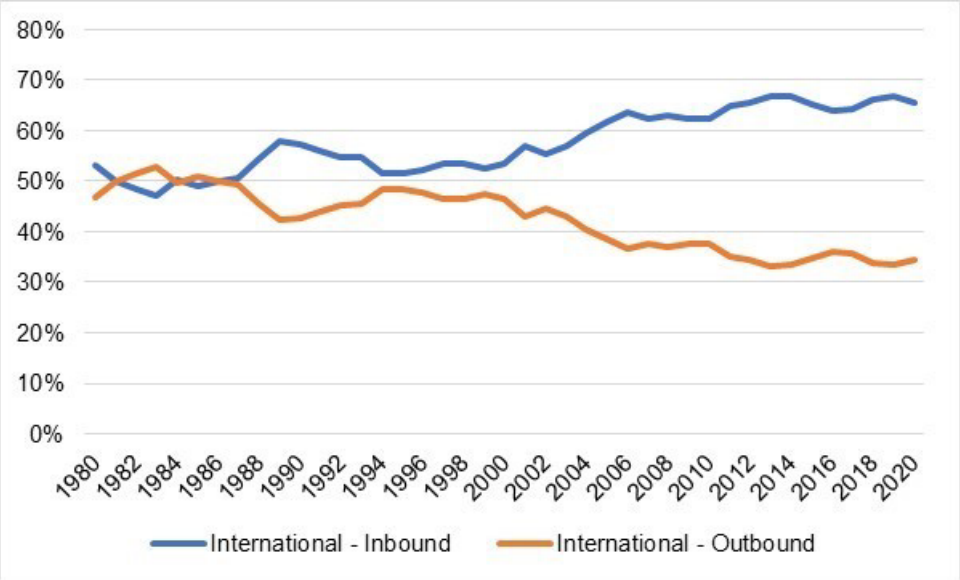
Notes:
International freight includes freight lifted by water, rail and air.
Domestic freight does not include road freight lifted by light goods vehicles (i.e. vans), road freight lifted by non-UK registered HGVs and air freight.
Source: calculated from data in Department for Transport, 1986, 1996, 2006a, 2021j, 2021k, 2021l.

The vast majority of this international freight transport to and from the UK takes place via sea. In 2020, maritime shipping accounted for approximately 93% of all freight tonnage transported to and from the UK, the Channel Tunnel for 6% (with the vast majority accounted for by HGVs conveyed on LeShuttle and a small proportion by through rail freight trains) and air accounting for less than 1% (Department for Transport, 2021j, 2021k, 2021l).

The extent to which imports of goods have exceeded exports at major UK seaports has continued to grow over the last forty years. In 2020, imports at UK major seaports accounted for 65% of all international cargo handled by weight (see **Figure 22**). Since 2000, outbound cargo has fallen in absolute terms, while inbound cargo has continued to increase at times when the economy has been growing.

These imported consumer and capital goods destined for warehouses are mostly moved in containers, with those arriving via short sea routes either being transported by powered HGVs or unaccompanied HGV trailer on ferries (referred to as Roll-On Roll-Off (RoRo) movements) or on container ships (referred to as Lift-On Lift-Off (LoLo) movements). Inbound RoRo and LoLo have been the fastest growing categories of freight handled at UK seaports, increasing by 41% and 26% in tonnage terms between 2000 and 2020 (calculated from data in Department for Transport, 2021m).

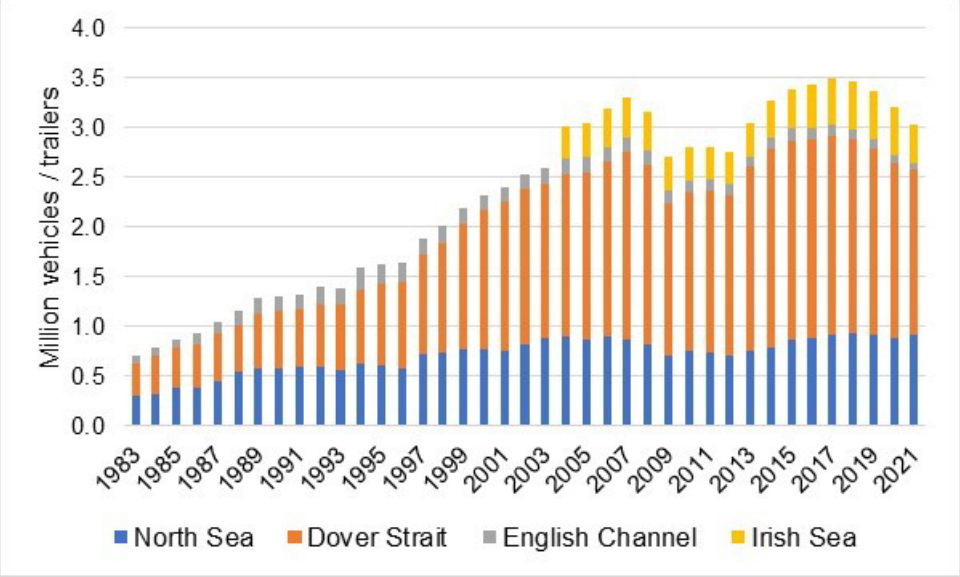
Figure 22: Proportion of inbound and outbound international freight to and from UK major seaports, 1980-2020 (based on tonnes)



Source: calculated from data in Department for Transport, 2021j.

There were 3.0 million goods vehicle/trailer crossings departing the UK via seaports and the Channel Tunnel to EU ports in 2021 (both loaded and empty HGVs and trailers). This compares with only 0.7 million in 1983 – an increase of 327%) (calculated from data in Department for Transport, 2021n). In terms of routes taken by RoRo powered vehicle and unaccompanied trailer crossings from UK to the EU, the vast majority use Dover Straits routes, with this traffic increasing by approximately 400% between 1983 and 2021 (see **Figure 23**).

Figure 23: RoRo (powered goods vehicle and unaccompanied trailers) crossing from UK to EU seaports by route/port group, annually 1983-2021



Notes:
North Sea: Ferry routes from all GB ports on the east coast, north of and including the Thames estuary.
Dover Strait: Ferry routes from Dover, Folkestone and Ramsgate, along with the Channel Tunnel (opened 1994).
English Channel: Ferry routes from all GB ports on the south coast, west of Folkestone.

Irish Sea: Ferry routes from all GB ports on the west coast.
Until 2004 data is only for journeys to mainland Europe; data for the Republic of Ireland commenced in 2004.
Source: calculated from data in Department for Transport, 2021o.

RoRo crossings of the Dover Straits are almost entirely of powered HGVs (i.e. with the driver present), whereas North Sea RoRo crossings are mostly of unaccompanied HGV trailers. In 2021, the Dover Straits (including both sea and rail crossings through the Channel Tunnel) accounted for 84% of all UK powered vehicle crossings (up from 76% in 2004), the North Sea for 8%, the Irish Sea for 6% and the English Channel for 2% (Department for Transport, 2021p). Once in the UK, most of these RoRo powered vehicles transport their loads to UK warehouses. The border crossing problems resulting from Brexit and Covid-19 have caused growing road traffic problems in Kent as drivers return to mainland Europe.

6.4 Road freight transport operations at warehouses

Goods both enter and leave warehouses as they move along their supply chains. This is facilitated by inbound and outbound goods movements the vast majority of which take place using road goods vehicles. Inbound goods can be delivered by vehicles either operated directly by the warehouse operator or by a third party (i.e. a goods supplier or a freight transport operator working on the suppliers' behalf).

Planning of these inbound goods flows and vehicle movements is easier to coordinate if operated by the warehouse operator themselves rather than by suppliers. Over recent decades, the growing concentration of retail markets (see **section 4.2**) has meant that major retailers have taken greater control over both upstream and downstream goods movements, whether or not these freight movements are operated by logistics providers working directly for them. Arrangements have to be made and planned for inbound goods flows and vehicle arrivals at a warehouse. These include managing delivery schedules (which often involves booking goods delivery slots for arriving vehicles that need to be communicated to and agreed with relevant parties), preparing the warehouse resources required for these vehicle arrivals, having systems in place for the reception of arriving vehicles (including informing drivers of warehouse site rules and procedures, and the unloading point - usually a loading bay number), and operating a holding area for vehicles that have to wait until the loading bay becomes available). Once these vehicles are at the warehouse unloading point it is necessary to validate the goods being delivered and any documentation associated with them and provide confirmation of the delivery. Goods are unloaded from the vehicle to the warehouse typically using either handling equipment or automated systems and then taken to a holding point in the warehouse where they are sorted and allocated to their planned storage location.

Issues that can arise dealing with inbound vehicles include late or early arrival of vehicles and vehicle queuing issues. These can depend on the number of organisations and vehicles delivering goods to a warehouse in a given period of time, the quantity of inbound goods, the adequacy of the planning systems in place, prevailing traffic conditions and factors encountered by the driver at other warehouses visited that affect vehicle arrival times. A suitable holding area is required for arriving goods vehicles at such times to prevent queueing affecting traffic flow on the road from which access to the warehouse is obtained. Warehouses require suitable plot ratios (see **section 7.1**) to be able to accommodate vehicles waiting to unload in such holding areas. If suitable off-street holding space does not exist at the warehouse then drivers can be contacted prior to arrival to redirect them to an alternative waiting location to prevent traffic problems in the locality.

Outbound goods flows require that goods are prepared for despatch which involves goods picking from storage locations, followed by product and load preparation. As for inbound goods flows this requires the use of planned systems for dealing with this in a careful, consistent and accurate manner. In addition, outbound goods flow planning requires that the transport resources are available and in place when required to facilitate the deliveries made from the warehouse.

Many warehouses handling fast-moving goods or operating cross-docking operations (in which large quantities of goods are held at the warehouse for short periods of time) make use of additional vehicle trailers to facilitate the preparation of loads prior to the actual planned departure times. This helps to make best use of resources and maximises goods throughput. Although this requires additional investment in vehicle trailers this is more than offset by the economic, efficiency and punctuality benefits it offers, especially in terms of drivers and tractor units spending less time waiting for loads to transport. These pre-loaded trailers are usually repositioned at a holding point on the warehouse site from which they are collected by drivers in tractor units. Procedures need to be in place to achieve effective vehicle loading to make best use of the vehicle carrying capacity and also to meet the unloading issues associated with the deliveries it will make. Vehicles operated by the warehouse need to be specified to match the goods flows and warehouse features.

Several surveys carried out at warehouses between 2002 and 2007 studied the time utilisation of vehicles operated from warehouses in various sectors. These survey results indicated the considerable amount of time that HGVs involved in warehouse operations spent at these locations either carrying out loading/unloading or inactive. In the non-food retail sector, goods vehicles and trailers were found to be unproductive for 54% of the time (either empty and stationary - 21%, pre-loaded, awaiting departure - 21%, or delayed/loaded and inactive 12%). These vehicles spent 23% of their time running on the road, 15% of their time loading/unloading (either at warehouses or other locations), 7% of their time receiving maintenance/repairs and 1% of their time stationary while drivers took rest breaks (Department for Transport, 2002).

In the food sector (production and retail operations), a 2002 survey found that rigid goods vehicles and articulated trailers were unproductive for 47% of their time (either empty and stationary - 28%, pre-loaded, awaiting departure - 15%, or delayed/loaded and inactive 4%). These vehicles spent 28% of their time running on the road, 16% of their time loading/unloading (either at warehouses or other locations), 7% of their time receiving maintenance/repairs and 2% of their time stationary while drivers took rest breaks. Vehicles were, on average, pre-loaded three and a half hours before their departure from the warehouse. Temperature-controlled vehicle operations were found to consume far more energy and emitted more CO_2 than goods stored in the warehouse, given the energy requirements to store such products in a vehicle compared to a cold store (Department for Transport, 2003). A follow up survey in the food sector in 2007 produced comparable results, finding that rigid vehicles and articulated trailers were unproductive for 50% of their time, running on the road for 30%, loading/unloading for 14%, and receiving maintenance/repairs for 6% (Department for Transport, 2007).

In the pallet sector, articulated HGVs used for trunking operations between warehouses were found to be unproductive for 42% of the time (either empty and stationary - 32%, pre-loaded, awaiting departure - 4%, or delayed/loaded and inactive 6%). These vehicles spent 38% of their time running on the road, 16% of their time loading/unloading (either at warehouses or other locations), 1% of their time receiving maintenance/repairs and 3% of their time stationary while drivers took rest breaks (Department for Transport, 2005).

In the parcels sector, vehicles used for trunking operations between national/regional sortation centres and local depots were found to be unproductive for 50% of the time (either empty and stationary - 48%, or pre-loaded, awaiting departure - 2%). These vehicles spent 21% of their time running on the road, 26% of their time loading/unloading (at hubs and depots), and 3% of their time stationary while drivers took rest breaks (Department for Transport, 2006b).

The total and hourly number of goods vehicle movements generated by a warehouse depend on many factors including its size, the size and weight of goods handled, the speed with which goods move through the warehouse, the size and frequency of deliveries required to be made from the warehouse, the hours of operation of the warehouse and the size of vehicles used (see **section 7.2** for further discussion of vehicle trip generation at warehouses).

The goods vehicle journeys generated by warehouses impose social and environmental impacts on those living in the area immediately surrounding these facilities. The warehouse operation itself can impose land use and landscape changes, visual impacts (from the building and external lighting), noise (from on-site equipment and staff), ecological effects (from fuel spillage, water and land contamination, and waste disposal). Meanwhile, the goods vehicle and worker car movements associated with the site operations can impose noise, air pollution, and traffic safety concerns. The long operational hours of warehouses can exacerbate the duration of these impacts.

Given that warehouses are typically located in places with cheap land and low-wage labour within their vicinity, these transport-related warehouse impacts often occur where poor or minority people predominantly reside (Giuliano, 2019). This is especially likely in suburban and edge of urban area locations. Research in California in America has shown that warehouses are disproportionately located in medium-income and minority neighbourhoods (with less warehousing in low-income neighbourhoods possible due to inadequate land availability and poor transport accessibility (Giuliano and Yuan, 2017). Further research in California has indicated that those involved in warehouse location decisions seek out minority populations, thereby subjecting those living in these neighbourhoods to the associated freight transport impacts (Yuan, 2018).

7. External space and facilities at warehouses

7.1 Plot ratios

The 'plot ratio' of a warehouse is a metric used to measure the area of building on a plot of land and is commonly used for a range of non-residential buildings. The plot ratio is expressed as a ratio of the gross floor area of the building to the total area of the site that surrounds it. Therefore, the higher the plot ratio, the greater the land area of the entire site that the warehouse building covers. For instance, a site with an area of 1 hectare (10,000 square metres) which has a warehouse with a gross floor area of 4,000 space metres would have a plot ratio of 40%.

In addition to the warehouse, there can be a need for land for other activities on the site that reduce the proportion of site area that the main warehouse building can occupy. In terms of goods vehicle movement space is required for ingress and egress routes for vehicles to enter and leave the site, and operational yard space is required for vehicle circulation with turning circles for vehicles, and sufficient space to access and manoeuvre vehicles into loading bays to optimise site efficiency. In terms of other functions, site space can be required for external storage (such as pallet storage areas), vehicle maintenance workshops and other related outbuildings, fuel storage facilities for goods vehicles at the warehouse site. Parking space is also required for the cars and other passenger vehicle of warehouse workers and visitors. Parking space should also be provided for vehicles waiting for a loading bay to become available for loading/unloading (located at various points around the site in the case of a large warehouse), the overnight for storage of goods vehicles based at the site, and for visiting goods vehicles so that their drivers can take rest breaks. This may extend to parking space for visiting drivers to make longer overnight and weekend stops.

Plot ratios tend to be lower at warehouses outside urban areas than those within it due to the lower cost of land, with businesses typically opting to site non-goods storage and handling activities (such as vehicle maintenance) at larger sites located on land with lower rental values. Other factors affecting the plot ratio include the size and number of vehicles operated.

An employment land review by the UK Government published in 2004 suggested that planning authorities allocating land for employment purposes in development plans should work on the basis of warehousing plot ratios of 40-60% in converting floorspace into site areas (ODPM, 2004). Meanwhile, another report suggests that this range of warehouse plot ratios is high and likely to be due to warehouses with high automation and low employment density (and therefore limited worker car parking requirements) and with limited vehicle circulation requirements due to their design. It instead adopted a plot ratio of 35-40% itself (Roger Tym and Partners et al., 2008). This latter range of 35-40% is far more typical of most warehouse developments.

Plot ratios are sometimes higher in urban areas due to high land values and pressure from local planning authorities to intensify sites. An analysis by CBRE on behalf of SEGRO of industrial and warehousing site information in the London Plan evidence base data showed that the most plot ratios were between 40%-60%. CBRE also reviewed 56 urban logistics developments in London. For these sites, the plot ratios ranged from 20-62%, and the mean and median average plot ratio were 45% and 43% respectively (SEGRO, 2019).

In his consideration of how best to protect industrial and logistics land by not permitting any loss of existing floorspace capacity in locations designated as strategically important for these uses, in 2017 the Mayor of London defined floorspace capacity as either that already on site or the potential industrial and warehousing floorspace that could be accommodated on logistics and industrial land at a 65% plot ratio (whichever was the greater) (Mayor of London, 2017). This led to written responses to this draft London Plan consultation for warehouse occupiers and developers. Amazon stated that it, "operates from a variety of premises types and sizes, ranging from circa 5,000sqm to 145,000sqm. These facilities have varying requirements but all need servicing areas, loading bays, yards, HGV parking, access roads and vehicle holding areas. These substantial servicing and vehicle staging requirements mean that it would not be possible to operate

effectively and efficiently with a 65% plot ratio. A high plot ratio does not necessarily result in the most efficient or best use of a site. The service areas are as important as the building space for logistics operations. In addition, it is beneficial to accommodate sufficient staging and van parking within sites as it reduces the need for offsite staging, reduces traffic movements and increases efficiency" (Amazon, 2019).

In its response, SEGRO, the storage and distribution site developer, explained that floorspace requirements of sites vary greatly depending on the type of occupier and that a 65% plot ratio would exclude many logistics and industrial activities that rely on operational yard space. It went on to note that "floorspace doesn't reflect the intensity of the use of industrial land, and so a focus on floorspace in new development will result in sub-optimal operational efficiencies, jobs and economic output." An example of a SEGRO development operated by parcel delivery company DPD in Newham (outer London) was included as a case study. This 45,000 sq ft urban delivery depot has a 25% plot ratio as the yard space is a critical operational element of the facility and provides a highly efficient process of receiving and distributing goods without the need for storage on site. It noted that a minimum 65% plot ratio would be likely to favour self-storage sites (as these do not require large yard spaces and are often capable of being multi-level given their relatively infrequent access requirements and no need for vehicular access into the building). SEGRO reviewed other sites that it had developed in London: developments on its Origin Business Park (Park Royal) provide buildings at plot ratios of 35-45%. It redrew these schemes at 65% and asked current occupiers to comment on the impact that this change would have on their ability to operate from their units. Four of the six customers that responded to SEGRO (John Lewis Partnership, Mash Purveyors, Ocado and Wasabi) all confirmed that they would not take occupation of their unit if it was built to a plot ratio of 65% due to the impact it would have on their ability to operate their business efficiently (SEGRO, 2019).

In its written response, the London Industry and Logistics Sounding Board (ILSB) noted that its members had "significant concerns about the proposed 65% plot ratio as a tool for managing and monitoring industrial capacity, and the type and extent of new industrial development that this mechanism might deliver. The requirement to re-provide existing floorspace or 65% plot ratio in new industrial development would, in some cases, create inappropriately designed premises with insufficient yard capacity to cater for logistics vehicles and operational needs. Imposing the 65% plot ratio would in some instances compromise the ability to meet the objectives of the Mayors Transport Strategy, as constrained yard spaces impact upon the safe turning and movement of vehicles both within and outside of the site. Overall, we do not believe the 65% ratio to be justified. Notwithstanding our concerns about the floorspace-based approach….from a market and operational perspective, we consider that a more appropriate measure would be a minimum plot ratio of 40%. This would ensure that mixed-use/co-location schemes and developments achieving industrial land consolidation could provide for a more varied range of industrial needs, including those uses which require operational yard space" (London Industry and Logistics Sounding Board, 2019).

The Planning Inspectorate's review of the Draft London Plan noted that "The Plan assumes an average plot ratio of 65% building footprint to 35% outside space based on analysis of a wide range of industrial sites. However, there is a significant amount of evidence from boroughs and industrial site developers and occupiers of much lower plot ratios in some areas and for some uses, including storage and distribution. Whilst this does not mean that the average of 65% could not be achieved in the future, it does suggest that it may be challenging in some locations and for some types of development (The Planning Inspectorate, 2019).

Despite this proposal by the Mayor of London not appearing in the final version of the London Plan, it reflects the pressure in urban areas from policymakers to intensity the use of sites used for warehousing and distribution activities. In the final version of the London Plan, the Mayor has encouraged the intensification of logistics and industrial development sites in London, arguing that multi-occupancy (such as residential housing above logistics and industrial facilities) and multi-storey warehousing and distribution developments will help to save space and use land more

efficiently. However, local planning officers are unlikely to be keen on mixing logistics and residential space given the timing and impacts that can be associated with logistics operations, while multi-storey warehousing with ramps or lifts is more expensive to construct and operate from and reduces the speed of logistics operations. Therefore, although a handful of such multi-storey sites do exist in the UK they are often viewed negatively by potential occupiers.

As well as varying in size and plot ratio, warehouses also vary in height, depending on its purpose, age, location/land costs, degree of automation and prevailing planning requirements in any given area. Some warehouses have mezzanine levels within them to maximise storage space. In modern developments, especially those for the online retail market, there is a growing focus on the volume of the building as technological improvements facilitate use of vertical storage solutions. Warehouse heights of 10-12 metres facilitate such intensive storage and handling activities. In addition, stronger warehouse floors are required to permit higher racking and increased loading from automated machinery. Within the warehouse, some floorspace has to be made available for non-storage activities, including space for goods transfer from vehicles to/from storage locations, picking and packing activities, automated equipment and/or routes for fork lift trucks, worker rest areas, offices and canteens.

7.2 Goods vehicle parking space and trip generation at warehouses

The size and layout of warehouse sites should be sufficient to accommodate goods vehicle movements and parking in a manner that does not lead to the public highway being used for loading/unloading, queuing or parking. Underestimates of goods vehicle trips in Transport Assessments required as part of the planning process for new developments can lead to the under-specification of site parking space, resulting in vehicle queuing to use the space or parking on-street instead and the related impacts of these outcomes. The method usually used by developers for predicting goods vehicle movements to and from new warehouse developments and submitted as part of the planning application (which is called TRICS) typically assumes an HGV trip rate of 0.535 vehicle movements (combined in and out trips) per 100 sq m gross floor area (GFA) and a ‘peak hour’ ratio of 0.57 trips per 100 sq m GFA. It has been noted that these TRICS trip rate assumptions often lead to underestimates in goods vehicle trip generation at warehouses (and other large developments) and that “it is arguable that this method does not reflect the recent evolution of supply chain logistics for B8 developments nor reflects seasonality” (Drury, 2017).

The Chartered Institute of Logistics and Management (CILT) has issued guidance that the trip estimates in Transport Assessments for warehouses and distribution centres should be based on forecast stock throughput including seasonal variations by supply chain and has made this guidance available to the UK Government for adoption. This guidance proposes an alternative methodology and a worked example for producing these goods vehicle trip generation estimates. It states that local planning authorities should use this alternative methodology to check and query the estimated goods vehicle movement derived using TRICS provided in Transport Assessments submitted as part of applications for new developments to ensure that the application has provided sufficient on-site (i.e. off-street) space for visiting goods vehicle drivers to use while waiting to make collections and deliveries to be able to take rest breaks to conform with drivers' hours regulation. It advises that this provision needs to be built into developer's plot ratio assumptions of 35% site cover and warns that if the plot ratio approaches 42-45%, the area provided for goods vehicle parking should be reviewed (Drury, 2017).

This CILT guidance also tells local planning authorities to ensure that the planning application includes provision of driver welfare access to toilets and washing facilities and to accommodation on the site for rest areas and refreshment. It also advises that in the case of “major multi-warehouse unit developments where there may be pressure to increase site cover for economic viability, either recommend a planning condition for on-site secure goods vehicle parking or under a Section 106 agreement provision for off-site secure goods vehicle parking with driver welfare accommodation provided adjacent to the development with provision for sanitation, trailer

exchange and refrigerated vehicle chill-down. An off-site secure truck park is an employment site requiring the same screening and protection provisions as apply for any employment site close to urban or rural residential areas" (Drury, 2017).

Current planning requirements for on-site (i.e. off-street) goods vehicle parking requirements for new developments vary between local planning authorities. In the case of warehouses and distribution centres these typically range from one goods vehicle parking space per 200 - 400 sq m GFA (gross floor area). Many transport consultants employ an average of one goods vehicle parking space per 300 sq m GFA when designing new developments (based on typical warehouse design practice of one loading dock/bay per 1000 sq m GFA plus one buffer goods vehicle parking/waiting bay opposite, and design practice for transhipment/cross dock operations that requires one loading dock/bay per 500 sq m GFA plus one with one buffer goods vehicle parking/waiting bay often located on two sides of the warehouse). However, it is important to note that this standard industry provision is proving insufficient for vehicle parking for visiting goods vehicle drivers to use welfare facilities and take rest breaks and longer stops (Drury, 2017).

In its report on freight transport to the UK Government, the National Infrastructure Commission has noted that, "Providing sufficient loading bay capacity at new developments means delivery drivers spend less time looking for space to park and load, and vans or lorries are not parked in a way which restricts traffic flow on the road (National Infrastructure Commission, 2019).

7.3 Facilities at warehouses for visiting goods vehicle drivers

HGV and LGV drivers frequently make collections and deliveries at warehouses and distribution centres. Sometimes, these facilities are run by the company for which the driver works but often they are operated by the shipper or receiver of the goods being transported. In these cases, the driver is a visitor to the site when making the collection or delivery. The driver may often need to use the toilet or take a legally required rest break when making these collections and deliveries but some sites are reluctant to make toilet and washing facilities available (despite it being a legal requirement) and provide no parking space for rest breaks, or even if such space exists, refuse to make it available to visiting HGV drivers.

Oral witnesses from the CILT and Unite the Union explained to the Transport Select Committee's inquiry into road haulage in 2015/16 that inadequate provision was being developed for visiting HGV drivers at new warehouses, distribution centres and retail parks. Another witness told the Committee that, "Quite a number of [drivers] said that they are treated like scum - that having facilities is a basic human need and it is as if they are not human." It was suggested to the Committee that secure parking should be a planning requirement for such developments over a certain size and that section 106 agreements could be made use of to help fund lorry park facilities (House of Commons Transport Select Committee, 2016a). However, this idea was not taken up by the Government. In its response to the Transport Select Committee's report, the UK Government stated that it would "work with the industry bodies to consider whether and if so how to establish a good practice standard or code of conduct for businesses when receiving visiting drivers. We believe that the provision of access to facilities for visiting drivers at depots and customer facilities should not require specific Government regulation. It is in the interests of companies to treat visitors in the manner they would wish for their employees while offsite. A good practice standard combined with an identifiable "charter mark", promoted by industry bodies could provide a visible commitment to drivers which could then be promoted to customers outside the logistics sector" (House of Commons Transport Select Committee, 2016b). Nothing was subsequently published about this work that the UK Government pledged to carry out with industry.

In 2017, Logistics UK published a 'Commercial Vehicle Driver's Rest Facilities Charter'. This document sets out the notion that "proper provision and use of facilities is a shared responsibility – between the service area providers, public and highway authorities, and industry. Drivers and operators also have a part to play in ensuring facilities are used correctly and respectfully. The conditions in this Charter show what is expected from all sides to ensure that the needs of those

who keep Britain supplied with goods everyday are met." It explains that "the provision of adequate stopping places provides benefits for drivers, operators, the community and the economy as a whole", and is important in ensuring that HGV driving is an attractive and respectable profession. In relation to the warehouses and distribution centres that HGV driver visit, it states that the provision of parking space for rest breaks at the off-street sites of shippers and receivers who HGV drivers make deliveries to also helps to improve vehicle utilisation (as drivers do not have to waste time finding another location in which to take a rest break). The Charter urges that shippers and receivers of goods at all sites that HGV drivers visit "must play their part in the overall provision of basic facilities" (i.e. as a minimum access to sufficient toilet and washing facilities without unreasonable delay) (Logistics UK, 2017).

The size and layout of the warehouse site should be sufficient to accommodate goods vehicle movements and parking in a manner that does not lead to the public highway being used for loading/unloading, queuing or parking. Underestimates of goods vehicle trips for new developments can lead to the under-specification of site parking space, resulting in vehicle queuing to use the space or parking on-street instead and the related impacts of these outcomes (see **section 6.2**).

This led the Chartered Institute of Logistics and Management (CILT) to issue guidance in 2017 about the problem of HGV parking in residential areas due to lack of parking availability for them to take mandatory rest breaks at warehouses, distribution centres and other facilities they had visited to make collection or deliveries. It noted that, "there is insufficient secure HGV overlay parking provided within or adjacent to logistics 'hot spots', a situation made more urgent with pressures for growth in stockholding and order processing as a result of redesigning the supply chain. This situation results from outmoded planning guidelines for HGV access and parking for the B8 use class provided by county and local authorities to support and assess the Transport Statement in planning applications by developers and designers" (Drury, 2017). The CILT guidance stated that goods vehicle trip estimates in Transport Assessments for warehouses and distribution centres should be based on forecast stock throughput including seasonal variations by supply chain and proposed an alternative methodology and a worked example for producing these goods vehicle trip generation estimates. It states that local planning authorities should use this alternative methodology to check and query the estimated goods vehicle movement derived using TRICS provided in Transport Assessments submitted as part of applications for new developments to ensure that the application has provided sufficient on-site (i.e. off-street) space for visiting goods vehicle drivers to use while waiting to make collections and deliveries to be able to take rest breaks to conform with drivers' hours regulation (Drury, 2017). This CILT guidance also told local planning authorities to ensure that the planning application includes provision of driver welfare access to toilets and washing facilities and to accommodation on the site for rest areas and refreshment. It advised that in the case of "major multi-warehouse unit developments where there may be pressure to increase site cover for economic viability, either recommend a planning condition for on-site secure goods vehicle parking or under a Section 106 agreement provision for off-site secure goods vehicle parking with driver welfare accommodation provided adjacent to the development with provision for sanitation, trailer exchange and refrigerated vehicle chill-down. An off-site secure truckstop is an employment site requiring the same screening and protection provisions as apply for any employment site close to urban or rural residential areas" (Drury, 2017).

Oral and written evidence provided to the Transport Select Committee's 2021 inquiry into road freight transport that addressed the issue of HGV drivers visiting sites to make collections and deliveries mentioned that, even when warehouses and distribution centres visited have sufficient parking space for a visiting driver to take a rest break, it is often not being made available to them. It was suggested that existing planning rules need to be reconsidered, so that it is compulsory that new developments have facilities for HGVs to be able to park while drivers take rest breaks. One witness stated that in some mainland European countries, developments of major distribution and retail parks were required to provide sufficient space for visiting HGVs to park (for rest breaks and longer stays) and provided on-site facilities and security. Additionally, it requires that a requirement

needs to be put in place to ensure that warehouses and distribution centres with sufficient space for visiting HGV drivers to take a rest break are compelled to do so (House of Commons Transport Select Committee, 2021).

The current National Planning Policy Framework only states, “Proposals for new or expanded distribution centres should make provision for sufficient lorry parking to cater for their anticipated use” (Ministry of Housing, Communities and Local Government, 2021). It makes no reference to ensuring adequate space is developed to facilitate visiting HGV drivers to park and take their rest breaks at these sites.

One witness to the Transport Select Committee’s 2021 inquiry commented on the poor standard of many toilet facilities that have to be used by HGV drivers at lorry parks and workplaces. They suggested the need for the requirement of suitable standards for these facilities that can then be reported on and enforcement action taken when they are sub-standard (House of Commons Transport Select Committee, 2021).

HGV drivers visiting sites to make collections and deliveries should legally be provided with access to toilets and washing facilities at readily accessible places. This has been in place since 1992 (HSE, 2013) but this does not always mean that such access is always readily forthcoming. The regulations state that suitable toilet and washing facilities should be sufficient in number to allow everyone at work to use them without unreasonable delay (with minimum numbers provided based on size of workforce), should be located so they are convenient and available at all times when workers are in the workplace, that toilets should provide privacy for the user (in a separate room or cubicle, with a door that can be secured from the inside, and that separate toilet facilities should be provided for men and women (except where they are inside a room with a door that can be secured from the inside and are only used by only one person at a time) (HSE, 2013). HGV drivers, like all workers, must also be provided with drinking water and access to worker rest areas if required (but not parking spaces in order to park their vehicles while making use of these rest facilities).

Access to toilet facilities (but not necessarily their standards) have improved to some extent for drivers visiting sites in recent years. This followed a long-running campaign by Gill Kemp at Truckers Toilets (UK) and Unite the Union, which in 2017 led the HSE to state that its guidance would in future state that, “Drivers must have access to welfare facilities in the premises they visit as part of their work” (it had said ‘should’ rather than ‘must’). However, this is not reflected in the legal requirements published in 2013 still provided by the HSE on its website (HSE, 2013).

During the Covid-19 pandemic in March 2020 some sites visited by HGV drivers refused to let them use toilet and handwashing facilities. On receiving complaints about this, HSE had to make businesses aware of their legal responsibilities and that failure to do so was against the law and conflicted with advice from Public Health England that regular handwashing was a control measure against the spread of the virus. The RHA told its members that any driver being denied the use of toilet facilities, when delivering and collecting goods, should report this to them and that they would follow it up, in the first instance, by contacting the site and asking that appropriate signage was displayed, which clearly states that toilet facilities can be accessed by drivers. This also led to the Under-Secretary of State for Transport and the CEO of HSE providing a letter in 2020 that they had signed that could be presented to sites visited by HGV drivers telling the site operator that preventing such access was illegal. However, in April 2021, Logistics UK reported that it was receiving reports from some members and other sources “that many commercial drivers are still being refused access to basic facilities at customer sites. One fleet professional reported that drivers from his company were being denied access to their customers’ facilities, even after presenting official notification from the HSE stating that it is against the law to prevent drivers from using basic toilet facilities” (Logistics UK, 2021a).

Goods vehicle drivers who are members of Unite the Union produced a driver manifesto in 2021 in response the HGV driver shortage. One of its seven points focused on parking, stating that in

order to comply with driver rest break rules, all industrial sites should provide off-street parking areas for drivers making deliveries and collections to and from and make facilities available, and that local authorities should ensure that new park and ride facilities can be used by and have space for HGV parking when not used for passenger car parking. A second point referred to toilets and stated that in addition to the strengthening of the regulations for driver (and other worker) access to toilets at sites that they visit. However, this is not always provided, so the Health and Safety Executive (HSE) or authorities should enforce these regulations and sanction businesses that refuse drivers access to toilets (Unite the Union, 2021).

8. The warehousing workforce and working conditions

UK Government data from the Business Register and Employment Survey shows that between 2010 and 2020, the total employment of UK registered companies that are primarily engaged in the warehousing and storage sector (SIC code 52.1 – i.e. not including retailers, manufacturers, wholesalers and other businesses with warehousing operations) rose by 120% from 160,000 to 350,000 people).

Data from the UK Government's Labour Force Survey provides insight into the top ten occupations in businesses specialising in warehousing and storage (SIC code 52.1). These are shown in **Table 21**. The implementation of automation and technology is likely to reduce the proportion of elementary storage jobs within the sector (which represent 45% of warehouse sector jobs in 2017), while the share of managers and professionals is likely to increase.

Table 21: The ten largest occupations within warehousing and storage businesses (SIC code 52.1) in the UK, 2017

Warehousing and storage occupations	Percentage of employment
Elementary storage occupations	44.8%
Large goods vehicle drivers	7.4%
Fork-lift truck drivers	7.0%
Packers, bottlers, canners and fillers	5.2%
Managers and directors in storage and warehousing	5.1%
Stock control clerks and assistants	3.3%
Other administrative occupations	3.0%
Van drivers	2.4%
Book-keepers, payroll managers and wages clerks	1.0%
Managers and directors in transport and distribution	1.0%
% of employment accounted for by above top ten occupations	**80.2%**

Source: Labour Force Survey, January to December 2017, provided in Kik et al., 2019.

UK Government data from the Annual Population Survey shows changes in employment levels by Standard Occupational Classification 2010 codes (ONS, 2010). Three of these codes are especially relevant to the warehousing and storage industry:

- 'managers and directors in storage and warehousing' (code 1162 – "Managers and directors in storage and warehousing plan, organise, direct and co-ordinate the activities and resources necessary for the safe and efficient receipt, storage and warehousing of goods and for the maintenance of stocks at an optimal level"),

- 'stock control clerks and assistants' (code 4133 – "Stock control clerks and assistants receive orders from customers, prepare requisitions or despatch documents for ordered goods, maintain and update records, files and other correspondence in relation to the storage and despatch of goods"),

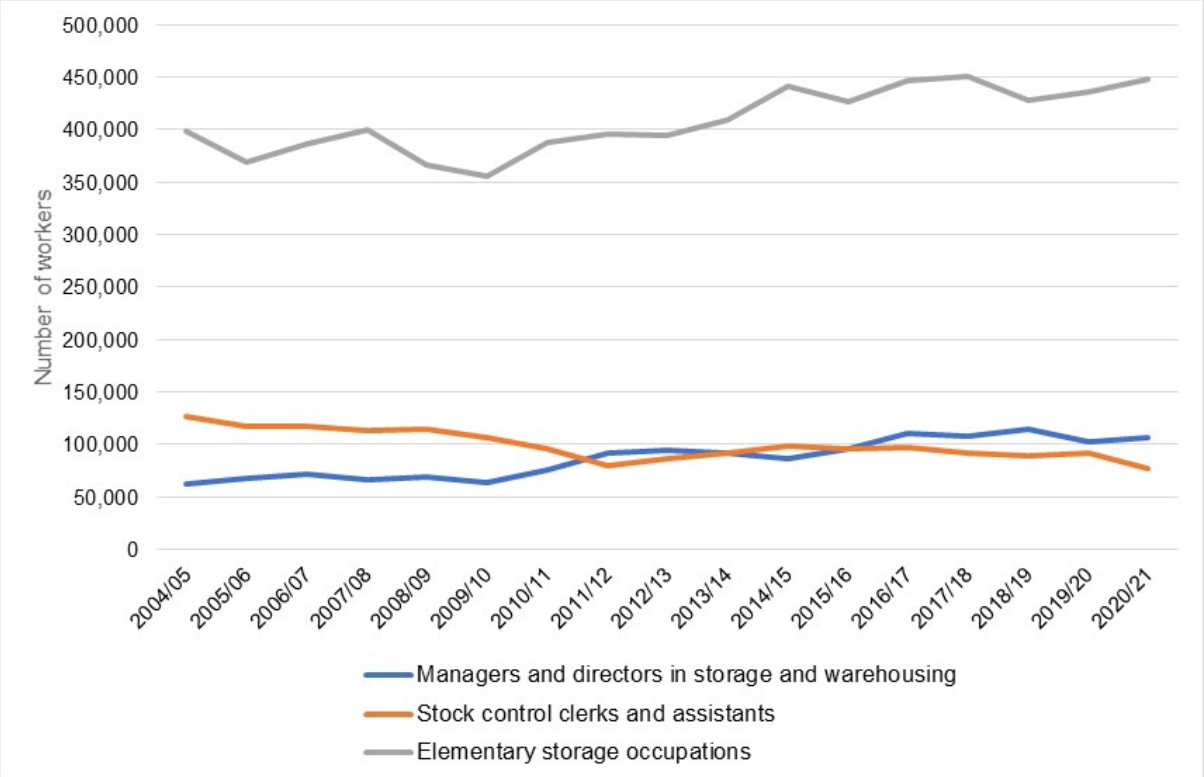
- 'elementary storage occupations' (code 9260 – "Workers in this unit group supply berthed ships with water, oil and petroleum, load and unload cargo from ships, boats and barges, convey household and office furniture, goods, equipment or other items in or near warehouses, depots, slaughterhouses, etc., prepare requisitions or despatch documents of stocks held, accompany drivers of road vehicles, and perform other elementary goods handling and storage related tasks").

This APS data includes those performing these warehousing-related roles in any company regardless of its primary business (so including retailers, manufacturers, wholesalers and other

businesses operating warehouses). Between 2004/5 and 2020/21, there was an increase of 69% in managers and directors in storage and warehousing in the UK (from 69,000 to 103,000 personnel) and a decrease of 39% stock control clerks and assistants (from 126,000 to 78,000 personnel) (see **Figure 24**).

Those workers in 'elementary storage occupations' (i.e. those involved in picking and packing and other fundamental warehousing labour tasks) increased by 12% between 2004/05 and 2020/21 (from 588,00 to 632,000 personnel) according to the Annual Population Survey (APS) (ONS, 2022b). However, warehousing floorspace increased by far more than those in 'elementary storage occupations' over this period. VOA data shows that warehouse floorspace in England and Wales increased by 5% between 2004-2008 and CoStar data shows that warehouse floorspace increased in England by 6% between 2012-2018, and this does not account for the seven years from 2008-2012 and 2018-2021 (Valuation Office Agency, 2012; Turley, 2019). This APS employment data indicates the effects of technology and automation in warehouses, with a substantial increase in skilled, professional staff, an absolute reduction in clerks and assistants and only a small increase in workers carrying out physical warehousing tasks over the last 15 years.

Figure 24: Employees in warehousing and storage-related work in the UK, 2004/5-2020/21



Source: ONS, 2022b.

Surveys of occupiers by warehouse developer Prologis in 2006 and 2018 in their warehouses has provided further insight into the change of types of warehouse occupation. Many of the warehouses owned by Prologis are large; in the 2018 survey for instance, 24 of the 33 workforces surveyed were in warehouses of more than 100,000 sq ft (16 of which were over 200,000 sq ft), and five of the nine that were smaller were between 50,000-100,000 sq ft. Automation and other technology is most likely to highly implemented in these large warehouses. The survey findings show that warehouse workers handling goods reduced in relative importance from 68% of warehouse total warehouse staff in 2006 to 48% in 2018, while office and managerial staff increase in relative importance from 18% in 2006 to 37% in 2018 (Prologis, 2019a – see **Table 22**).

Table 22: Workers by type of occupation in large Prologis warehouses in the UK, 2006-2018

Type of worker	Proportion of workers	
	2006	**2018**
Warehouse staff	68%	48%
Vehicle drivers	13%	9%
Office staff	11%	25%
Managerial staff	7%	12%
Other	1%	6%
Total	**100%**	**100%**

Source: Prologis, 2019a.

Large warehousing sites have become increasingly clustered in certain locations in the UK especially the Midlands and often not being served by good public transport services (see **section 3**). This can increase competition between neighbouring warehousing sites for a relatively small potential pool of workers.

Analysis of data from the UK Government's Labour Force Survey shows that in 2021 (quarter 2) 12.2% of those working in elementary storage occupations were non-white, compared with 2.1% of managers and directors in storage and warehousing. Women represented 23.5% of workers in elementary storage occupations and 19.0% of managers and directors in storage and warehousing (Logistics UK, 2021b). This data indicates the under-representation of non-white and women workers in better paid and managerial roles in the warehousing industry.

Elementary roles in warehouses are especially subject to substantial increases at peak times of year, especially from October to December in the run up to Christmas, and the period immediately after Christmas/January sales, with many temporary workers recruited and hired via agencies. The use of agency workers was much greater in the warehousing sector than for the UK economy as a whole in 2017 (with 10% of warehouse workers sourced via an agency compared with only 2% of all UK workers). Women were almost twice as likely as men to be agency workhouse workers. Warehouse workers born outside the UK were twice as likely as UK-born workers to be agency workers in 2017 (14% of non-UK born workers compared with 7% of UK-born workers). Agency workers can get paid much less than directly employed staff doing the same work (Kik et al., 2019).

Median hourly pay rates (excluding overtime) in the UK in 2021 for all employees working in warehousing and storage occupations were £10.39 for workers in elementary storage occupations (up 3.9% annually), £11.25 per hour for stock control clerks and assistants (up 4.4% annually) and £14.31 for managers and directors in storage and warehousing (up 3.3% annually) (ONS, 2022g). This compares with a median hourly wage for all employees in the UK of £14.05, reflecting the relatively poorly paid nature of warehouse work despite the annual increase due to worker shortages in warehouses. Differences between full and part time wages are shown in **Table 23**. The UK National Living Wage was £8.91 in 2021, so for those working in elementary storage occupations, whether full- or part time, and those working full-time in stock control clerk and assistant roles their hourly median rate of pay excluding overtime, was closer to the National Living Wage than to the median hourly wage across the UK economy.

Table 23: Hourly pay (excluding overtime) (£) for employees in warehousing and storage occupations in the UK in 2021

Job	Full-time	Part-time	All employees
Elementary storage occupations (9260)	10.65	9.34	10.39
Stock control clerks and assistants (4133)	11.77	10.00	11.25
Managers and directors in storage and warehousing (1162)	14.54	9.56	14.31
All UK employees in all occupations	15.59	10.65	14.05

Source: ONS, 2022g.

Evidence from the ONS Annual Survey of Hours and Earnings (ASHE) in 2018 indicated that no more workers in the warehousing sector were underpaid minimum wage than in the UK economy as a whole (ONS, 2018). However, there has been evidence, "that some warehousing sites are being established to take advantage of the relatively low wages in high unemployment areas, in which employers can exploit the availability of staff who may be more willing to accept low wages" (Director of Labour Market Enforcement, 2019, p.126). There has also been evidence that a disproportionately high number of migrant workers were employed in the warehousing industry (Labour Force Survey data quoted in REC, 2017).

The Director of Labour Market Enforcement, the official appointed by the UK Government as part of The Immigration Act 2016, to bring together a coherent assessment of the extent of labour market exploitation and identifying routes to tackle such exploitation, ruled in 2019 that in the warehouse sector, "Vulnerable workers are being exploited, in some cases indicative of modern slavery. Many more workers in the sector are not receiving National Minimum Wage" (Director of Labour Market Enforcement, 2019, p.15).

Research has shown that elementary warehouse workers tend to be allocated tasks as required by the business, with little scope for worker decision-making or discretion. Low task discretion is associated with a negative impact on wellbeing and motivation compared to high task discretion. Research has indicated a relatively high proportion of annualised hours contracts and zero-hours contracts in elementary warehouse occupations in comparison to the UK all industries average (Kik et al., 2019).

A survey of 160 logistics workers in the UK in February 2022 asked respondents about nine aspects of their jobs to understand how important these were to them and how satisfied they were with them. The participants included those in warehousing and driving roles in both non-managerial and managerial roles. The results are shown in **Table 24** (Frontier Economics, 2022). The three most highly rated aspects of the respondents' jobs were 'my job security', 'my pay' and 'amount of work'. Net satisfaction scores were considerably lower than net importance scores for all nine job aspects. Of the most three important aspects, net satisfaction scores were lowest for 'my pay', and 'the amount of work'. The difference between net importance and satisfaction scores for these three aspects was considerable (28-52%).

Table 24: Net importance and satisfaction of different aspects of work for logistics workers

Job aspect	Importance rating	Satisfaction rating
My job security	67%	39%
My pay	67%	15%
The amount of work	57%	28%
The ability and efficiency of the management	56%	13%
Being able to use my own initiative	52%	40%
My relations with my supervisor or manager	52%	34%
The opportunity to use my abilities	46%	31%
The variety in the work	37%	28%
My promotion prospects	8%	2%

Note: The net scores were calculated by summing the responses that rated the importance of and satisfaction with each aspect as 'fairly important' or 'very important' and subtracting those that rated it 'as not that important' or 'not important at all' (while not taking into account those respondents who stated that they did not know).
Source: Frontier Economics, 2022.

The warehousing and storage sector tends to receive relatively little media attention in the UK. However, the media attention it does receive is typically negative, including coverage of low pay, use of agency workers, zero hours contracts poor working conditions and overzealous performance management and penalisation in a small number of businesses. Examples include the expose of the Sports Direct business model and especially its warehouse in Shirebrook, Derbyshire that led to the boss, Mike Ashley, appearing before the House of Commons Business, Innovation and Skills Committee as part of its investigation into Sports Direct's working practices in 2016.

An investigation by The Guardian newspaper had found that up to 5,000 workers at Sport Direct's Shirebrook warehouse were subjected to on-site body searches at the end of every shift, which involved examinations down to the last layer of clothing, rolling up trouser legs and showing the top of underwear which took up to fifteen minutes to carry out and were unpaid, resulting in staff being paid an effective rate of around £6.50 an hour against the statutory rate of £6.70. Staff were also told over loud speakers in the warehouse when they were not working fast enough and warned that they would be dismissed if they received six warnings over a period of six months for offences including "period of reported sickness", "errors", "excessive/long toilet breaks", "time wasting", "excessive chatting", "horseplay", and "using a mobile phone in the warehouse". Many instances of workers being banned from wearing other clothing brands in the workplace also took place. Local primary schoolteachers told reporters from the newspaper that pupils could remain in school while ill and returned to empty homes as parents working at the warehouse could be too frightened to take time off work, while union officials said that the treatment of workers had led to them being afraid to speak out pay and conditions for fear of losing their jobs (Goodley and Ashby, 2015).

At the Select Committee public inquiry Mike Ashley admitted that 80% of workers were on zero-hours contracts and agreed with MPs that more staff should be transferred to permanent contracts. He also told the Committee that he was unaware of the conditions for his workers (House of Commons Business, Innovation and Skills Committee, 2016).

Media coverage also focussed on the online clothing retailer Boohoo's working conditions and unauthorised pay deductions at its Burnley warehouse in 2017 and a subsequent newspaper article in 2020 about its wider supply chain practices in Leicester that led to an independent review of its business practices (Levitt, 2020), and regular media reports of warehouse workers deliberately damaging customers' parcels with and the theft of valuable parcels and letters by staff from Royal Mail and other parcel carriers' sorting and delivery depots.

Action films often provide the only occasion on which the general public get to see inside warehouses. However, the warehouse is typically portrayed as a place of crime and violence in which fights, shootouts and torture are conducted. The use of warehouses can be traced back many years in films such as the 1960 action comedy heist ‘The League of Gentlemen’ in which a Lieutenant-Colonel upset about his redundancy from the army recruits a gang to carry out a bank robbery; they plot their raid from a rented warehouse. Over time, the scenes that take place in warehouses have become increasingly violent with the torture and murders of suspected informants in ‘Reservoir Dogs’ (1992), and the shootouts and subsequent torture and immolation of the vigilante Big Daddy in ‘Kick Ass’ (2010) by the criminals he has pursued. An internecine warehouse shootout between rival gangs is portrayed in the Hong Kong action thriller ‘Hard Boiled’ (1992). Warehouse-based drugs and arms deals resulting in shootouts and killings are central to ‘Layer Cake’ (2004) ‘Baby Driver’ (2017), respectively. Industrial buildings and warehouses are key locations for chase scenes in the Terminator film and television franchise (1984 onwards). The final scene in Raiders of the Lost Ark (1981) shows the crate containing The Ark of the Covenant that Indiana Jones has recovered from the Nazis, thereby preventing them from gaining its invincible power, stacked among numerous other crates in a large warehouse.

In 2021, the BBC screened a drama entitled ‘Life and Death in the Warehouse’ by the BAFTA-winning director Joseph Bullman and writer Helen Black. It was based on working in an online retail warehouse and told the fictional story of how, in an attempt to keep her job, a trainee distribution centre manager pressurises a pregnant warehouse worker who she has known since childhood to improve her picking performance, thereby putting the woman and her unborn baby at risk. The drama addressed issues including worker surveillance and monitoring, even when using the toilet, the high work rate targets that are set, lack of concern about staff reporting sickness while on the job, zero-hour contracts, and anti-union activity by employers. The director and his team reported carrying out a year-long research process which included speaking to people who worked in the industry. The director said, “There's stuff that makes your jaw drop so you look at it and think, 'Is this a joke, or is this true?' Well, I can reassure you that every single scene and every single line is marinated in real-world research. It is true." The writer stated that, "It's really hard work and it's really physical. They get zero contract hours so they don't know how many days they’re going to work each week. The working conditions are just not right and just not fair" (BBC, 2022).

9. Gaining permission for warehousing development

Traditionally, warehousing development has often been viewed by local planning authorities and their economic development officers as generating relatively few jobs per unit area of building, as well as the majority of their jobs being relatively low paid (see **section 8**). Together with its high goods vehicle trip generation rates, large land requirements and what is often viewed as an unattractive appearance, local authorities tended to show indifference or even hostility to developers' proposals for new warehousing (McKinnon, 1983; Watt, 1977). A survey carried out in 1984 found that although local authorities in the East Midlands were less hostile to warehouse developments than those in South East, the picture that emerged from the former was "of warehousing neither attracting much attention nor being the subject of clear policy statement, despite the fact that it comprises roughly a quarter of all commercial floorspace in the East Midlands and that since 1974 its floorspace has grown almost five times as fast as that of factories" (McKinnon and Pratt, 1984).

Table 25 shows the estimated employment densities for warehouses provided by national Government for use by local planning authorities in setting their economic development and spatial plans. It shows how these estimates have been revised for the three such employment density guides that have been issued in 2001, 2010 and 2015. The warehousing employment densities provided in these guides can be seen to have worsened over this period.

Table 25: Warehouse employment densities, 2001, 2010 and 2015 (sq m of Gross External Area per FTE[1,2])

Type of warehouse	Employment Density Guide - (sq m of Gross External Area per FTE[1,2])		
	2001	2010	2015
General	50[3]	70[3]	n/a
Large Scale and High Bay Warehousing	80[4]	80[4]	n/a
'Final mile' Distribution Centre	n/a	n/a	70
Regional Distribution Centre	n/a	n/a	77
National Distribution Centre	n/a	n/a	95

Notes:
1. FTE - full-time equivalent worker. Gross External Area (GEA) includes walls, plant rooms and outbuildings but excludes external space such as balconies and terraces.
2. sq m - square metres. 1 sq m = 10.764 sq ft.
3. Wide variations in FTE per sq m exist between sectors using general warehousing facilities. The higher the capital intensity of the business, the lower the employment density.
4. Technological developments and automation are reducing employment densities in warehouses. Long-term and large scale storage have much lower employment densities than smaller and short-term storage. However, the use of technology and automation in warehousing can create higher paid engineering and related jobs.
n/a – not available
Source: English Partnerships, 2001; Drivers Jonas Deloitte, 2010; Bilfinger GVA and the Homes and Communities Agency, 2015.

Survey work carried out by Prologis, the major developer of large warehouses, among its occupiers in 2006 and 2018 estimated that the employment density for a 500,000 sq ft warehouse remained unchanged at 95 square metres of gross external warehousing space per worker (Prologis, 2019a).

Table 26 shows the comparison between employment densities for warehouses and other commercial and industrial purposes in the 2015 national guide. This indicates the relatively poor performance of warehousing in job creation compared to office work, retailing and manufacturing. other This has resulted in many planning authorities in the UK preferring and supporting other

forms of economic development including office work and retailing in preference to warehouse development.

Table 26: Employment Density Matrix, 2015

Use class	Sub-category	Sub-sector	Employment density (sq m per FTE)	Area calculation basis
B8	Storage and distribution	'Final mile' Distribution Centre	70	GEA
		Regional Distribution Centre	77	GEA
		National Distribution Centre	95	GEA
B1a offices	General office		10-13	NIA
B1a offices	Call centre		8	NIA
B1c	Industrial & manufacturing		36	GIA
Mixed B class	Small business workplace	Co-worker, studio, maker spaces	10-40	NIA
A1	Retail	High street / food store	15-20	NIA
		Retail warehouse	90	NIA
A2	Financial & professional services		16	NIA
A3	Restaurant / cafe		15-20	NIA
Sui Generis	Data centres	Co-location, wholesale, wholesale dark site	180-1440	

Notes for area calculation basis:
Gross External Area (GEA) – includes walls, plant rooms and outbuildings, but excludes external space such as balconies and terraces.
Gross Internal Area (GIA) – includes the entire area inside the external walls of a building and includes corridors, lifts, plant rooms, service accommodation (e.g. toilets).
Net Internal Area (NIA) – this is commonly referred to as the net lettable or 'usable' area of offices and retail units. It includes entrance halls, kitchens and cleaners' cupboards, but excludes corridors, internal walls, stairwells, lifts, WCs and other communal areas.
sq m - square metres. 1 sq m = 10.764 sq ft.
Use Classes were amended by the UK Government in September 2020 with Use Classes A1, A2 and A3, B1a and B1c replaced with new Use Class E.
Use Classes B2 (general industrial) and B8 (storage or distribution) remain valid.
Source: compiled from Bilfinger GVA and the Homes and Communities Agency, 2015.

The employment density guide used in London also shows that warehousing (which is assumed to involve small sites) creates fewer jobs than other activities (see **Table 27**). In this London guide, warehousing is estimated to employ only one-third the number of workers of office space and only half the number of workers of shops, restaurants, cafes and drinking establishments per unit area of floorspace.

Table 27: Default Employment Density Assumptions (sq m GIA per worker) by Use Class for central, inner and outer London

Use class	Sub-category	sq m GIA per worker
A1	High street shop	17.5
A2	Financial & professional	16
A3	Restaurants & cafes	17.5
A4	Drinking establishments	17.5
A5	Hot food takeaways	17.5
B1	Offices	11.3
B2	Industrial & manufacturing	36
B8	Final mile distribution centre	36
C2	Residential institutions	45
D1	Non-residential institutions	45
D2	Fitness centre	45

Notes: Use Classes were amended by the UK Government in September 2020. Use Classes A (1-5), B1, D1 and D2 were replaced with new Use Class E. Use Classes B2 (general industrial) and B8 (storage or distribution) remain valid.
Source: CAG Consultants, 2017.

The ratio of warehouse workers to floorspace is being further eroded by the uptake of automation in warehouses which can result in a reduction in elementary tasks being carried out by human workers. However, highly automated warehouses can support a higher proportion of better paid jobs given their relatively greater need for engineers and managers.

However, other changes are taking place which may make warehousing development relatively more attractive to local planning and economic development officers. The number of retail shops is declining as a result of the increase in online retailing and this trend has been greatly increased by the Covid-19 pandemic. The pandemic has also brought into question the future demand for office space and the job creation that goes with it, with far more office personnel working remotely for part or all of the week. This reduction in office workers has major implications for the cafes, restaurants and other retail businesses supported by these office workers. A switch has also been taken place in consumer behaviour away from eating in restaurants to ordering online meals that are delivered to their home or place of work. Although this trend commenced before 2020, it has also been greatly accelerated by the Covid-19 pandemic and is resulting in restaurant closures and a growth in development of dark kitchens.

It has previously been noted (see **section 5**) that the greatest challenge facing the UK warehousing sector is a major shortage of readily available land, especially for warehouses over 100,000 sq ft, which although a problem for the last decade, has become a crisis during the last two years due to supply chain pressures caused by Covid-19 and Brexit and the lack of warehouse supply entering the market. Referred to in planning terms as ‘strategic employment land’, there is a major shortfall of it in the UK regions where warehouse demand is greatest (including the East and West Midlands, London and the South East, the East of England and Yorkshire and the North East) (Turley, 2021).

The UK Government has set a national target for the building of new housing and planning authorities are required to set district-level requirements as a result of the approach adopted. There is no comparable UK Government approach and target for warehousing and the employment land it requires nationally or locally. At a national level, there is no reflection of this warehousing land need in the 2020 Planning White Paper or the amendments to the National Planning Policy Framework, and the Industrial Strategy was replaced in favour of the ‘levelling-up’ agenda (Turley, 2021). The amendments made to the National Planning Policy Framework simply state that, “Planning policies and decisions should recognise and address the specific locational

requirements of different sectors. This includes making provision for clusters or networks of knowledge and data-driven, creative or high technology industries; and for storage and distribution operations at a variety of scales and in suitably accessible locations" (Ministry of Housing, Communities and Local Government, 2021). Such a brief, general statement is unlikely to have much material consequence in the approach and practice of local planning authorities. A section was also added to the UK Government's Planning Policy Guidance on 'Housing and Economic Needs Assessment' in 2019 explaining to local planning authorities that the logistics industry "has distinct locational requirements that need to be considered in formulating planning policies (separately from those relating to general industrial land)" and specifically refers to "last-mile facilities serving local markets". It goes on to suggest that planning authorities should engage with logistics developers, occupiers and Local Enterprise Partnerships, and make use of market analysis and signals and economic forecasts of supply and demand in making strategic policy concerning the appropriate Strategic policy-making authorities will then need to consider the most appropriate locations for meeting these logistics land needs (Ministry of Housing, Communities and Local Government, 2020a). Similarly, such general guidance is unlikely to result in much material change at a local planning authority level. None of these changes to UK Government planning policy and guidance place any new requirements on local authorities in terms of safeguarding logistics land or approving applications for warehousing developments, address the issue of the competing needs for housing and logistics developments, or tackle the time taken to assess development applications for major logistics developments such as strategic rail freight interchanges.

The local planning system has not responded to the growth in demand for warehousing in the UK either over the last decade nor the rapid further increase in demand over the last two years. Instead, planning authorities continue to express concerns about the relative lack of employment generated by warehousing. There is also limited evidence of local economic and industrial strategies and plans being reflected in local spatial plans (Turley, 2021).

However, additional population and housing leads to the need for greater levels of warehouse space. In 2019, it was calculated that the UK Government's plan for building 300,000 homes per year would require an additional 21 million sq ft of warehouse floorspace in England per annum (based on a ratio of 69 sq ft of warehouse space for each new home delivered) (Turley, 2019). In 2020 the ratio had increased to 73 sq ft of warehousing per new home, indicating that approximately 22 million sq ft of warehousing could be required throughout England each year in order to maintain the current ratio (Turley, 2021).

A study of a sample of employment land studies by local planning authorities in England checked their compliance with Planning Policy Guidance (PPG) provided by the UK Government and analysed the evidence and methods used in them. The results showed that while the studies reviewed and compared broadly met the requirements set out by the UK Government in the PPG, differences in how these studies are carried out affects the quality and consistency of the employment land evidence. These two differences arise from: (i) the local planning authorities are not compelled to examine the specific requirements of various business sectors, and (ii) even when such specific requirements are assessed, the approaches taken vary, leading to inconsistencies and weaknesses (these include the use of different methodologies to forecast land requirements, different methods of assessing land supply, general lack of engagement with industry in carrying out these studies, the amalgamation of general industrial (B2) and storage and distribution (including warehousing) (B8) land requirements into a single category, insufficient and variable updating of these studies due to lack of guidance in the PPG about how frequently these studies should be carried out (Turley, 2017). It has been argued that local authority employment land studies and the local plans that they inform are, "backwards looking and projecting forward historic trends as a proxy for future demand. As a result, modern day growth drivers are not taken into account, for example: housing growth, online retailing growth, increasing UK freight volumes and the need for larger premises, all of which generate increased demand for I&L (industrial and logistics) land and floorspace" (BPF and Savills, 2022, p.19). Ways in which the UK Government could reform and improve Planning Policy Guidance (PPG) have been proposed to help ensure

that warehousing and other industrial land requirements are better reflected by local planning authorities (Turley, 2017).

Other recent actions and announcements by the UK Government could provide faster and easier planning approval for new warehouse developments. In 2020, the UK Government published a Planning White Paper in which it considered how to reform the planning system in England (Ministry of Housing, Communities and Local Government, 2020b). The Government proposed that Local Plans should be reformed so that they communicate key information clearly and are standardised thereby allowing users to easily understand them and participate in a new community engagement process. The Plans should also "set clear expectations on what is required on land that is identified for development, so that plans give confidence in the future growth of areas". It suggested that Local Plans should identify three types of land "Growth areas suitable for substantial development, Renewal areas suitable for development, and areas that are Protected" (Ministry of Housing, Communities and Local Government, 2020). The Government has yet to bring forward its new approach to the planning system in England following its consultation process concerning these proposed changes.

In April 2021, following a consultation process, the UK Government introduced extended permitted development rights (PDR) for ports (UK Government, 2021). PDR allow specific types of development to be carried out without the need for planning consent. These changes apply to operational land attached to existing facilities. The introduction of these additional PDR for ports brought them into line with PDR that already existed for rail and airports. This allows port operators to erect buildings up to 500 sq metres (approximately 5,000 sq ft) intended to be used in connection with the operation of port facilities and services without the need for local authority planning permission. Such buildings allowed as part of PDR are limited in scale, size, height and proposed use (Bower and Wex, 2021; Travers Smith, 2021).

In 2021, the Government announced its a strategy to establish Freeports centred around one or more air, rail, or seaport, but which can extend up to 45 km beyond the port(s). As well as providing different tax incentives and reliefs, business rates retention, customs measures, and trade and investment support, these will also be subject to different planning measures (Department for Levelling Up, Housing and Communities, 2021). However, details of these economic and planning reforms for Freeports have yet to be announced. In its 2020 consultation on Freeports, the UK Government proposed that local planning authorities could make greater use of zonal planning through Local Development Orders (LDOs). LDOs are currently mostly used in Enterprise Zones (EZs) to provide a grant of planning permission to specific types of development within a defined area, establishing "a clear framework for development, giving certainty to applicants, businesses and communities" (UK Government, 2020a). However, research into EZs set up since their introduction in 2011 has shown that most local authorities with EZs have not adopted LDOs for them despite the requirement to put in place a 'simplified approach to planning'. This could be due to lack of resources, skills or knowledge in local planning authorities, lack of best practice concerning LDOs, and local authorities deciding that LDOs were not the correct type of planning permission to facilitate development (David Lock Associates, 2019). Eight English Freeport locations were selected through a competitive process in 2021, seven around sea ports and one around an inland air port.

In September 2022, the UK Government announced that as part of its Growth Plan it was "in discussions with 38 local authorities to establish Investment Zones (IZs) in England and intend to work closely with the devolved administrations and local partners to deliver this opportunity to drive local growth in Scotland, Wales and Northern Ireland." These IZs would provide time-limited tax benefits to businesses, government funding and accelerated development through the release of "more land for housing and commercial development", while "the need for planning applications will be minimised and where planning applications remain necessary, they will be radically streamlined" (UK Government, 2022b). However, specific details of the planning arrangements for IZs are yet to be published.

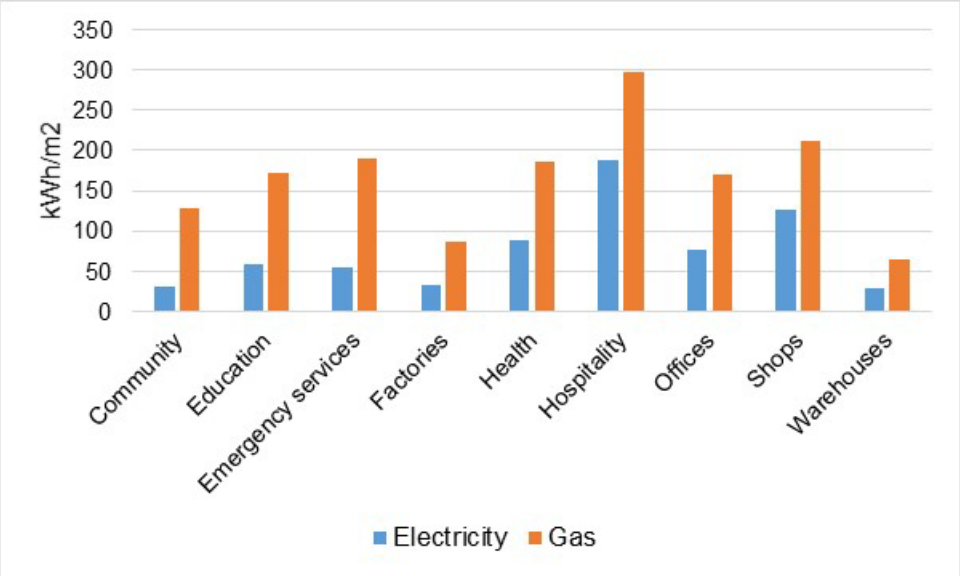
10. Decarbonising warehouses

10.1 Warehouse operations and energy consumption

Lighting is the major source of energy consumption within an ambient warehouse, accounting for 65%-95% of total energy consumed (Carbon Trust, 2019). Warehouse picking and packing tend to result in less lighting and heating energy use than in store (with warehouses using less energy per unit of space than a store, especially if a manual warehouse) (Lovins, 2001). Manual warehouses with human workers carrying out picking, packing and storage activities will require heating and lighting, whereas more automated warehouses will use electricity to power this handling equipment (e.g. conveyors, robots, packaging machinery etc.) and computing. However, even manual warehouses of any size are likely to make use of forklift trucks and pallet trucks that will require recharging.

Data collection and analysis by BEIS provides insight into the metered energy consumption (electricity and gas) of non-domestic buildings including warehouses in England and Wales[2] (BEIS, 2022a). **Figure 25** shows the energy intensity (i.e. the median electricity and gas used per square metre of building) of non-domestic buildings by building use in England and Wales in 2020. Warehouses can be seen to have a relatively low electricity and gas consumption rate per unit area of building. This is likely to be due to the factors including the average size of warehouses compared to other type of non-domestic building and the activities that take place inside them (which are less energy hungry than activities in buildings such as hospitality venues, offices and health buildings such as hospitals) with most warehouse energy used for not very intense lighting and heating, and the powering of warehouse machinery, vehicles and computer systems.

Figure 25: Median electricity and gas consumption of non-domestic buildings in England and Wales by building use, 2020 (kWh/m^2)



Note: 'Community' - Buildings used for community, arts and leisure purposes.
Source: BEIS, 2022a.

However, warehouses with refrigeration requirements for chilled or frozen products have far higher power requirements than ambient ones. A study by Savills and the Cold Chain Federation in 2020,

[2] The energy consumption analysis carried out by BEIS uses the following categories of warehousing in the Valuation Office Agency (VOA) database: CW ('wholesale warehouses'), CW1 ('land used for storage and premises'), CW2 ('storage depots and premises'), and CW3 ('stores and premises'). Any outdoor, open-air storage facilities included in category CW1 will affect BEIS estimates of electricity and gas use in enclosed warehouses.

identified 678 warehouses with cold stores in the UK that had floorspace of over 50,000 sq ft, with a total floorspace of 134 million sq ft in all these warehouses. Overall, within these 678 facilities, 49 million sq ft of space was dedicated to frozen or chilled storage (37% of total floorspace). The study also identified a further 16.7 million sq ft of cold storage under construction. Of these 678 warehouses with cold stores, the retail and food service sector occupied 54.5 million sq ft (40% of the total floorspace),the food processing and sector 45 million sq ft (34% of total floorspace), third party logistics providers 31.5 million sq ft (23% of total floorspace), with the remaining 3% of floorspace occupied by farmers and other primary producers, other specialist operators or unoccupied. The retail and food service sector operated the largest average size of warehouse with cold store (Savills Research and Cold Storage Federation, 2020).

Warehouse will also have greater electrical power requirements in future due to the need to provide vehicle recharging infrastructure. It has been estimated that a 120,000 sq ft warehouse may require 600 kW of electrical power supply today but may require 3-6 MW in future when cars and goods vehicles require recharging (CBRE, 2022b).

It is estimated that in total, non-domestic buildings in England and Wales used 127 TWh of electricity and 147 TWh of gas via meter-point usage in 2020 (i.e. this does not include any energy consumed that is not supplied via the electricity or gas grid such as energy generated onsite from renewables). The breakdown of this total electricity and gas consumption by building use is shown in **Table 28**. This indicates that warehouses were responsible for 12% of total electricity use and 6% of total gas use in non-domestic buildings in England and Wales in 2020 (and 8% of total energy use in non-domestic buildings). The total quantity of warehousing floorspace in England and Wales (34% of total non-domestic floorspace in 2020) accounts for the considerable proportion of total energy consumed across all warehouses despite their relatively low average energy intensity per unit area.

Table 28: Total electricity and gas consumption of non-domestic buildings in England and Wales by building use, 2020

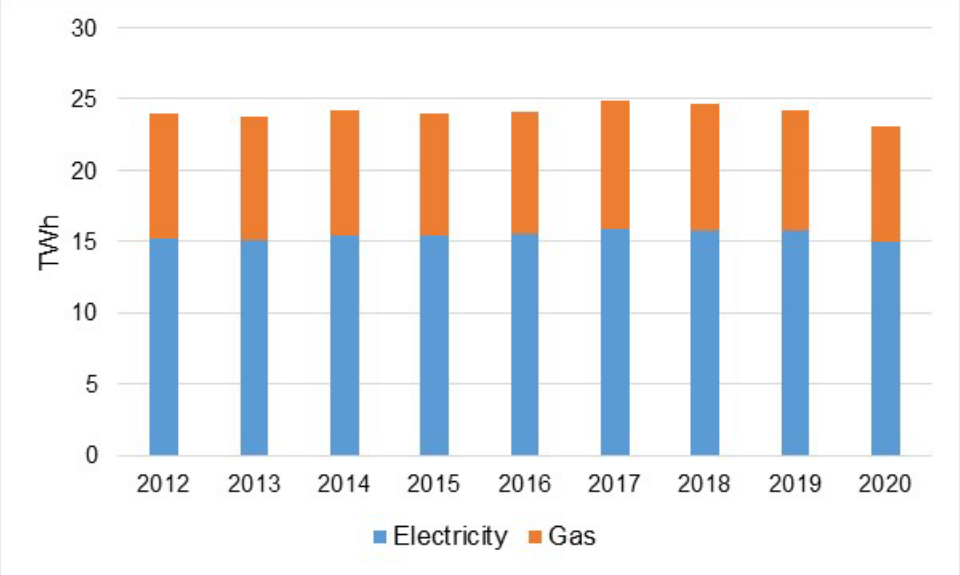
Building use	Electricity	Gas	Total
Community*	2%	3%	3%
Education	4%	9%	6%
Emergency services	1%	1%	1%
Factories	33%	38%	36%
Health	2%	7%	5%
Hospitality	5%	6%	6%
Offices	15%	8%	11%
Shops	12%	6%	9%
Warehouses	12%	6%	8%
Other	15%	16%	16%
Total	**100%**	**100%**	**100%**

Note: * - Buildings used for community, arts and leisure purposes.
Source: BEIS, 2022a.

Figure 26 shows the change in total electricity and gas consumption in all warehousing floorspace in England and Wales between 2012 and 2020. Electricity and gas consumption in all warehouses is estimated to have been, respectively, 2% and 7%, lower in 2020 than 2012, with total energy consumption (electricity plus gas) being 3% lower. This indicates a likely improvement in energy efficiency per unit area of warehousing given the growth in total warehousing floorspace over the period. However, this reduction in total energy use over this period in warehouses is far less than for many other building uses (see **Table 29**). This is likely explained by the growing quantity of warehousing floorspace over the period and the growing use of automated machinery.

Considering the period from 2012 to 2019, and therefore ignoring the effects of the Covid-19 pandemic, total energy consumption by warehouses in England and Wales is estimated to have been 1% higher in 2019 than 2012. By comparison, the fossil fuel used by light and heavy goods vehicles in Britain is estimated to have been 8% higher in 2019 than in 2012 (calculated from data in Department for Transport, 2021q). This indicates that total road freight transport energy consumption rose faster than warehousing energy consumption over the period, indicating the ever-greater reliance on and use of road freight transport in UK supply chains.

Figure 26: Total electricity and gas consumption in warehouses in England and Wales, 2012-2020 (TWh)



Source: BEIS, 2022a.

Table 29: Change in total electricity and gas consumption in non-domestic buildings by building use in England and Wales, 2012-2020 (based on TWh)

Building use	Electricity	Gas	Total
Community*	-34%	-27%	-30%
Education	-18%	-3%	-7%
Emergency services	-13%	-10%	-11%
Factories	-13%	10%	-1%
Health	-12%	11%	5%
Hospitality	-33%	-28%	-30%
Offices	-24%	-7%	-19%
Shops	-27%	-4%	-19%
Warehouses	-2%	-7%	-3%
Other	17%	20%	18%
Total	**-14%**	**2%**	**-7%**

Note: * - Buildings used for community, arts and leisure purposes.
Source: calculated from data in BEIS, 2022a.

In the case of online retailing, warehouses tend to be large, which can help to reduce total inventory levels compared with the use of a greater number of smaller facilities, and hence lower carbon emissions. However, the small order sizes and the scale of returned products can result in additional warehousing operations, and thereby greater carbon emissions per order (Mangiaracina et al., 2015). However, there is no existing research that has analysed the net effect of these factors (Pålsson et al., 2017). No overall comprehensive analysis of the warehousing and order picking supply chain effects of online retailing on energy use and CO_2 was identified during this literature review.

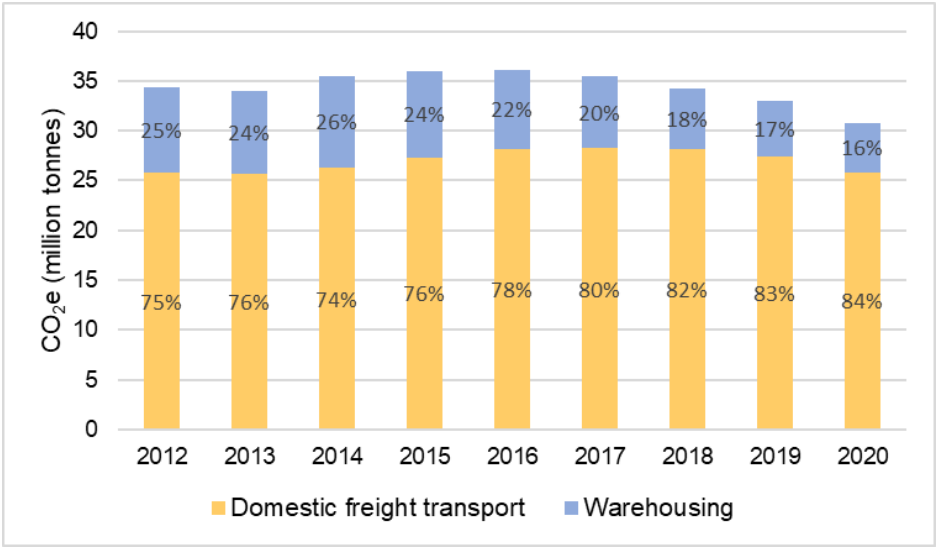
10.2 Comparing warehousing and road freight transport GHG emissions

The UK was the first country to introduce legally binding long-term greenhouse gas (GHG) emissions reduction targets through the Climate Change Act in 2008. This committed the UK to an 80% reduction in GHG emissions relative to the levels in 1990. In 2019, the UK became the first major economy to enact a legally binding target of 'net zero' GHG emissions by 2050. This requires that the UK reduce GHG emissions by at least 100% relative to 1990 levels by 2050. 'Net zero' refers to achieving at least a balance between the amount of GHG emitted and the amount of GHG removed from the atmosphere. This net zero target can be achieved by reducing GHG emissions as well as removing GHG from the atmosphere. In addition, the UK Government is committed to a 68% reduction in GHG emissions compared to 1990 levels by 2030, and a 78% reduction by 2035.

Whilst goods are in storage in such buildings, energy is consumed in the provision of heating and lighting. It is estimated that the operational energy used by warehouses in the UK accounted for approximately 16% of the GHG emissions (CO_2e) from the UK supply chain in 2020, with 84% accounted for by freight transport operations (based on domestic freight transport activity and operational warehousing energy used in 2020 – this data only includes warehouse energy use in England and Wales). If both domestic and international freight transport activity are taken into account, then warehousing energy use in the UK accounted for 11% of the GHG emissions (CO_2e) from the UK supply chain in 2020 and freight transport operations for 89% (calculated using data in BEIS, 2022a, 2022b, 2022c). This estimate is comparable with those derived in other studies which suggest that warehousing accounts for approximately 10% of GHG emissions in the supply chain in the UK (two estimates put it at 11% while another puts it at 13% - AEA, 2012; Baker and Marchant, 2015; World Economic Forum/Accenture, 2009).

Figure 27 shows the estimated change in the relative contribution of UK warehousing to GHG emissions from UK supply chain operations since 2012 (based on warehousing and all domestic freight transport activity making collections and deliveries). The relative (and absolute) contribution of warehousing to these GHG emissions has been falling due to the increasing renewable content of UK electricity and the increase in freight transport activity levels (and these goods vehicles use of fossils fuels that are not becoming more renewable to the same extent as electricity).

Figure 27: Estimated contribution of warehousing operations to domestic UK supply chain GHG emissions, 2012-2020



Note: The estimated supply chain GHG emissions are based on total domestic UK freight transport operations but warehousing only in England and Wales due to coverage in BEIS data collection.
Source: calculated from data in BEIS, 2022a, 2022b.

Holding goods in fewer, more-centralised, larger warehouses results in reductions in total stockholding levels (due to the square root law) but increases the distances over which goods need to be transported (Romm et al., 1999). Thus, holding a given quantity of goods in fewer locations is likely to reduce warehousing energy consumption for these goods but to increase freight transport energy consumption associated with them. Given that freight transport energy use is far greater than warehouse energy consumption in a supply chain, the overall effect can be an increase in net energy / carbon intensity of the upstream supply chain. This is dependent on the efficiency of transport operations from the storage location (World Economic Forum and Accenture, 2009). By contrast, picking and packing in more local fulfilment centres, closer to the customer, can increase warehouse energy use but reduce transport energy use, depending on the transport operations from those centres.

10.3 Warehouse whole of life energy use - construction, refurbishment and disposal

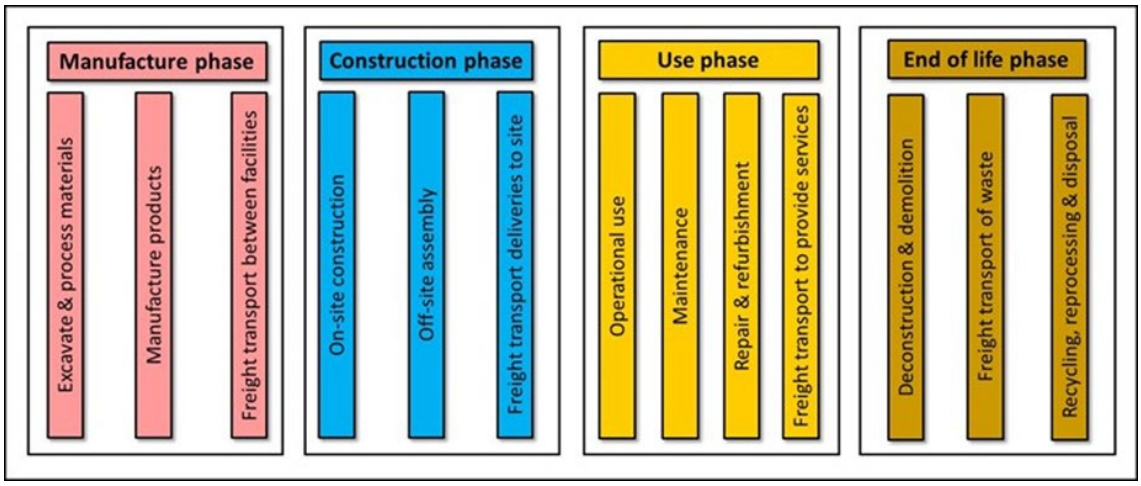
In 2008, the UK Government introduced a target that all new non-domestic buildings should be zero carbon by 2019 (UKGBC, 2014). However, this was scrapped by the new Government in 2015. Further policy concerning non-domestic buildings and GHG has been slow to come forward. In 2021, the UK Government conducted a consultation for a 'Future Buildings Standard for England'. The Government has stated that it intends to "ensure non-domestic buildings are constructed to be highly efficient, better for the environment, and fit for the future, with implementation of this standard starting from 2025….In addition to building regulations, we will continue to examine how we can ensure that all new buildings are designed and constructed to be ready for Net Zero". The Government also noted that "Between 2018-2019, around 60% of EPC (Energy Performance Certificate) registrations in England and Wales for non-domestic buildings were below EPC band C. For non-domestic buildings, estimates suggest it could require around £20 billion in investment to deliver our Clean Growth Strategy commitments" (BEIS, 2021b). In 2021, the UK Government also conducted a consultation on its proposals "to introduce a national performance-based policy framework for rating the energy and carbon performance of commercial and industrial buildings above 1,000m² in England and Wales, with annual ratings and mandatory disclosure as the first step" (BEIS, 2021c). The Government's Future Homes and Buildings Standards "will not come into force until 2025 at the earliest, are limited in their scope to reduce the performance gap and will not in themselves meet net zero construction by 2030" (South West Energy Hub, 2021). In addition, 80% of the buildings that will be in existence in 2050 are already built (UKGBC, 2022a).

Assessment of energy use and GHG emissions related to buildings often only takes account of their operational life ('use phase') of the building. Even then, such assessments often omit energy use and GHG emissions associated with maintenance and refurbishment during the building's life. Proper consideration must take account of energy use and GHG emissions at all phases and in all activities of the life of a building. This includes the manufacturing, construction, use and end of life phases (see **Figure 28**). Warehousing, like all other UK business sectors, will have to take steps to meet the UK's GHG reduction goals discussed above.

The energy used in the manufacturing, construction and end of life phases (which includes deconstruction, demolition and disposal activities) is referred to as 'embodied' energy. The manufacture and use of suitable construction materials and building design improve the embodied energy and efficiency of a warehouse. The use of construction site equipment, goods transport of materials to and from the construction site and worker transport to and from the site during these phases also contributes to the warehouse's embodied energy.

During the operational life of a warehouse, the energy used to power it includes lighting, heating, cooling and equipment use inside the building, as well as goods and worker transport to and from the warehouse associated with its daily functioning.

Figure 28: Activities involved in each phase of the life of warehouse building that involve energy consumption



The GHG emissions associated with warehouse energy consumption during its operational life are influenced by the materials and products used in its building, the building design and layout, and its construction methods. It was estimated that in 2008 operational use accounted for 83% of the CO2 emissions associated with all buildings in the UK, compared with 17% being associated with embodied CO2 emissions (BIS, 2010).

In 2019, the construction industry accounted for approximately 10% of total global energy-related CO2 emissions, while the operation of residential and commercial buildings (i.e. after building has been completed and these buildings are actively used) is estimated to have accounted for 28% of total global energy-related CO2 emissions (United Nations Environment Programme, 2020). In total, the built environment account for approximately 40% of UK energy consumption and 19% of UK GHG emissions (HM Government, 2018).

GHG emissions arise from several aspects of warehouse construction and refurbishment, including the processing and production of the building materials and products used in them, the activities carried out at the construction site during the building phase, the freight transport and logistics operations required to move these materials and products in the construction supply chain and deliver them to site as well as removing and transporting waste, and the personal travel associated with the warehouse construction site.

The manufacture, construction and end of life phases of warehouses (i.e. those associated with embodied energy and emissions) are likely to be more difficult to decarbonise than their operational use due to the fossil-fuels used in blast furnaces, the carbon release from the production of cement, and the use of diesel-fuelled vehicles and machinery to transport these materials and carry out on-site activities. These are more difficult to provide alternative clean technologies for that are financially viable than is the case for the heating, cooling and lighting of buildings and other infrastructure.

Given the demand for new buildings and infrastructure globally, together with efforts to reduce energy use and emissions during their operational life, it is estimated that carbon emissions in the manufacture and construction phases will be responsible for half of the entire carbon emissions of new construction up to 2050 (World Green Building Council, 2019). However, assessing the embodied carbon emissions of the construction of buildings is not required by current UK Government policy (Environmental Audit Committee, 2021).

The major construction company Skanska UK commissioned a report in 2019 into the CO2 emissions associated with its entire operations, broken down by activity (Skanska UK, 2019a). The analysis took account of both direct and indirect emissions (i.e. carbon emissions from

activities Skanska carried out itself as well as those produced by other companies in its supply chain when working on Skanska projects). It also included construction and maintenance activities and took account of embodied carbon in the materials Skanska uses in its projects. It excluded emissions that arise from a construction once Skanska has completed work on it and handed it over to the client (i.e. operational emissions from a building or infrastructure asset constructed were not included). This work provides a recent and helpful insight into the source of CO_2 emissions from the perspective of a major construction company. The direct and indirect emissions for the following eleven categories were included and calculated in the analysis (Skanska UK, 2019a):

- Fuel (used on the construction project in all commercial vehicles and site plant and equipment either leased or owned by Skanska) – direct and indirect emissions,
- Fuel (used in all Skanska premises) – direct and indirect emissions,
- Process and fugitive emissions (from Skanska's industrial activities such as fuel processing and leaks from air conditioning not related to construction) – direct emissions,
- Electricity (used by Skanska at its construction sites and project offices) – direct and indirect emissions,
- Electricity (used in Skanska permanent premises) – direct and indirect emissions,
- Imported heat – direct and indirect emissions,
- Vehicle fuel (used in vehicles operated by Skanska staff) – direct and indirect emissions,
- Public transport (for Skanska staff work-related travel by rail, taxi and air) – indirect emissions,
- Subcontractors (who provide construction, transport and maintenance activities on the project – taking into account fuel used in subcontractor goods vehicles and their plant and equipment used on Skanska construction sites) – indirect emissions,
- Waste (from the generation and disposal of waste across Skanska operations including premises and construction sites and the waste of subcontractors working on Skanska projects) - indirect emissions,
- Materials (from the 56 most commonly used materials across all Skanska operations, projects and premises and also their transportation) – indirect emissions.

The European Network of Construction Companies for Research and Development (ENCORD) protocol was used for calculating these CO_2 emissions. Wherever possible actual emissions were calculated. In cases in which this was not possible emissions were estimated using carbon factors from DEFRA (the Department for Business, Energy & Industrial Strategy) and Bath University's Inventory of Carbon and Energy.

The contribution of these eleven categories to CO_2e emissions in Skanska's entire supply chain are shown in **Table 30** which indicates that the most important categories in terms of CO_2e emissions in Skanska's operations were materials and their transport (76%), subcontractors (14%) and fuel used by Skanska in their vehicles, plant and equipment (6%). Together these three categories were estimated to account for 96% of CO_2e emissions (Skanska UK, 2019a).

In the 'fuel' category, diesel accounted for approximately 52% of CO_2e emissions, red diesel for 48% and petrol for less than 1%. In the 'subcontractors' category, red diesel used in plant and equipment accounted for approximately 85% of CO_2e emissions and diesel used in goods vehicles for 15%. In the 'waste' category, waste transport accounted for approximately 60% of CO_2e emissions, disposal to landfill about 20% and recycling and reuse about 20%. In the 'materials' category, steel was estimated to account for approximately 40% of CO_2e emissions, concrete and cement for about 17.5%, plastics for about 10%, other materials for about 25%, and the transport of materials for about 5% (Skanska UK, 2019a).

Table 30: Estimated CO_2e emissions from Skanska operations in 2018

Category	Proportion of CO2e emissions
Fuel (project)	6.1%
Fuel (premises)	0.2%
Process and fugitive	0.01%
Electricity (project)	0.6%
Electricity (premises)	0.1%
Imported heat	0.0%
Vehicle fuel	1.5%
Public transport	0.2%
Subcontractors	13.8%
Waste	1.5%
Materials	75.9%
TOTAL	**100%**

Source: Skanska UK, 2019a.

Overall, freight transport operations by Skanska, its subcontractors, waste operators, and freight companies and suppliers delivering materials were estimated to account for about 10% of total CO_2e emissions in the Skanska operation in 2018. Plant and equipment used on construction sites by Skanska staff and subcontractors accounted for about 15% of total CO_2e emissions. While personal travel by Skanska employees accounted for about 1.5% of total CO_2e emissions (Skanska UK, 2019a).

In total, Skanska's emissions in 2018 were estimated to be 413,000 tonnes of CO_2e. Of this, direct emissions by Skanska comprised about 8% and indirect emissions from materials and subcontractors in the Skanska supply chain about 92% (Skanska UK, 2019b).

10.4 Sustainability views and actions of warehouse investors and occupiers

Survey work in 2021 with real estate occupiers and investors in Europe, USA and Asia (426 occupiers and 221 investors) asked participants a range of questions concerning the company strategy on GHG emissions reduction, the adoption of targets, the establishment of a roadmap for delivering on targets, and data capabilities from measuring GHG emissions of their companies and, on the basis of responses, categorised each respondent company to one of three levels of decarbonisation 'maturity' ('starting out', 'on the path' and 'leading'). Nineteen percent of both occupiers and investors were categorised as 'leading'. More occupiers (57%) were categorised as 'on the path' than investors (39%). Meanwhile, 24% of occupiers and 42% of investors were categorised as 'starting out' (JLL, 2021a).

In a survey of UK investors in January 2019, only 7% of respondents selected environmental changes in their top three long-term trends impacting real estate, the lowest of any option provided. In January 2020, more than two thirds of investors surveyed selected sustainability and climate in their long-term real estate trends, making it the most popular response. Key motivations among respondents for investing in sustainability were corporate responsibility (55% of respondents), long-term returns available (48%) and regulatory change (41%) (JLL, 2020b). Meanwhile another survey of 220 UK real estate investors and occupiers in 2021 found that in relation to GHG emissions the top priority of both was to comply with regulatory requirements (with 81% of respondents stating this). Sixty three percent of investors and 47% of occupiers said that they were "already thinking about whether the buildings they make decisions about can be made 'net zero'", with landlords concerned about "building insurability and future-proofing and adapting assets to the consequences of climate change" (CBRE, 2021). A study of UK major warehouse occupiers found that three-quarters of them either 'strongly agreed' or 'agreed' that reducing GHG emissions associated with their warehouse operations was very important (JLL, 2020a).

These results indicate the increasing importance of GHG emissions among the consideration of investors and occupiers. However, one of these surveys of all real estate investors and occupiers found that respondents were more concerned about the building achieving an Energy Performance Certificate of at least E rating than actually reducing energy usage related to the building. This is presumably related to the need for a building to achieve this standard to be lettable in England and Wales, rather than the compliance standard being focused on actual energy use. This survey found that respondent occupiers whose brand positioning, or need to attract and retaining talent, were significant drivers of their sustainability strategies, were more likely to be willing to pay for reduced 'embodied carbon' than occupiers as a whole (with 41% of occupiers saying they would pay at least as much as it cost the landlord to reduce embodied carbon in building construction, but not necessarily prepared to pay to reduce it to zero). This survey also showed that the importance of biodiversity and protecting local was of far less importance to many UK investors and occupiers of real estate, with 45% of occupiers and 33% of investors give it either no or minimal coverage, and of those that did take it into account, it was half as likely to be rated as so important that the decision in question would turn on it, compared with the average importance given to all fourteen issues posed (CBRE, 2021).

Research has indicated that sustainable office buildings in central London (those with a BREEAM rating or EPC certificate) have a rental premium in the range of 6% and 11%, and that at both 12 months and 24 months after completion, vacancy was lower in buildings with an 'Outstanding/Excellent' BREEAM rating compared to those that were rated 'Very Good' (JLL, 2020b).

10.5 Examples of actions taken and sites built to improve warehouse sustainability

'Sustainable' warehouses have been promoted by developers for at least fifteen years. No comprehensive statistics are available on the total stock of sustainable warehouses in Europe (JLL, 2020a), but the proportion is likely to be relatively small at present. However, examples of sustainable warehouses exist across Europe. Design features that these buildings typically incorporate are shown in **Table 31**.

Table 31: Selected sustainable design features for warehouses

Feature	Comment
Significant proportion of building materials sourced locally/ regionally	Reduce transport emissions during construction phase
High-efficiency roofing and walls	Optimise interior temperatures, minimise energy wastage
Rooflights (and/or above dock areas)	Reduce need for lighting in day
Internal/external LED lighting	Reduce energy usage and light pollution
Rainwater harvesting	Minimise water consumption
Rooftop solar panels	Generation of green energy
Wind turbines & other green energy generation	Generation of green energy
Electric car charging stations	Reduce emissions from commuters
Battery storage	Allow occupiers to vary their battery requirements
Designed for deconstruction / disassembly	Reduce emissions at end of life demolition

Source: JLL, 2020a.

Various actions are being taken to reduce energy demand at some warehouses in the UK. These include (BPF and Savills, 2022):

- Reducing energy demand for lighting: Use of skylights and clerestory windows, LED bulbs, and light sensors to active lights when required,
- Reducing energy demand for cooling: use of high-reflectance roof membranes,
- Reducing overall energy demand: use of smart meters to monitor energy consumption,
- Reducing transport fossil fuel use: providing parking and charging facilities for net zero tailpipe forms of transport such as for bicycles, eBikes, EV cars and vans,.
- Reducing use of non-renewable resources and improving indoor air quality: use of compounds and chemicals with non-petroleum bases.

Energy supply and provision at warehouses can be improved by using renewable energy sources. Such approaches can include using flat roofs of large buildings for solar photovoltaic (PV) panels (with research indicating that new warehouse developments can be almost energy independent if at least 40% of the roof space is used for PV installation) (BPF and Savills, 2022). It is estimated that the largest 20% of warehouses in the UK have sufficient roof space (75 million sq metres or approximately 750 million sq ft) to double the UK's solar generation capacity from 14 to 28 GW. Payback periods for the capital and installation costs can be as low as 4 to 6 years with an estimated internal rate of return of 10-15% per annum on self-financed projects (depending on warehouse location, building size, orientation of the building, on-site energy demand and market electricity prices) (Delta Energy & Environment, 2022).

Other available renewable energy generation approaches to energy supply include wind turbines, borehole thermal energy storage, electric air source heat pumps, water source heat pumps, electricity recharging points and hydrogen fuel cells for on-site handling equipment (BPF and Savills, 2022).

Barriers to installing solar panels and other renewable energy generation technology at warehouses include: the relatively low energy consumption at some warehouses, that most warehouses occupiers lease rather than own the building and may have short remaining lease durations, the risk of stranded assets if the occupier leaves the warehouse, obtaining permission from landlords who may be reluctant to grant approval, the design knowledge and expertise required, and the potentially high cost and long timescale of obtaining necessary grid connection upgrades from Distribution Network Operators (DNOs).

Some developers are also beginning to focus on including warehouse design features and amenities which are intended to improve worker wellbeing, primarily in order to improve attraction and retention rates amongst the workforce. This can include greater attention to air flow, light, temperature, sound, water use, space for movement and exercise, and other features that can enhance mental and physical wellbeing. Prologis has focused on outdoor space for workers and the local community for walking, running, cycling and resting. Its DC5 warehouse in Tilburg in the Netherlands and the GLP developed Altitude building, in Magna Park, Milton Keynes both completed in 2018, were Europe's first warehouses to meet the WELL Building Standard (GLP, 2020; JLL, 2020a; Prologis, 2019b).

A survey among UK real estate (not just warehouse) investors and occupiers found that 60% of respondents said that "adding features to buildings to improve the health or wellbeing of users was very important or critical to their decisions." However, only 31% of respondents said that achieving a health or wellbeing building certification was important to them (CBRE, 2021). Examples of 'sustainable' warehouses are provided below.

The 60,000 sq ft parcel sortation hub at Symmetry Park, Bicester occupied by DPD and owned by Tritax Symmetry is the first 'net zero carbon in construction' building in the UK (as regulated by the UK Green Building Council (UKGBC). Where possible, it made use of locally sourced, low embodied carbon construction materials, with timber used being certified and renewable. The

building design used efficient fabric and shading design and natural daylight features to reduce heating, cooling and lighting energy needs and design and materials ensure a high degree of airtightness. Air source heat pumps were installed and the roof contains 5,500 sq ft of solar panels (25% of its useable area), with the remaining roof space available for further solar panels if required for an increase in electric goods vehicles or other energy demand in future. Smart energy/building management systems were incorporated to monitor and reduce energy consumption. The service yard was fitted with 30 EV charging points (BPF and Savills, 2022).

Magnitude 314 at Magna Park in Milton Keynes is a 300,000 sq ft warehouse with 15,000 sq ft of office space. It was developed by GLP and is the "first building verified as net zero carbon – construction in line with UKGBC's Net Zero Carbon Buildings Framework Definition" as well as having a BREEAM 'Excellent' standard and EPC A rating and designed to WELL principles. The verification process has determined that the building design "has resulted in a 25.8% reduction in embodied carbon compared to a standard logistics building." Building design and choice of materials focused on reducing embodied carbon (with glass granulated blast furnace slag (GGBS) used in the concrete mix rather than cement where possible) and improving the overall environmental performance of the warehouse through air tightness levels and use of natural lighting. With a solar PV ready roof structure, solar thermal panels were used for water heating, hybrid air source heat pump heating and cooling, and rainwater was harvested for toilet flushing. Any remaining carbon was offset as per the UKGBC Net Zero Carbon Buildings Framework Definition (UKGBC, 2022b).

PLP completed its first net zero speculative logistics development in 2020. It is a 343,000 sq ft warehouse at Smithywood, Sheffield. Life cycle assessment was carried out at the design stage to assess GHG emissions and the building design and construction materials selection reflecting the net zero target. Remaining GHG emissions were offset to net zero by funding high quality carbon offset projects (PLP, 2020). In 2021, PLP and Ivanhoé Cambridge announced their acquisition of a new 135 acre site in Milton Keynes, on which they will develop a business park for modern logistics and manufacturing. The site will be the first major logistics park in the UK to be delivered with carbon net-zero construction and carbon net-zero ready for occupation, under the UK Green Building Council Framework. The site will provide over 2 million sq ft of space with the first phase of development intended for completion in the second half of 2022 (PLP, 2021). PLP has announced that it intends to deliver all future speculative warehouse builds to the UK Green Building Council's (UKGBC) Net Zero Carbon Ready standard (PLP, 2020).

Sustainable and carbon neutral warehouses are also being developed in the rest of Europe. These include the L'Oreal warehouse in Germany developed by Prologis, the Biocoop warehouse in France developed by Barjane, the Nike Campus in Belgium and the Amazon site at Prague Airport in the Czech Republic (JLL, 2020a). As part of its decarbonisation strategy, An Post, the national mail and parcel carrier in the Republic of Ireland, achieved 100% use of renewable electricity in its buildings by 2019. The company has set targets to reduce electricity use within buildings by 40% by 2022 from a 2009 baseline and to replace all lighting with energy efficient lighting by 2022 (An Post, 2019).

10.6 Refuelling zero emission goods vehicles serving warehouses

According to UK Government plans, new LGVs purchased after 2030 will have to be zero GHG tailpipe emissions, while for HGVs this will apply for vehicles up to 26 tonnes gross weight from 2035, and for heavier vehicles from 2040. Zero GHG tailpipe emission HGVs may be powered by hydrogen, electric batteries, and/or an Electric Road System (ERS). Whilst an ERS provides energy directly to the vehicle during its connection with it, HGVs powered by batteries or hydrogen will require recharging/refuelling.

Zero GHG tailpipe emission LGVs servicing warehouses and distribution centres are likely to be battery powered; such vehicles already exist and are in use in small numbers in the UK LGV fleet. At the end of 2021, there were a total of 30,609 plug-in electric LGVs and 28,312 zero-emission

LGVs licensed and being used on the road in the UK, which represented 0.7% and 0.6% of the total LGV fleet, respectively. This was a 628% increase in the number of plug-in electric LGVs and a 574% increase in the number of zero emission LGVs compared with the end of 2014 (calculated from data in Department for Transport, 2022b). In 2021, 3.9% of newly-registered LGVs were plug-in electric and 3.6% were zero emission (calculated from Department for Transport, 2022c).

For battery electric HGVs and LGVs, warehouses and distribution centres that these vehicles either visit or are resident at will need to be equipped with recharging facilities. This could take the form of slow charging or rapid charging infrastructure, with the latter being considerably more expensive than the former. In addition, it may be necessary for the warehouse to have an upgrade to its grid connection depending on its current grid connection and electricity use, the local grid infrastructure, the number of vehicles that will need to be charged at the same time and the speed of charging required.

Depot infrastructure required to facilitate vehicle recharging can be expensive and can take considerable time to carry out. The parcel carrier UPS upgraded its London depot in Kentish Town to be capable of recharging sixty five 7.5 tonne vehicles. This required a significant network upgrade to the grid capacity provided to the depot and the installation of EV charging points at the depot to accommodate these new vehicles. The grid upgrade was both expensive and complex to organise. It cost £600,000, required permission from three-tiers of depot landlords, with the added complication that the landlords rather than UPS are the long-term beneficiary of the upgraded grid capacity asset. It took two years to organise and carry out with UPS working closely with electricity distributor and substation owner UK Power Networks (UKPN) and the depot landlords (Quak et al., 2017).

The parcel carrier, DPD, has noted that the cost of installing suitable EV charging equipment at its depots has been at least £250,000 per depot, compared to the cost of installing a diesel tank which is approximately £50,000 (DPD, 2021). Western Power Distribution, a Distribution Network Operator (DNO), provides estimates of £60,000 to £2 million for a large installation with multiple charge points and an installation lead time of six months or more. It notes that installation costs will depend on the groundwork costs, legal costs for easement and wayleaves, and whether planning permission and space is required for a substation (Western Power Distribution, 2021).

The upgrading of grid capacity is, as mentioned above, also subject to law that can delay or prevent its installation. If a communications or energy network provider needs to use another party's land to carry out the necessary work it must obtain this other party's agreement to do so. The UK Government has put in place specific legislative framework that aims to support electricity and communications infrastructure deployment and assist in the making of agreements between site providers and communications network providers. There are two types of such contractual agreement a wayleave and a lease (UK Government, 2022a). Obtaining such permission to access and use the land of a third party for electrical works is a private negotiation between the company and the third party, and the third party is under no obligation to agree. If no agreement can be reached", the electricity licence holder (the electricity company) has powers under the Electricity Act 1989 to apply, on behalf of the company seeking a wayleave, to the Secretary of State for Business, Energy and Industrial Strategy for a compulsory wayleave" (Transport Select Committee, 2021). When needing to place electrical equipment on the land of a third party, DNOs can also obtain such permission through a Deed of Easement, which is a permanent right registered against the title deeds of the property of the third party. The gaining of agreement to access and use the land of third parties for the upgrading of grid capacity and other electrical installation associated with EV charging infrastructure is a potentially time consuming and expensive process.

Ofgem carried out a consultation on the financial costs and time involved in connecting EV charging points to the electricity grid for businesses. This consultation considered whether the cost of grid connection upgrades should continue to be paid for by the company requesting the connection or whether this cost should be more equitably shared between all consumers through

energy bills. In May 2022, Ofgem published its revised strategy which is intended to prevent companies and other organisations or individuals requiring grid connection upgrades from being put off doing so due to the upfront costs charged to them by DNOs. Ofgem, considers this new approach to be “a more strategic, efficient, and joined-up way of planning and paying for new connections to ensure costs are kept down for all customers”. In the new charging approach, to be introduced in April 2023, “more of the costs of these new connections will be shared in a fair and proportionate way amongst all network users, making the likes of electric vehicle charging points and heat pumps, more accessible and affordable for individual customers” (Ofgem, 2022a, 2022b). These changes will result in the removal of the payment for wider network reinforcement for demand connections (with some exceptions) and a reduction in the contribution to wider network reinforcement for generation connections, together with a standardised option for larger network users (Ofgem, 2022b).

As well as the expensive ground works and high costs associated with grid capacity upgrades, charging points vary considerably in terms of their purchase cost and installation lead time depending on their power rating and the associated work required, with super rapid chargers being extremely expensive. Charging points can vary in cost between £1,000-£40,000 each depending on the ratio of vehicles to chargers needed and the power specification of these chargers (National Infrastructure Commission, 2019).

In relation to HGVs powered by hydrogen, whether or not the depot has its own refuelling network is likely to depend on the scale of vehicles using the site, given the costs of installing a hydrogen refuelling station and of transporting hydrogen to it. In order to be economic, hydrogen refuelling stations are likely to require substantial throughput of hydrogen and vehicles (UK H2 Mobility, 2022). It is therefore likely that only very large operators’ depots would be able to support hydrogen refuelling infrastructure.

11. Conclusions and recommendations

11.1 Changes and developments in UK warehousing

Warehousing has changed markedly in the last fifty years as a result of various changes in the UK economy and logistics practices. Important factors responsible for this change include: the rise of the service and relative decline of the manufacturing sector in the UK economy (resulting in a growing dependence on the importation of finished goods); the growth in the UK retailing sector and market concentration in the retailing market (resulting in the increasing dominance of major retailers operating their own warehouses); rises in interest rates during the early 1980s; the internal rationalisation of stockholding by large businesses leading to ever-larger but fewer warehouses primarily located on the strategic road network with a reliance on longer distance freight transport journeys (which has been driven by the relative costs of stockholding and freight transport); and the growing deployment of materials handling equipment and automated stock control and picking systems. These factors have led to dramatic changes in the size and location of warehouses and the operations taking place within them, supported by an increasing degree of computer technology and automation and thereby a reduction in total workforce otherwise required.

Changes in logistics practices over this period resulted in the role of the warehouse shifting from being a relatively inactive place where goods were held in store with poor stock visibility along the supply chain to a dynamic supply chain node through which goods are channelled in accordance with demand. In conjunction with the increase in the dominance of large businesses and substantial increases in urban land values this has led to a reduction in stockholding levels in shops and offices in order to convert stockholding space into sales areas and other value-added activities and reduce total space requirements in these facilities. This has been achieved by placing greater reliance on frequent deliveries from warehouses to these urban sites by goods vehicles.

Over recent decades the average size of warehouse has increased markedly, with an ever-growing proportion of warehouses with more than 100,000 sq ft of floorspace as well as increasing eaves heights. This has been combined with a greater centralisation of these large warehouses especially in the middle of the country (particularly the East and West Midlands) located in close proximity to the motorway network which receive goods arriving in the UK via ports and which rapidly transfer these goods onwards to locations across the country to retail and business locations where they are sold and used. This inbound and outbound warehouse transport primarily takes place using articulated HGVs. The amount of time that goods are stored in warehouses has diminished over recent decades as logistics management has become more efficient and demand focused, with the warehouse increasingly becoming a transhipment point used to organise and co-ordinate the supply chain rather than primarily a place of inactive stockholding.

Despite the increasing speed with which goods move through their supply chains and the warehouses in those chains, the total quantity of warehousing has increased nationally at a considerable rate over recent decades, primarily as a result of the growth in retailing in the UK together with the relative decline in UK manufacturing and the consequent rise in importation of consumer and capital goods. Warehousing uptake in the UK in 2020 and 2021 was the strongest on record and warehouse vacancy rates reached an all-time low. Supply chain difficulties experienced as a result of Covid-19, Brexit and the war in Ukraine have led to businesses wanting to hold increasing stock levels. In addition, the rapid growth in online shopping in the last five years, exacerbated by the onset of the Covid-19 pandemic in 2020, has further fuelled the demand for warehousing as the focus of retailing and the provision of retail goods moves increasingly away from physical shops to fulfilment centres. This recent surge in online retailing has also reversed the previous decline in warehousing in urban areas as retailers acquire sites from which to fulfil same- and next-day deliveries.

11.2 Planning for future warehousing requirements

The future demand for warehousing in the UK is somewhat uncertain. Some commentators expect warehousing demand to continue to increase in the coming years as UK businesses require greater 're-shoring' (also referred to as 'on-shoring' and 'near-shoring') of goods that they currently import from distant, international locations to mitigate against continued or future supply chain disruptions at ports and borders. However, implementing such a change to supply chains takes considerable time to implement, so it is too soon to be able to say with any certainty whether many businesses are implementing such a strategy. Such a near-shoring production strategy can also lead to greater risks from national disruption and that in nearby countries to raw material inputs and labour markets, as well as transport infrastructure, so does not necessarily improve supply chain resilience. Clearly greater thought needs to be given by businesses to supply chain resilience to prevent disruption to long distance goods transport.

Another approach being discussed by some commentators to achieve greater supply chain resilience involves businesses implementing less centralised stockholding with warehousing sites located closer to the sales markets served. Similar to near-shoring of production this involves relocating stockholding closer to customers. However, the impacts of such a strategy on avoiding supply chain disruption is unclear especially if production continues to take place in very distant locations, as this leaves much potential for goods flows to still be affected in their movements between the point of production and stockholding. It would also be likely to lead to substantial investment costs in new warehousing facilities, possibly in locations with higher land values and rental prices . It would also be likely to result in higher logistics operating costs due to the benefits that centralising stockholding and placing more reliance on freight transport provides.

Economic factors that began to emerge in 2022, including the cost of living crisis and a looming recession, may damp down demand for goods and hence warehousing space, and are adversely affecting the growth of online retailers, especially those providing instant deliveries that emerged during the pandemic providing groceries and meals and taking out urban premises to store, pick and despatch these goods. Meanwhile, inflationary pressures that are driving up energy, labour and transport costs are liable to also result in rising warehouse rental prices making them unaffordable for some occupiers.

Warehousing supply and demand are dealt with by the market, with occupiers deciding how much space they require and developers and investors providing that space, with the market determining its rental value. However, the UK Government plays an important role in terms of national planning law and guidance concerning the granting of planning consent for warehouse development, while local planning authorities make decisions on individual warehouse applications.

Warehousing has traditionally been viewed by public sector economic development officers and town planners as generating low employment density, low paid, unskilled work. Whilst the pay of manual warehouse workers has not improved considerably in recent years, and the work of many doing so has become increasingly precarious with the introduction of zero hours contracts, the increasing deployment of automation in large scale warehouses is providing higher skilled better paid work for those involved in its implementation and maintenance. In addition, the land uses typically viewed as superior to warehousing by public officials, such as offices, retailing outlets and manufacturing sites, are far less in demand as a result of changes in working practices (with many more people working from home since the pandemic leading to a reduction in office demand) in retailing provision (with the growth in online retailing over the last twenty years resulting in a gradual but progressive decline in the demand for retail space) and in the continued relative decline in UK manufacturing. In addition, warehousing developments been viewed less preferentially than housing schemes in local authorities' efforts to meet the dwelling needs of a growing population.

It is therefore an appropriate time for a reconsideration of the importance and status of warehousing by public sector economic development officers and town planners given the decline

in other types of work and their demand for buildings, and the need to create jobs for a workforce that will expand in future. Reconsideration of the importance of warehousing should go beyond national Government guidance concerning the decision-making process for warehouse development at a local level and should instead involve a coherent national strategy for warehousing that takes account of its importance in modern, efficient, decarbonised supply chains and the provision of space for it and which could be enshrined in the National Policy Planning Framework. The publication of the Department for Transport's 'Future of Freight Plan' in June 2022 marks an important start in this process, with the UK Government acknowledging the importance that it identifies, "a National Freight Network (NFN) across road, rail, maritime, aviation, inland waterway and warehouse infrastructure", pledging that "our long term aim will be to remove the barriers which prevent the seamless flow of freight" (Department for Transport, 2022a). Within this plan the government has also noted that it "is working with industry to explore ways to protect and expand the warehousing land capacity" (Department for Transport, 2022a). In order to achieve change, this work by the UK Government will clearly need to go far beyond 'exploring ways' but the statement is an acknowledgement of the importance of this issue.

This Plan also recognises that current local planning system is not working adequately for warehousing and other logistics development proposals, with proposals often dealt with too slowly, thereby "reducing the level of certainty for applicants, investors and communities. This increases the uncertainty of delivering development associated with freight and logistics, actively discouraging promoters from bringing forward schemes and can lead to sub-optimal outcomes." The government argues that "all of these considerations can be better met through better collaboration between industry and local authorities supported by an agile and responsive planning system" (Department for Transport, 2022a).

At a regional and local level, efforts to ensure the provision of suitable quantities and types of land for warehousing in appropriate locations as well as to safeguard such land for future demand should be reflected in Local Plans. These can be supported by Local Industrial Strategies that highlight the role and importance of warehousing. Industry has an important role to play in achieving this by communicating to national, regional and local governmental bodies its warehousing needs and working with these public policymakers to help ensure that outcomes of such efforts are suitable and realistic. Town planners will also have to be realistic about the plot ratios that are required at warehouse to facilitate all the outdoor activities and facilities that are necessary. Any efforts by planners to insist of higher plot ratios to adversely affect the functioning of the warehouse and the cost of warehouse operations and the negative impacts of its operations on neighbouring sites. Some planners and politicians have shown enthusiasm for the intensification of industrial sites either through co-location or the development of multi-level facilities. In the case of warehousing, the former is liable to be impractical when the co-located developments are residential dwellings given the noise and operating hours associated with warehouses, while the latter is liable to lead to less efficient and more expensive warehouse operations (see Allen and Piecyk, 2023d for further discussion of these issues).

Greater attention should also be paid by local planning authorities to vehicle trip generation estimates submitted as part of planning applications for new warehousing developments. Research suggests that the current methodology used to produce these traffic flows underestimates its actual volume, thereby imposing negative traffic and associated social and environmental impacts on residents and others in close proximity to such sites. This current methodology is based on assumptions that are outdated for warehouses operating in modern, demand-responsive supply chains, with goods being conveyed at all times of day and night.

The warehousing and logistics industry (comprising developers, investors, occupiers, freight transport and logistics operators and relevant trade associations and professional bodies) needs to better communicate the economic and other benefits warehousing has to offer the general public and local communities as well as to take a joint stance against the practices of those among its ranks that behave in an unethical manner towards their workforce (in terms of pay and working conditions). It needs to communicate to the general public and potential workforce the growing

diversity of roles that are being created by the growth in adoption of automation and robotics in warehouses, including computing, engineering and management roles with attractive rates of pay. At the same time, Government needs to ensure that the pay and working conditions of elementary warehouse workers are monitored and changes made to existing labour law in respect of zero hours contracts. The industry needs to also make greater efforts to provide washing, toileting and rest facilities to those vehicle drivers visiting warehouse sites to make collections and deliveries.

Automation is already affecting the level of employment in larger warehouses that have adopted it. In the longer term, the total size of the warehousing workforce per sq ft is likely to fall as ever-greater levels of sophisticated technology is introduced across sites of all sizes. This reduction in employment will especially affect manual roles in warehouses. However, humans performing manual roles are likely to continue to co-exist alongside this technology given the substantial costs of making a warehouse fully autonomous and of doing so to the extent that such technology is capable of meeting all the seasonal peaks in demand. It is likely to remain more cost-effective to cope with peak periods in warehousing operations by using additional human labour rather than having expensive technology that is under-utilised. Questions remain about which tasks should be left to humans to achieve optimum joint performance with machines, how to ensure that humans have a good working environment when collaborating with automated machines, and how to remove the tasks most associated with human worker injury, discomfort and boredom. In addition, little research has been carried out into the environmental impacts of the various automated technologies being developed for and used in warehouses.

Goods vehicle queueing problems on motorways and other roads in Kent as drivers attempt to reach Dover ports and the Channel Tunnel have become more frequent since Brexit. This may, in the longer term, lead to less reliance on roll-on roll-off (RoRo) goods vehicle traffic using these routes between Britain and mainland Europe for the import and export of goods. Such RoRo traffic may be redirected via other ports, together with a shift away from the use of accompanied vehicles towards unaccompanied trailers (to save driver time and costs) as well as greater use of lift-on lift-off (LoLo) container flows to other major ports beyond Kent. Any such changes in decisions about routeings for and methods of transporting goods between mainland Europe and Britain would also be expected to influence warehousing location decisions.

Warehouse contracts between owners and occupiers need to become fairer and more flexible. Such changes would allow occupiers to make alterations to buildings and their fixtures and fittings they require for operational efficiency (such as installing mezzanine floors, technology and automation), how they use the building and with which other businesses they share the space without this being prevented or delayed by owners. This contract flexibility also needs to address the ownership of such capital investments which currently often reside with the owner, thereby potentially deterring occupier investment in making their warehouses best suited to their needs. The fairness and flexibility of the contract also has implications for the carrying out of energy efficiency improvements and the installation of equipment required to decarbonise warehouses (such as upgrading energy infrastructure at buildings for electric vehicle recharging and installing solar panels on roof spaces). It would also prevent the absurdity that can occur of occupiers having to remove infrastructure at the end of their lease that would have been of use to subsequent occupiers and which has to be reinstalled by them, and the environmental impacts of such situations. The parties in the warehousing industry (owners, occupiers, property agents and consultants and insurers) need to work together to bring about such changes to lease flexibility that facilitates operational efficiency and decarbonisation.

11.3 Decarbonising warehousing and the supply chain

The total quantity of electricity and gas consumed operationally in warehouses fell far less between 2012-2020 than for many other types of non-domestic building. This is likely to have been due to the growth in total warehousing floorspace and the increasing use of automation, computing and other technology on their energy requirements.

Analysis indicates that in 2020, the operational energy used by warehouses accounted for approximately 16% of the GHG emissions (CO_2e) from the UK supply chain, with 84% accounted for by freight transport operations (based on domestic freight transport activity and operational warehousing energy used in the UK in 2020 – this data only includes warehouse energy use in England and Wales). If both domestic and international freight transport activity are taken into account, then warehousing energy use in the UK accounted for 11% of the GHG emissions (CO_2e) from the UK supply chain in 2020 (calculated using data in BEIS, 2022a, 2022b, 2022c).

Assessments of energy use and GHG emissions related to buildings often only take account of their operational life ('use phase') of the building. Even then, such assessments often omit energy use and GHG emissions associated with maintenance and refurbishment during the building's life. Proper consideration must take account of energy use and GHG emissions at all phases and in all activities in the life of a building including warehouses. This includes the manufacturing, construction, use and end of life phases. A few 'sustainable' warehouses have been constructed in recent years, indicating the steps that can be taken by developers and the construction industry to contribute to the UK's net zero GHG target.

The current UK Government and devolved administrations have been slow to bring forward new legislation concerning energy efficiency and GHG emissions of new and existing warehouses. An increase in the rate of Government action in building standards and energy efficiency requirements for non-domestic buildings is required if the warehousing industry is to meet net zero GHG emissions by 2050 given the lifespan of warehousing and the legal and operational difficulties associated with retrofitting existing buildings and installing infrastructure to decarbonise them. Many warehouses being built now will still be in operation in 2050 so urgent action is required to address these issues. Far greater consideration of the refuelling of zero emission goods vehicles is also required by developers and local and national Government. The UK Government has been far slower to set targets and actions for reducing warehouses GHG emissions than for transport vehicles. Policymakers need to acknowledge the related nature of logistics activities and therefore set GHG emission reduction targets for both.

At present, the UK Government strategy for decarbonising warehouses is rather unclear and BEIS (the department responsible until recently) has had relatively little to say about this since 2015, when the Government scrapped its predecessor's target that non-domestic buildings (including warehouses) should be net zero by 2019. Any changes to national planning law (including the National Planning Policy Framework) that are necessary as part of this come under the remit of the Department for Levelling Up, Housing and Communities (DLUHC). Meanwhile, the Department for Transport is responsible for the decarbonisation of goods vehicles and other freight transport modes and has published plans concerning this, but these do not address their refuelling at warehouses and other distribution centres. The Department for International Trade is responsible for the importation of goods to the UK. Therefore, far closer working and co-ordination between BEIS, DLUHC, and the Departments for Transport and International Trade will be necessary to achieve supply chain decarbonisation that takes account of warehouses and associated logistics buildings and the freight transport activity that handles goods to & from them (domestically and internationally).

the freight transport activity that provides these to them together with the provision of the goods they receive (internationally and domestically).

As the Climate Change Committee has stated, the target for net zero GHG emissions "can only be achieved if government, regional agencies and local authorities work seamlessly together" (Climate Change Committee, 2020). It noted that local authorities have powers or influence over a third of emissions in local areas. This includes responsibility for local planning law concerning consent for new warehousing and the conditions imposed on it. Therefore, national government must work far more closely with local government and other regional governmental bodies and executive agencies if the decarbonisation of warehousing and freight transport is to be achieved in a timely, cost-effective and efficient manner.

The Department for Transport also needs to work with DLUHC and BEIS to ensure that Government infrastructure investment in railways and ports helps to facilitate freight modal shift to non-road modes by improving these transport links between ports, warehouses and centres of demand. This would help stimulate greater private sector warehousing provision and demand at strategic rail freight terminals and in UK ports that can make use of alternative freight transport modes. These modal shift efforts should also include streamlining the time taken for planning decisions for such rail and port developments which currently hinder their provision and results in excessive costs for developers, thereby discouraging them. Consideration should also be given to including requirements in national and local planning policy that new large warehouses need to be co-located with and incorporate rail and water facilities. The provision of financial or other incentives for property developers to include rail and water facilities in their applications for large new warehouses to encourage modal shift should also be considered.

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