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Factors in the design of order picking systems that influence manual handling practices

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Factors in the design of order picking systems that influence manual handling practices

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Order picking can be defined as the retrieval of stock keeping units from a warehouse according to a pick list generated from a customer order prior to the despatch of the completed order to the customer.

There is a variety of order picking systems that are used in warehouses and distribution centres and the choice of system will determine the amount and type of manual handling that occurs within those locations. In order to understand the factors that influence the design of order picking systems a literature review was undertaken and telephone interviews were conducted with six industry stakeholders. The stakeholders included were two retailers with distribution networks operating across the UK, two specifiers who design order picking systems of different types and complexity for the end users, and two major suppliers of order picking systems.

The factors that influence the amount of manual handling within warehouses and distribution centres are complex and inter-locking. The key factor is the design of the order picking system, particularly how much automation is used and whether pickers travel between pick slots or whether items are automatically delivered to them. It also depends on the nature of the goods that the warehouse handles. There are financial trade-offs between high capital costs of automated systems, and increased labour costs in manual systems.

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KEY MESSAGES

- The factors that influence the amount of manual handling within warehouses and distribution centres are complex and inter-locking. The key factor is the design of the order picking system, particularly how much automation is used and whether pickers travel between pick slots or whether items are automatically delivered to them. Automated systems have high capital costs and manual systems have increased labour costs.
- Levels of activity and staffing often vary within warehouses and distribution centres due to seasonal and other factors. This may impose additional physical and mental demands on pickers, which may result in increased sickness absence, injuries, accidents and near misses during busy periods.
- Controls to implement weight limits on items handled manually may include automation, the use of manual handling aids, or team handling. Training in manual handling techniques is often provided. Poor manual handling practices may be evident where high levels of productivity are expected.
- Recent trends in retail towards internet shopping, home delivery and small format supermarkets are all affecting manual handling practices in distribution warehouses.
- In large-scale internet operations, automated order picking systems cannot cope with the volume of orders for some lines, so many retailers are relying increasingly on manual order picking.

EXECUTIVE SUMMARY

There is a variety of order picking systems that are used in warehouses and distribution centres and the choice of system will determine the amount and type of manual handling that occurs within those locations.

In order to understand the factors that influence the design of order picking systems a literature review was undertaken and telephone interviews were conducted with six industry stakeholders. The stakeholders included were two retailers with distribution networks operating across the UK, two specifiers who design order picking systems of different types and complexity for the end users, and two major suppliers of order picking systems.

Order picking systems are complex and there are a number of elements that go into their design. As far as is practicable, most will design out manual handling but this is not always possible due to the variable shape and size of products, customer demand, as well as the cost of implementing automated systems. Order picking activities by themselves can represent as much as 60% of all labour activity in a warehouse.

The most common order picking system used in warehouses is called *picker to parts* with pickers walking or driving along aisles to pick items to complete a single order, or a batch of multiple orders. The norm within the industry is for pickers to receive instructions about what items to pick via a handheld or vehicle-mounted computer. These terminals typically provide pickers with information about location, weight, centre of gravity and whether the items require one or more operatives to lift them.

Most businesses try to make productivity improvements within their picking process by eliminating inefficiencies and seeking to increase pick rates. This may result in increased physical demands being placed on the operatives. In *parts to person* systems, where the items are delivered to the picker who does not have to move between picking locations, it is possible for targets to be set at up to 1,000 picks per person per hour. Other management practices may also result in operatives working long shifts and overtime; sometimes they may be discouraged from taking breaks and pressure of work may also result in poor manual handling.

The use of manual handling equipment may be limited by the design of the order picking system and can range from forklift trucks, work platforms through to ladders. Good practice is to establish lists of compatible storage and handling equipment. The workplace should be designed so that operatives are able to pick the most frequently ordered items from working zones that are between their shoulders and knees. Manual order picking above shoulder height is a high risk activity so where possible some attempts should be made to look at ways of either lowering the items or raising the employees, reducing object size and weight or reducing picking frequency and duration.

The retailers interviewed use a variety of manual handling aids depending on the site in question and they include pallet trucks, fork lift trucks, roll cages, hanging rails, overhead conveyor belts and cranes. They also provide operatives with manual handling training.

The specifiers also identified different types of manual handling aids they recommend to their customers and include narrow aisle order picking trucks that enable operatives to be lifted up to 12 m to pick items from high racking locations. The demands placed on operatives to increase productivity and the stress this puts the operatives under, is thought to be the new ‘hidden injury’ to workers’ mental health within the distribution industry.

The suppliers interviewed tend to supply conveyor based systems and provide customers with method statements for automated order picking systems so they also have information about how to gain access to machinery in case of a breakdown. Noise is considered when supplying equipment and the suppliers are aware that different countries require different standards of noise control. Suppliers have also noticed that the growth of internet shopping has meant that whilst clients may have an automated order picking system they are not increasing the level of automation in their warehouses. Instead, they are increasing the manual picking and packing operations, firstly because extensive automated systems are expensive but also because they find that automated systems do not have the flexibility to pick some items at the frequency they are being ordered over the internet.

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1. INTRODUCTION

1.1 BACKGROUND

Manual handling when picking orders is common in warehouses. The amounts and types of manual handling that occur in such places are influenced by the use of automated order picking systems that are currently prevalent within the industry. HSE identified that there needs to be a review of current order picking systems used by picking warehouses to determine the factors that influence the amounts and types of manual handling that occur in such locations.

1.2 AIM

The aim of the research described in this report was to:

Study the factors that influence the design of order picking systems and therefore affect the amount of manual handling required

2. UNDERSTANDING ORDER PICKING SYSTEMS

2.1 WHAT IS ORDER PICKING?

Order picking can be defined as the retrieval of *stock keeping units* (SKUs)[1] from a warehouse according to a *pick list* generated from a customer order, prior to the despatch of the completed order to the customer.

2.2 A REVIEW OF THE LITERATURE

A search was undertaken of peer-reviewed journals, grey literature and internet-based sources in order to identify the literature available relating manual handling to the design of order picking systems. As the amount located was relatively limited, it was only possible to carry out a scoping review that summarised important findings in the literature.

The findings suggest that with increasing numbers of 'out of town' retail outlets, larger scale supermarkets and the growth of e-commerce, there has been an increased pressure within the distribution supply chain to supply products to customers as quickly as possible[1, 2]. In manufacturing, an increase in order picking has been prompted by a move to smaller lot-sizes, point of use deliveries, order and product customisation and cycle time reductions[3]. There has also been an increasing trend towards more product variety and short response times resulting in logistic operations coming under pressure to improve efficiency[2, 4]. The target of filling customer orders within 24 hours is becoming the norm. As a result, distribution centres have no choice but to improve their order fulfilment operations through better planning, storage, picking and routing[1].

Typically, the order picking process involves:

- Clustering and scheduling of the customer orders;
- Assigning stock on locations to order lines (e.g., apples would be assigned to the fruit and vegetables order lines, but not to a wine and spirits order line);
- Releasing orders to the floor;
- Picking articles from the correct storage location;
- Despatch to the customer of the picked articles.

Order picking usually constitutes 50-75% of the total operating costs for a warehouse[3, 5]. It is also one of the most labour intensive of all warehouse processes, representing as much as 60% of all labour activities in the warehouse[2, 3, 6]. Picking activity is becoming increasingly important in supply chain management[2]. Any underperformance in order picking can lead to unsatisfactory service and high operational costs for the warehouse, and the whole supply chain[3]. Between the time an order is released to the warehouse and the time it takes to reach its destination, there are ample opportunities for errors in accuracy and completeness, as well as time lost. As a result, many warehousing professionals consider order picking as their highest priority for productivity improvements[2, 3]. One such productivity improvement the industry has made is that through the use of *parts to person* systems, it is now possible to attain productivity up to 1,000 picks per person per hour[3].

[1] *See Section 6 for a glossary of terms.*

2.3 ORDER PICKING SYSTEM ELEMENTS

Order picking systems (OPS) are complex, so the task of designing them is also complex[(2)]. There are several elements considered at the design stage which include:

- Products (number, size, value, packaging, inventory level and sales),
- Customer orders (number, size, number of order lines),
- Different types of functional areas (case pick for fast moving products, another for slow moving),
- Different combinations of equipment type (within the case picking area for slow moving products, there could be a picker-to-part area),
- Operating polices for each functional area (pick by order, or pick by line).

The design of an OPS may need to take into account differences between functional areas, as OPS owners may want to carry out several types of picking to supply their customers' orders. In this case, different tasks are assigned to separate functional areas, and appropriate equipment and control strategies are specified for each area.

Table 1 lists the parameters that a manager needs to consider when specifying or designing an OPS.

Table 1 Managerial considerations for the design of an order picking system

Parameters
Demand
Items/order
Wave length
Maximum orders/manual pack station
Labour cost/picker
Labour cost/packer
Interest rate
Years of service
Picking standard (manual)
Packing standard (manual)
Annualized cost/pack station (manual)
Picking standard (automated)
Packing standard (automated)
Annualized cost/pack stated (automated)
Conveyor speed
Nominal induction rate
Labour cost/inductor
Annualized fixed cost of sorter
Annualized cost/induction station

2.4 ORDER PICKING SYSTEM CLASSIFICATION

There are a number of decisions that are made in respect of order picking systems[2]. The main four decisions are:

- Who picks the goods (humans and/or machines)?
- Who moves in the picking area (pickers and/or goods)?
- Are conveyors used to connect each picking zone?
- Which picking policy is employed (pick by order or by item)?

The types of order picking systems that can be employed are identified in Table 2.

Table 2 Order picking systems

System	***Description***
Picker to parts	This is the most common order picking system used in warehouses[2, 7]. It can be considered as the basic system for order picking activity. Pickers walk or drive along aisles to pick items to complete a single order, or a batch of multiple orders. The picker immediately sorts picked items. There are low-level and high level order picking types[2]. The advantages of this system are cost reduction (in terms of labour hours and spaces required). This system can create bottlenecks so is preferable where there is a large number of items and a small system outflow.
Low-level picker to parts	In this system, the picker travels between pick slots and retrieves items from picking location that can be accessed from ground level.
High-level picker to parts (also known as Man on-board OPS)	This system uses high-level storage racks, where pickers on board order picking trucks visit picking locations at multiple racking levels.
Pick-to-box (also known as Pick-and-pass).	In this system the warehouse is divided into zones that are assigned to one or more pickers. A conveyer connects picking zones. Boxes filled with picked items are placed on the conveyor. Each box corresponds to a customer order. Customer orders can be picked sequentially zone by zone, reducing overall picker travel time. This method is preferable where item numbers are high, for small size items, medium flows and small order sizes.
Pick-to-sort	Operators in the picking area retrieve the correct total number of each SKU for a batch of multiple orders. These are then put on a takeaway conveyor. A computerised system determines the destination bay for each item. This system usually works with pick waves, where all orders are completely sorted before realising the following pick wave. This system works well where the batch size in constantly high and means that pick slots are visited less frequently, which reduces pickers' travel time.

2.5 ORDER PICKING ACTIVITIES / WAREHOUSE ZONES

The activities that occur in warehouses can be categorised into eight major areas[8].

1. **Receiving area** – where incoming shipments are unloaded and inspected.

2. **Pallet reserve area** – where products are stored and retrieved in whole pallet quantities, without pallet breakdown.

3. **Case pick area** – where products are retrieved in case quantities. Incoming loads and storage units are usually pallets, but may also be cases of 'over packs', which is an outer casing with smaller cartons contained with it, or mixed unit load.

4. **Item pick area** – where products are retrieved in item quantities. Incoming loads and storage units are often in cases, but may also be in totes.

5. **Sorting area A** – where different items of an order are consolidated, if this function is needed, because of orders being split into sub orders for picking efficiency.

6. **Sorting area B** – where the different cases and possible totes from sorting area A, (belonging to one order) are consolidated if required.

7. **Unitizing area** – where the different items, totes, cases, and over packs belonging to an order are unitized, such as into shrink-wrapped pallets.

8. **Shipping area** – where outgoing items are checked and loaded into vehicles.

There may be auxiliary areas where labelling, repacking and processing of returns takes place.

2.6 AUTOMATION AND MANUAL ORDER PICKING

There have been numerous recent innovations in warehouse technology[4]. Automation is often considered as a means of reducing labour costs. However, many companies continue using manual order picking due to the variability in shape and size of products, variability of demand, seasonality of products or the large investments required to automate order-picking systems[5]. Where paperless OPS are implemented, commonly used methods are the use of mobile handheld or vehicle mounted terminals and printers[6] or *pick by voice*. Paperless systems are advantageous, as the activities of both order pickers and operatives putting fresh stock into storage locations are recorded by the warehouse management system. This results in accurate and up to date stock information. Additionally, order pickers can obtain pick and store instructions without leaving the storage area. This leads to reduced errors and increased productivity[6]. Where order pickers have to leave the storage area, the travel time is an increasing function of the travel distance[3]. Reducing the travel distance is often a primary objective in warehouse design and optimisation.

2.7 AUTOMATED STORAGE RETRIEVAL SYSTEMS

Automated Storage and Retrieval Systems (AS/RS) are used for the storage and retrieval of products in distribution and production environments[9]. Automated systems have been widely used since they were introduced in the 1950s[9] and increased significantly between 1994 and 2004 in distribution[9]. This is partly in response to rapidly changing customer demand, small internet orders, tight delivery schedules, high competition and high service level requirements, which has meant that is has been increasingly difficult to maintain a good performance when using existing static solution techniques. As a result, requirements for AS/RS are becoming increasingly dynamic in nature. New models are developed with some degree of future proofing so it is imperative the design is right from the outset. In an *End of Aisle* system, the picker at the workstation takes the required number of products from the unit loads; the AS/RS then moves what is left back into storage[9]. Roodbergen *et al.*[9], identified that little attention has been paid to the relationship between AS/RS and other material handling systems in production or distribution facilities. They advocated the use of an integrated approach when assessing warehouse performance[9].

The advantages[9] of an AS/RS are:

- Reducing labour costs;
- Reduces the requirement for floor space;
- Increases reliability;
- Reduces error rates.

The disadvantages[9] of an AS/RS are:

- High investment cost;
- Less flexibility;
- High investment in control systems.

2.8 WAREHOUSE DESIGN ISSUES

The warehouse design process should run from a functional description, through to a technical specification, equipment selection and determination of a layout[4]. However, there is always the likelihood of a trade-off between conflicting objectives.

The main objectives in warehouse design and optimisation[3] are to:

- Minimise the throughput time of an order;
- Minimise the overall throughput time (from receipt to despatch);
- Maximise the use of space;
- Maximise the use of equipment;
- Maximise the use of labour to achieve more picks per hour;
- Maximise the accessibility of all items.

Figure 1 shows the major functional areas and flow of goods through a typical warehouse.

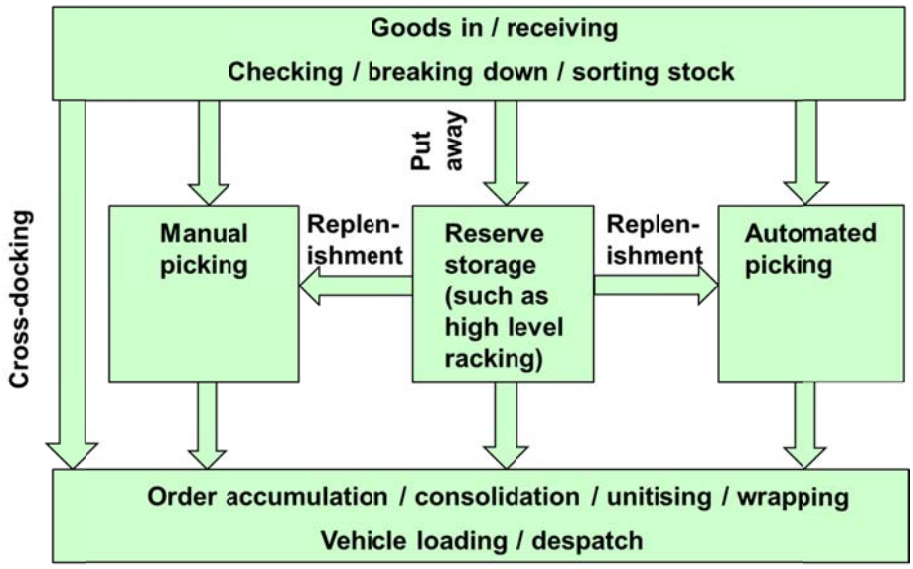

Figure 1 Typical flow through a distribution centre

The need to integrate the different functional areas of a warehouse may result in the need to modify the original system objectives. For example, the capacity of a sorting system may not meet requirements to deal with items coming out from an item pick area. This can change the requirements of the other functional areas, such as sorting and consolidation and despatch. Another example might be that the use of automated equipment in an item pick area may create a requirement for additional space in the case pick area[8].

2.9 ORDER PICKING SYSTEMS

Order picking typically occurs in warehousing, particularly in distribution systems, though it is also important in the manufacturing sector[8]. The purpose of an order picking system is to manage the storage and movement of stock, which is typically very diverse. This process of management provides the warehouse operator with stock control information and allows them to control costs[8]. However, the complexity of the design of these systems and hence the high potential cost, along with the variety of equipment types make it difficult to choose order picking systems[2]. As warehouses become larger, new problems have been studied and new models developed[3]. Many different order picking system types can be found in warehouses[3]. Often, multiple order picking systems are employed within one warehouse. The driving force for most systems is usually a measure of the performance of the system, such as efficient utilisation of storage space, or short system response times[8, 10].

2.9.1 Order picking system parameters

Some of the common decisions companies make on design and control of order picking systems[3] include:

- Layout design and dimensions of the storage systems;
- Assigning products to storage locations;
- Assigning orders to pick batches and grouping aisles into work zones;
- Order picking routing;
- Sorting picked units per order and grouping all picks of the orders.

The main system parameters affecting the layout design are the total length of the picking aisles and the number of pick stops per tour[11]. However, a typical design project for an order picking system area begins by identifying the required size of the area, the appropriate racking (e.g., flow racks, pallet racks or shelves) and the equipment (e.g., order picking trucks or picking carts). Next the layout of the structure is determined, then operating polices are chosen to control the picking process. This process does not always lead to the best possible solution[12] because there is the risk it fails to consider operational constraints and other considerations such as budget and future company growth.

2.9.2 The order picking design process

The order picking design process can be divided into three main phases[2, 8]:

1. Input – managerial considerations (e.g., budget and project life), operational constraints (e.g., total area available, ceiling height and number of shifts) and transaction data on customer order and products.

2. Selection/specification – Selection of features, looking at equipment type (e.g., gravity flow rack and order picking trucks).

3. Evaluation – Quantitative and qualitative reconciliation of the different subsystems. This may lead to further selection and specification.

There has been extensive research carried out into order picking[3], with the focus centred on four main issues that influence the order picking system: storage, batching, routing and zoning. These confirm the three process decisions considered most often[5] which are:

1. How to pick the SKUs;

2. How to store the SKUs;

3. How to route the pickers in the warehouse.

2.10 COMPONENTS OF ORDER PICKING SYSTEMS

2.10.1 Random storage

Random storage, which is the storage of goods wherever there is room, is widely used in many warehouses because it is simple to use, often requires less space than other storage methods, and results in a more equal utilisation of all picking aisles[5].

2.10.2 Order batching

Order batching is the picking of multiple orders in one pass using a consolidated pick list. Of all the process decisions, results suggest that batching orders yield the greatest savings, particularly when smaller order sizes are common[5]. Batching also has the largest impact on reducing total fulfilment time, particularly when small order sizes are common[5]. However, as the batch size being picked increases, the rate at which order pickers are expected to work (the picking standard) will increase but the expected rate at which their colleagues sort and pack the picked goods (the packing standard) will decrease because larger orders require less sorting[13].

2.10.3 Pick routing

The picking area layout has a significant influence on picking travel distance so it is important that time is taken at the design stage to consider the impact the layout will have on travel distance[6]. Picking efficiency is also improved by minimising the total picking time. Usually, there is some administration and process time at each pick location so any reduction in travel time can increase overall efficiency[11].

2.10.4 Zone picking

Zone picking can be compared to an assembly line. Zones within a warehouse are allocated to particular picking activities. This allows multiple types of picking to occur within the same building. Once all items in an order have been picked in a zone, the part order is then passed to the next zone. Also, there may be areas set aside for specific operations that may not involve manual handling, such as wrapping pallets or loading / unloading vehicles. Zoning can also refer to having areas designated for individual employees to work in or where one type of item can be found[14].

2.11 INJURY REDUCTION

2.11.1 Principles for manual handling in warehousing

Table 3 sets out eight key principles for manual order picking in warehousing[15]

Table 3 Eight key principles for manual order picking

- High volume picking and packing should be done predominantly by mechanical means.
- Physical changes to workplace design, layout and plant are more effective than administrative controls to make the workplace safer.
- The Best Working Zone for manual handling activities is between shoulder and knee height.
- High frequency picking and replenishing should occur within the Best Working Zone.
- Heavy objects should be handled within the Best Working Zone.
- No employee should be required to routinely pick, replenish, manually stretch-wrap or palletise objects above their head height.
- Where employees work at height, then the equipment used to raise them must be specifically designed for human loads (e.g., an elevated work platform) and must provide close access to the objects at heights and help ensure protection against the risk of fall.
- Adequate access to objects should be provided when picking, replenishing, palletising and stretch wrapping – so awkward postures are minimised.

2.11.2 Aerobic demands

A study of delivery drivers carrying out manual unloading at delivery sites showed that the relationship between aerobic capacity and subsequent rates of sprain-strain injuries was statistically significant with injury rate decreasing as aerobic capacity increased[16]. These drivers all had similar workloads, so the risk of injury increased as the percentage of aerobic capacity used increased. This suggests that reducing aerobic demands on warehouse workers would tend to reduce their risk of injury. Such reductions could come about through the provision of powered materials handling equipment or the control of the number of manual handling operations required in a lift.

2.11.3 Manual handling aids

The provision of manual handling aids such as order picking forklifts, work platforms, ladders and other equipment are often considered as ways to improve the way employees handle the load (by raising the employees)[15, 17]. The manual handling equipment that is usable in a particular warehouse is determined by the design of the order picking system, so it is useful to establish lists of compatible storage and handling equipment[8]. It is suggested that there should be a specified list of manual handling equipment that can be used in a particular storage area[8].

2.11.4 Suitable heights for manual handling

The *Best Working Zone* for manual order picking is the region between shoulder height and knee height of the picker and without excessive forward reach[15, 17]. It is suggested that the workplace should be designed to ensure employees work in this zone, and provide the necessary equipment to facilitate this[15, 17]. A number of risk factors have been identified such as picking frequency, object weight, object shape and over-reaching[15, 17].

Manual order picking above shoulder height is a high risk activity[15, 17]. Employees are particularly at risk when they:

- Work from floor level to obtain objects stored in pick slots at or above shoulder height.
- Stand on temporary platforms or other items that are not high enough to enable access below shoulder height.
- Compile an order on a pallet that is stacked too high.

Suggestions for injury reduction when reaching above shoulder height include[15, 17]:

- Lowering the goods;
- Raising the employees;
- Reducing object size and weight;
- Reducing picking frequency and duration;
- Moving good forwards.

Manual order picking below knee height is a high risk activity[15, 17]. Employees are particularly at risk where:

- Shelving may require employees to bend awkwardly to reach objects.
- In walk-in bays, rules such as 'Don't stand on pallets' may require the picker to over-reach.

Suggestions for injury reduction when reaching below knee height include[15, 17]:

- Raising the height of the work;
- Bringing the work to the employee;
- Reducing object weight and size;
- Reducing picking frequency and duration with work rates, based on consultation and improving access to the rear of the pallet racking beam.

Holding an item close to the body when lifting can also reduce injury[15, 17].

One solution that is sometimes used involves raising the picker to the work point to enable them to pick within the knee to shoulder region. This may involve the use of equipment such as order picking forklifts, work platforms, or ladders[15, 17].

All these methods increase the risk of injury due to falling from height, and some methods are safer than others. In particular it should be remembered that[15, 17]:

- The higher the person when they fall, in general the more severe the injury; however fatalities have occurred with falls from low heights;
- Risk increases with frequency of exposure to work at height;
- Work platforms are better than ladders;
- Work from floor level is best of all.

2.11.5 Working practices

Warehouse management practices (such as setting work rates, shift lengths including overtime and use of engineered standards or bonus systems) must not promote excessive work rates, poor manual handling or discourage the taking of appropriate breaks[15, 17].

3. INDUSTRY PERSPECTIVES

3.1 METHOD

In order to validate the information gleaned from the search of existing literature into order picking systems, six telephone interviews were conducted with industry stakeholders. The purpose of these interviews was to review the order picking systems used by picking warehouses and to determine the factors that influence the system design and the amounts and types of manual handling that occur in such locations. The interview question sets can be found in Appendix 1.

A thematic analysis was carried out on the data to identify any common factors shared by the participants. Short summaries of the interviews with the industry stakeholders can be found in Sections 3.4 and 3.5 and 3.6.

3.2 THE INDUSTRY STAKEHOLDERS

The industry stakeholders were chosen because they used, designed or supplied order picking systems and consisted of representatives of:

- Two large retailers – i.e., the end users of the systems;
- Two system specifiers;
- Two system suppliers.

3.3 OVERVIEW

Despite only a small sample of industry perspectives being collected, the industry stakeholders have come from organisations that have a significant involvement with the warehousing industry. Obviously, their views need to be treated with some degree of caution because of the sample size. However, they offer an insight into the different aspects of the industry and share some similar views about the direction the industry is heading in and the impact of increasing automation. This is most noticeable in their appraisal of the influence of internet or e-commerce on order picking systems. There is also some suggestion that regardless of an increase in the use of automated systems, the human interface is still an important element of any solution and this is born out in the literature. Some tasks, such as off-loading lorries, cannot be carried out successfully by machine because of the variety of sizes, weights and shapes of items that need to be off-loaded. The volume of items at certain times of the year, particularly during peak holiday periods also requires additional manual handling from pickers and packers as automated systems may struggle to replenish fast moving goods. With order picking normally representing as much as 60% of all labour activities in the warehouse[2, 3, 6], there will invariably be additional physical demands placed on order pickers and manual handling operations at peak times.

In addition, the specifiers have suggested that as internet business increases its share of the retail market, there will be a return to manual order picking and therefore more manual handling operations. The scales of some of these operations have the potential to become vast although currently there is nothing in the literature that indicates how businesses may respond to this. It is clear that a major consideration when deploying either a manual or an automated order picking system is keeping labour costs down whilst increasing productivity. Therefore, a balance will need to be found that does this while maintaining the health and safety of the workforce.

3.4 THE RETAIL PERSPECTIVE

- The types of manual handling aids used depends on the site and include palletisers, pallet trucks, forklift trucks, roll cages, hanging rails, overhead conveyor belts and cranes.
- Training is provided to operatives involved in manual handling tasks but there tends to be a weight limit placed on what can be lifted by one, two or more people.

The two UK retailers interviewed (see Table 4 and Table 5 for site details, products on site and order picking systems), suggest that the boom in e-commerce and internet shopping may be having an impact on the types of order picking systems that are used within their distribution centres. They are now handling larger numbers of items and in order to meet the demand for white goods they were also importing more items. These items arrived in containers that meant operatives had to be specifically trained to empty the containers and handle the white goods. One of the retailers remarked that historically, operatives were expected to open shipping cardboard cartons with safety knives but that over the past 18 months a system has been developed so that the cartons could be opened without damaging stock. Whilst there is still a mix of manual and automated systems in operation, increasingly they are looking for more automated systems and exploring ways of designing out tasks that cause harm to operatives. However, this means that by default fewer people are working in distribution centres and fewer still involved in manual handling operations. An example was given of a distribution centre with a high bay layout where cranes automatically pulled pallets. The conveyor was also automated so no humans worked in the area unless there was a blockage. Another example was of shrink-wrapping machines being used to wrap pallets of plastic tubs, thus reducing the manual element of the task. Both retailers remarked on the reduction in the number of manual handling issues they were faced with, with one noting that manual handling injuries had been reduced by approximately 46% in the last five years. It was envisaged by both retailers that the industry would continue to seek ways of automating all aspects of the order picking process.

3.5 THE SYSTEM SPECIFIER PERSPECTIVE

- The types of manual handling aids used may vary depending on the site. The forklift truck industry has developed trucks capable of picking pallets from ground floor level. *Narrow aisle order picking trucks* allow pickers to be lifted up to 12 m to pick items from high racking locations.
- One of the specifiers suggests that in designing out manual handling from order picking systems they have neglected "*…the stress placed on order pickers by implementing unfactored productivity targets that not only lead to operatives cutting health and safety corners to increase productivity but have created the new 'hidden injury' to their workers' mental health*."

According to the specifiers (see Table 6 and Table 7), their clients are looking for a significant return on investment on any capital investment they make. They also identified that often clients may make compromises about their choices to satisfy their marketing strategies or because too radical a change to the order picking system may make their Board members unhappy. The specifiers were aware of the manual handling issues associated with order picking systems but it was acknowledged that "*…order picking systems are productivity driven…"* so in the main, reducing manual handling injuries could be seen as a by-product of increased automation rather than a driver for increased automation.

As the specifiers might have some insight as to the direction the industry is headed they were asked how they saw order picking systems changing in the future. The growth in online shopping was seen as a factor that might decide the level of automation in the industry. However, one view was that because automated systems are expensive to maintain, some businesses may revert back to manual picking systems because it could give them more flexibility in relation to cost against volume.

3.6 THE SYSTEM SUPPLIER PERSPECTIVE

- Ergonomic solutions can drive up the price of the system so clients may opt for solutions that still require operatives to bend and pick up albeit within existing health and safety regulations.
- The growth of internet shopping and the variety of SKUs that clients need to supply means that clients may return to manual picking and packing operations as a way of building in flexibility to meet the demand.
- One supplier suggested that peak holiday periods such as Christmas may increase the manual handling demands placed on pickers/packers in some operations.

One of the suppliers was based in the UK; the other was based in Europe. According to them (see Table 8, Table 9, Table 10 and Table 11), the internet has changed the way businesses are operating and the supplier provides a range of solutions to meet the varying demands of its client base. Voice picking and radio frequency terminals (RFID readers or bar code scanners) are the most common type of system requested by clients although one supplier considers these to be entry-level systems. The growth in internet business has also led to multiple items for one customer being consolidated into one package in response to customer demand. The growth in internet shopping also means that there will be periods of peak demand, particularly holiday periods when the manual handling demands placed on pickers/packers in some operations will increase. One supplier suggested that as more internet businesses have to carry a variety of items to enable them to become a 'website of choice' they require a more flexible system which can be provided by using operators rather than relying wholly on machines.

Systems that are designed with ergonomic solutions that are built in tend to be more expensive, and hence their adoption depends on client attitudes. The latter can be, according to one supplier, correlated with international location.

Automated systems supplied to clients tend to be conveyor-based, with split case picking which involves operators picking individual items to make up an order or full case picking which is usually required for supermarkets.

One supplier provides clients with method statements for automated order picking systems so clients are aware of how they should gain access to machinery in case of a breakdown. Noise is also a consideration when supplying equipment and the supplier has to take into account the different requirements clients may have to meet their country's health and safety standards.

4. DISCUSSION

The purpose of the literature review was to provide the lay reader with an overview of how order picking systems operate and the amount of manual handling required. However, it is clear from the research that when it comes to the assessment of manual handling practice within warehouses and distribution centres, there needs to be a broader appreciation of the business decisions, equipment design and task design that lie behind this. What makes this more complex is the variety of order picking systems available, each type requiring different amounts of manual handling. Automated systems are capital intensive and manual picking systems are labour intensive and each have their own issues for the human operative. Whichever system is installed, it should not compromise the health and safety of the worker

Systems that require workers to travel between pick slots inevitably have lower rates of manual handling than systems that bring containers of items to a packing workstation so the picker remains in the same location. Paper-based systems are also slower as the picker has to handle and read the paper, whereas if picking instructions are given by a *pick by voice* system, this task is eliminated. Systems, such as pick to light, that indicate automatically where the picker can expect to find the next item to pick, are also quicker because they eliminate the task of finding the correct pick slot. Systems where the picker travels on a powered truck as opposed to walking with a hand pallet truck or roll cage will also either speed up the picking task or allow the picker to travel further between pick slots in the same time.

4.1 LITERATURE REVIEW

The review has identified a number of key factors that influence the type of order picking system put in place. One of the major factors is the increase in internet shopping which leads to increased competition, not just within the UK, but also across the globe. In order to retain their competitiveness, companies are constantly seeking ways of driving down their overheads which for the most part will be achieved by increasing productivity, especially as labour represents a significant proportion of their costs. Customers are demanding quicker delivery times, and with just in time ordering, the need to move stock through the warehouses and distribution centres in short timescales puts additional pressures on the order picking systems, pickers and packers. Supermarkets are opening more small-format stores as well as the large superstores. These need smaller volumes of each line stocked, meaning that each delivery pallet or roll cage carries a wider variety of items, making the task of assembling each order more complex.

The order-picking process itself requires a high degree of accuracy. Ordered items need to be available and the system needs to ensure that items that go missing from orders are kept to a minimum. The same goes for minimising substitutions of items or the despatch of incorrect items. The orders have to be sent out on time, so there is little give in the system, so the picker needs to have a streamlined interface with the automated system that reduces manual handling. If a *picker to parts* system is in place then the speed at which the picker must travel between pick slots is a key parameter. Problems with ensuring that the correct amount of stock is available in the pick slot when the picker arrives will lead to productivity problems, as pickers will have to wait for the correct stock or request that a colleague makes good any shortfall before the order is despatched.

The types of products being handled by an order picking system can vary in size, and again the growth of internet shopping has seen an increase in the size of items, e.g. furniture, white goods, being despatched directly to customers. Automated systems are efficient at handling small items. Larger items may need to be handled manually. Very large items may require material

handling equipment such as fork lift trucks or overhead travelling cranes. Even within broad size ranges, the systems need to be able to be flexible enough to cope with variations in the sizes and shapes of goods. However, even with the drive to increase the use of automation to improve productivity, manual picking still has advantages so will continue to be used.

There has been a trend over time to move from paper-based picking systems to paperless systems. The recent trend has been to install *pick by voice* systems rather than *pick to light* systems. Warehouse design issues are often overlooked. It is not unusual for areas to be split into zones using different picking processes which will have different manual handling requirements.

Warehouse temperature is also an issue because of the need to control the temperature for certain kinds of stock. Some limited life products need to remain chilled at between 0-4° C. Frozen stock has to be kept at -20° C. The need for pickers to wear extra clothing to keep themselves warm in these environments can restrict their ability to carry out manual handling operations. Workers operating in both ambient temperature and colder areas will need to adjust their clothing as they move between these zones.

The volume of stock if not handled efficiently may result in it being stored in such a way that does not lend itself to best practice in manual handling. For instance, the *Best working zone* for picking is between knee and shoulder. Bending down or reaching up will increase the likelihood of the operative developing musculoskeletal problems. Whilst the provision and use of manual handling aids can help, best practice is to keep goods at a height within the best working zone. Depending on the storage system in use, it may be possible to store slower moving lines outside the best working zone, while keeping the faster moving stock within it.

Job organisation practices will also have a bearing on manual handling practices. To increase productivity, workers may have pick targets and may also have some form of reward system such as a bonus/incentive scheme to speed the work rate. At certain holiday periods, such as Bank Holidays and Christmas, shifts may increase in length which puts more physical demands on the workers. Some things that can help reduce some of the impact on the worker may be to encourage job rotation, multi-skilling and manual handling training.

4.2 INTERVIEWS

The interviews with two retailers, two specifiers who design different types of order picking systems and two system suppliers, has provided some useful insights into the industry as well as reinforcing what we learnt from the literature. The impact of internet shopping and the resultant return to manual picking because it can provide greater flexibility than a fully automated system was stressed. Small orders of certain types of goods can be processed more easily in manual system. This can also be true for more complex activities such as dealing with returned goods. Some internet shopping channels, such as clothing, tend to generate high levels of returns. The interviewees thought that while increasing automation would reduce manual handling, smaller operators may still choose manual systems due to lower capital costs. There was also an acknowledgement that ‘ergonomic’ solutions can drive up the cost of a system.

4.2.1 Retailers

The two retailers identified a number of issues that require them to think carefully about manual handling. The lack of sufficient warehouse space often means that they are constrained when deciding what type of system they can put in place and sometimes the decisions they have to make require different manual handling solutions. They put weight limits on items and/or

containers used to handle multiple items, but they still require manual handling on the part of the operatives. The increased use of home delivery by customers has also meant that workers have to work with heavier items. Weight is not the only issues as stock can often be placed on over-height pallets and shipping containers from overseas may be filled to the roof.

4.2.2 Specifiers

The two specifiers identified other issues that have an impact on manual handling within warehouses and distribution centres. Their customers tend prefer *pick by voice* over arm/wrist mounted terminals. They suggested that bulk storage systems without racking and fork lift truck clamps systems would not be recommended due to issues around falling stock and manual handling. In addition, the use of *man up* high reach trucks can require the worker to reach and twist to pick from high level racking, exposing them to increased risk of low back pain.

4.2.3 Suppliers

From the suppliers' perspective, the manual packing of orders, especially those for internet shopping presents the most manual handling issues. There is usually a maximum parcel weight for shipping to internet customers and small items tend to be manually consolidated into a single package. The manual unloading of lorries in the warehouse *Goods In* area also presents some challenges, as does the decanting of tall pallets. Other issues raised by the suppliers included pick slot replenishment, and the variability of package sizes which often worked against automation or using handling aids. The warehouse managers may be happy for workers to bend and pick up stock rather than invest in pallet lifters to eliminate manual handling near the floor.

4.3 CONCLUSIONS

The factors that influence the amount of manual handling within warehouses and distribution centres are complex and inter-locking. The key factor is the design of the order picking system, particularly how much automation is used and whether pickers travel between pick slots or whether items are automatically delivered to them. It also depends on the nature of the goods that the warehouse handles. There are financial trade-offs between high capital costs of automated systems, and increased labour costs in manual systems.

Levels of activity vary within warehouses and distribution centres due to seasonal and other factors. If staffing levels remain constant this will impose additional physical and mental demands on the staff, which may result in increased sickness absence, injuries, accidents and near misses during busy periods.

Often weight limits are placed on individual items, on containers such as tote boxes and on weights of packages being despatched. Controls to implement these limits may include automation, the use of manual handling aids, or team handling. Also, training in manual handling techniques is often provided to operatives involved in manual order picking. Poor manual handling practices may be evident in warehouses where high levels of productivity are expected of pickers.

Recent trends in retail towards internet shopping, home delivery and small format supermarkets are all affecting manual handling practices in distribution warehouses.

In large-scale internet operations, automated order picking systems cannot cope with the frequency that some items/goods are ordered so many retailers are relying increasingly on manual order picking.

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6. GLOSSARY

Aerobic capacity	This is the maximum amount of oxygen the human body can use during a specified period, usually during a period where a strenuous activity is being carried out.
Automatic Storage and Retrieval Systems (AS/RS)	AS/RS is a system of rows of racking, each row has its own retrieval unit that moves vertically and horizontally along the rack picking and putting away loads. These systems can store products up to 100 feet high.
Batch picking	Multiple orders are grouped into small batches and the order picker will pick all the orders within the batch in one pass using a consolidated pick list. This method reduces travel time but can result in mixing of orders if the appropriate systems and checks are not in place to prevent that from happening.
Best Working Zone	For manual handling activities this is the region close to the body between shoulder height and knee height. This avoids the order picker having to reach forwards large distances or having to bend or stoop to reach low items or having to reach upwards to access high items.
Case picking area	This is an area is where full boxes or cases of items are picked, rather than subunits from inside the cases.
Cross dock warehouse	A warehouse layout where the goods-in area is on one side of the building, the despatch area is on the opposite side of the area and any storage and picking of SKUs happens between these two areas.
Cycle time	This is the amount of time it takes to get an order from order entry to the point of despatch.
Flow racks	These are slightly sloping tracks that use gravity to move goods (pallets bins, totes, cartons) to the pick face.
Goods to person picking	In this system, containers (e.g., totes) are transported automatically to a picking station where the picker retrieves the correct quantity for the order. High pick rates can be achieved, as the person does not spend time travelling between pick slots.
High level picker to parts	This is a type of picking where the order pickers uses a high-level order picking truck to visit picking locations in the upper levels of high level storage racks.
Low level picker to parts	This is a type of picking where the order picker travels to picking locations that can be accessed from floor level.
Man down reach truck	A high reach truck where the driver stays at the level of the truck body as the mast and forks are raised.
Man on board OPS	This is a synonym for *High level picker to parts*.
Man up reach truck	A high reach truck where the driver is lifted as the mast and forks are raised.
Manual pack station	This is a workstation in a warehouse where items are packed manually, ready for despatch.
Narrow aIsle Order Pickers	High level reach trucks designed for use in Narrow Aisle (2.4 m

(NIOPs)	wide) warehouses.
Nominal induction rate	This is the minimum number of items that are introduced into the order picking system at any one time (usually per hour).
Order picking	The process of selecting SKUs to fulfil an order from a customer.
OPS	Order Picking System.
Outflow	This is the rate at which items leave the warehouse.
Packing standard	The rate at which workers are expected to work when sorting previously picked goods and then packing them into orders for despatch.
Pallet racking	Pallet racking is a material storing system that stores items on pallets at multiple levels.
Pallet reserve area	This is an area is where products are stored and retrieved in whole pallet quantities, without pallet breakdown.
Picker to parts	This is the most common order picking system used in warehouses. It involves order pickers walking or driving along aisles to pick items to complete a single order or a batch of multiple orders.
Picking frequency	Picking frequency relates to the number of times an item shows up on the order lists. Items that are requested more regularly tend to be sited close to the starting point to reduce the travel distance for the order pickers.
Picking standard	The rate at which order pickers are expected to pick items.
Pick and pass	A system of order picking where picked items are placed in a box or on a pallet which is then passed to another picker in a different warehouse zone to add to the order.
Pick by line	A system of order picking where a picker transfers stock items from a single SKU or product line to multiple orders. This process is then repeated for the next product line. This system is effective for high volume products. It is also effective in cross-dock systems, especially when all items arriving at goods-in are expected to be transferred to the loading area without being held in a stock area.
Pick by voice	A system of order picking where picking instructions are transmitted to the order picker by a computer generated voice and which uses voice recognition software to identify responses from the picker. Often it requires the picker to wear a headset with earphones and a microphone.
Pick face	This is the edge of a pick slot where the picker is expected to pick the next item. When depalletising it will move as the pallet is emptied.
Pick list	A list of items that need to be picked to fulfil a customer order, or a list of items that an individual is expected to pick. Traditionally pick lists were printed; in current systems they may be displayed on computer terminals or screens, or a *pick by voice* system may be used to interact with the picker.
Pick slot	A pick slot is a warehouse location where stock of a SKU is placed for pickers to retrieve. In a racking system it will often be the allocated space for a stock pallet.

Pick to box	This is a synonym for *Pick and pass*.
Pick to light	This is a picking system where a light or display above each pick slot indicates the next line to be picked and the number of items needed.
Pick to sort	This is a picking system where order pickers retrieve multiple items of a SKU to meet several orders. The items are then sorted into the correct orders.
RF systems	A Radio Frequency system communicates between the computer terminal the picker uses and the central warehouse management system.
RFID	'Radio Frequency Identification Device': This is a data collection technology using electronic tags for storing data. The tag is made up of an RFID chip attached to an antenna that transmits data when interrogated by an RFID reader. RFID tags do not require line of sight to the reader, so do not need to be visible.
Productivity	Productivity in order picking is measured by the pick rate.
Stock Keeping Units (SKUs)	'Stock keeping units' are unique units or items of stock, usually with a unique identifying number or code.
Unitizing area	This is an area in a warehouse where the different items, totes and cases, and over park belonging to an order are unitized, such as into shrink-wrapped pallets.
Warehouse Management System (WMS)	This is a computer system that processes incoming orders, monitors stock levels, assigns picking activities to individuals and schedules goods inward and goods out activities.
Wave-length	This is the distance covered by the picker while fulfilling one order.
Wave picking	This is a system of picking where pickers pick from all the zones and then the items are sorted later and consolidated into individual orders.
Zone picking	This is a system of picking where the picking area is separated into discrete pick zones and order pickers pick within a zone, not across the whole warehouse.

7. APPENDIX 1 – INTERVIEW SCHEDULES

Factors in order picking systems that influence manual handling
Questions for System Managers

SITE DETAILS

Can you classify your site?
- Distribution centre?
- Warehouse?
- Other storage? If so, what?

What kind of layouts are used on site?
- Racking?
- Roll cages?
- Pallets?

How long does stock typically stay on site?
- 0-8 hours?
- 8-24 hrs?
- 4-7 days?
- 7 days or more?

How does stock move through the warehouse/distribution centre?

PRODUCTS ON SITE

What kind of items are held on your site?

Can you give me an idea on the minimum and maximum item weight?

What is the value of the items handled?
- Min?
- Max?

How often are products damaged as a result of handling / movement on site?

Most common type of damage?

ORDER PICKING SYSTEMS

Can you tell me what order picking system you use?
- E.g., Headset?
- Wrist mounted?
- Pick to voice?
- Paper?

Can you tell me <u>why</u> this system was selected, and <u>when</u>?

What type of information is provided to the picker?
- E.g., Item?

Location?
Quantity?

Can you tell me why this system was selected?
E.g., Cost?
Efficiency?
Improved health and safety?
Reduce manual handling?
Damage reduction?

Can you describe in more detail, how the features you just described have played a part in the order picking system?

Do you know if any compromises were made when selecting this system?

What improvements could be made to your current system?

What are the benefits of your current system?
Can you describe in more detail or provide examples?

If you were selecting a new system, can you tell me what factors would influence your selection criteria?
And why
Examples? Detail?

What is the role of the workforce / human in the picking process?
Details

What are people asking for that they weren't 5 years ago?
How have things changed

How do you see order picking systems changing in the future?
Especially in terms of manual handling & technology

MANUAL HANDLING

Can you tell me about the manual handling on site?

What manual handling aids are used for order picking?

Are any specific manual handling aids required with the current order picking system?
E.g., a specific type of hand truck that allows displays to be attached?
Fork trucks that are compatible with certain technologies?

What mechanical handling equipment is in use?
Powered trucks?
Robots / automated removal?
Conveyors?

Is there anything else you would like to tell me about order picking?

Especially manual handling / human involvement

Factors in order picking systems that influence manual handling
Questions for System Specifiers

Can you tell me about your clientele?

Type of industry?
Distribution centre? Warehouse?
Other storage? If so, what?

What kind of layouts are used on the sites you are involved with?

AND what is the most / least common?

Racking?
Levels?
Roll cages?
Pallets?

What is the most common use for the systems you provide?

What is the product in most demand by your clientele?

Why do you think that is?

Can you tell me how your services work?

ORDER PICKING SYSTEMS

Can you tell me what order picking system you recommend most frequently?

AND why?

E.g., Headset?
Wrist mounted?
Pick to voice?
Paper?

Can you tell me what order picking system you recommend least frequently?

AND why?

Can you tell me what clients are looking for in a new order picking system?

AND why?

E.g….
Reduced cost?
Efficiency?
Improved health and safety?
Reduced manual handling?
Damage reduction?
Improved use of space?
Reduction in transport costs?
Improved picking accuracy?
Reduced labour costs?
Reduced stock levels / improved stock management

Can you describe in more detail, how the features you just described have played a part in the order picking system?

What compromises do you have to make in recommending order-picking systems?

What improvements would you make to the order picking systems you currently provide?

AND why?

If you were designing a new system, can you tell me what factors would influence your selection criteria?

And why?
Examples? Detail?

What is the role of the workforce / human in most picking processes?
Details

What are people asking for that they weren't 5 years ago?
How have things changed?

How do you see order picking systems changing in the future?
Especially in terms of manual handling & technology

MANUAL HANDLING

Can you tell me about the manual handling in order picking systems?

Are there any specific manual handling aids required that need to be supplied with the order picking systems?
E.g., a specific type of hand truck that allows displays to be attached?
Fork trucks that are compatible with certain technologies?

Is there anything else you would like to tell me about order picking systems?

Especially manual handling / human involvement

Factors in order picking systems that influence manual handling
Questions for System Suppliers

Who are your order picking systems aimed at?

Why?

Can you tell me about your clientele?
- Type of industry?
- Distribution centre? Warehouse?
- Other storage? If so, what?

What is the most common use for the systems you provide?

Can you give me an idea on the minimum and maximum item weight your systems can cope with?

What is the product in most demand?
- Why do you think that is?

ORDER PICKING SYSTEMS

Can you tell me what order picking system you provide?
- E.g., Headset?
- Wrist mounted?
- Pick to voice?
- Paper?

What type of information is provided to the picker?
- E.g., Item?
- Location?
- Quantity?

Can you tell me what clients are looking for in a new order picking system?
- E.g….
- Reduced cost?
- Efficiency?
- Improved health and safety?
- Reduced manual handling?
- Damage reduction?
- Improved use of space?
- Reduction in transport costs?
- Improved picking accuracy?
- Reduced labour costs?
- Reduced stock levels / improved stock management
- DETAILS!

Can you describe in more detail, how the features you just described have played a part in the order picking system?

What compromises are made in designing an order picking system?

What improvements could be made to your current systems?

What are the benefits of your systems?
Can you describe in more detail or provide examples?

If you were designing a new system, can you tell me what factors would influence your selection criteria?

And why
Examples? Detail?

What is the role of the workforce / human in the picking process?
Details

What are people asking for that they weren't 5 years ago?
How have things changed

How do you see order picking systems changing in the future?
Especially in terms of manual handling & technology

MANUAL HANDLING

Can you tell me about the manual handling in your systems?

Are there any specific manual handling aids required with your order picking systems?
E.g., a specific type of hand truck that allows displays to be attached?
Fork trucks that are compatible with certain technologies?

Is there anything else you would like to tell me about your products?
Especially manual handling / human involvement

8. APPENDIX 2 – PERSPECTIVES OF RETAILERS, SPECIFIERS AND SUPPLIERS

Table 4 Perspectives of Retailers – Site and Systems Information

	Site details	*Layouts/systems used on site*	*The stock*	*How the stock moves around the site*	*Damage to products*	*Information provided to the picker*	*System selection and the compromises that need to be made*	*Benefits of current system*
Retailer A	A workforce of tens of thousands full and part time employees and distributes to over 1,000 retail outlets in the UK and Ireland. It has multiple distribution centres, run either in-house, or by third parties.	Conveyors, racking including parallel and pallet racking, palletisers, high bay.	The type of stock varies from the size of a piece of jewellery to the size of a large piece of furniture. There is an expectation that there will be a quick turnaround of stock but it depends on the type of goods. Food and plants will go through very quickly but other continuity lines can be much longer. The maximum weight they handle in stores is 25 kg. However, if the stock is over this weight, they will usually rework the packaging to bring the weight down. Heavier items are home-delivery only.	The company uses cages within their stores and totes for some small pick items. Danish trolleys are used for plants, cages for cardboard, and ottos and pallets for larger stock.	There is significant damage to products although it is mainly confined to packaging/boxes. Although the content is not damaged, customers are reluctant to accept goods contained in damaged packaging.	The picker is given information on location and item code. The information can either be on a voice or paper pick list which will say how many items they can carry and whether they will require a trolley. Every product has a weight and centre of gravity so the information will also indicate whether the items require a 1 or 2 person lift.	The selection criteria depend on the product and the demand of the system. The criteria vary, but the company is currently investing in voice pick because this system is efficient and needs less space. There have been some compromises in the selection of the system particularly in the older warehouses where they were limited by the layout until they were ready for refurbishment.	The current system allows for innovation. It is flexible, fast, efficient and cost effective.
Retailer B	Employs several thousand people and they have warehouse distribution centres in 13 sites across the UK. It distributes goods to over 500 retail	Boom conveyors, racking system, picking trolleys and pallet trucks.	The company stocks small packaged food but also stocks clothing, home wares and furniture, so the amount of time the stock stays on site varies. The maximum weight of items processed through the site is 90 kg.	Stock moves around the site via conveyors. For certain items of stock, manual picking trolleys are used in addition to pallet	Returned products range from soiled clothing, through to broken mirrors and other home ware items. To deal with the issues created by these types of	In any one warehouse there can be up to 100,000 product lines. The information the pickers receive tells them which line they are should pick next. Additionally, information about the size, shape, numbers required etc., of the item comes up on a	The pick by line operation has largely come out of an operational intent to avoid building additional warehouses or using square footage on the ground. The safety team, who have been able to	The company has seen a significant reduction in manual handling issues. Some of the reduction is due to automation and also to the manual handling

	Site details	*Layouts/systems used on site*	*The stock*	*How the stock moves around the site*	*Damage to products*	*Information provided to the picker*	*System selection and the compromises that need to be made*	*Benefits of current system*
	stores and has over two million customers who order over the internet.			trucks.	returned goods, the retailer has a specific returns warehouse.	computer screen in front of them. Voice-to-pick systems provide pickers with a guide to the most effective route, location and description of the stock to be picked.	build a strong business case for this, has also influenced the selection of the pick by line system, built on the reduction of manual handling operations.	training the company provides. All in all they have seen 'massive operational efficiencies'.

Table 5 Perspectives of Retailers – Site and Systems Information (continued)

	What systems are people asking for that they weren't 5 years ago?	*How are order picking systems likely to change in the future*	*What is the role of the workforce/ human in the picking process*	*Manual handling on site*	*Are any specific manual handling aids required with the current system?*	*What manual handling equipment is in use?*	*Additional comments about order picking, particularly manual handling/human involvement.*
Retailer A	No direct comment to this question but retailer has said that there has been a drive to become fast, efficient and cost effective so constantly looking at ways to improve. Particularly, ways in which to handle increased numbers of containers being brought in from the Far East.	Improvements are constantly being made and the retailer currently has nothing new to add to the wish list. Order picking systems need to be able to lift products and there needs to be an available workforce to do the tasks required. The retailer expects there will be more automation which will take individuals out of the process. This is not feasible in stores but in distribution centres they will become more automated.	The workforce carries out a variety of tasks such as driving forklifts, walking.	Manual handling takes place in stores, distribution centres and warehousing. A store is just a mini-warehouse. In one side of their business they use forklifts in their DIY stores and in the other part they do not. However, they noted that in the last 5 years there has been a 46% reduction in manual handling injuries.	The retailer gave no specific examples other than to say that "all of them" were used.	Aids used are determined by the type of operation in use, what is required and whether the trader/supplier has told them if there is a manual handling issue with any items they supply to the retailer.	There has been an increase of white goods in stores which means more containers have to be emptied. Individuals are given specific training at each site to handle these items. In their high bay system all cranes automatically pull pallets so there are no humans in there. The conveyor system is automated, so unless there is a blockage the workers do not enter. The design of order picking systems is very complex. The retailer has experts to look at the systems. Different products make it complex and the quantities that are being move around add to the complexities. They have 5,000 new products, 20,000 products on line and 30,000 different products go through the system.
Retailer B	Historically operatives were expected to open cardboard shipping cartons with safety knives. However over the last 18 months a system has been developed so those can be opened	In warehouses there will be little human interaction. In one of the most up to date warehouses there is already stock movement from an automated stocking area into a	The retailer did not give a specific answer to this question	In a standard box warehouse manual handling will be the emptying of shipping containers. They use a boom	Picking trolleys, pallets and training is provided. There is a nominal use of roll cages but they are used in a different way to supermarkets. The robotic system puts the stock into roll cages which are then moved around the country. In	The significant elements are that pickers use plastic tubs, so once they are full they have to be lifted off the trolley onto a conveyor. Therefore, in a voice picking operation pickers are trained in the safe way to lift, and	In furniture and homeware departments where there are heavier goods, teams of 2 or 3 people are used to lift goods.

	What systems are people asking for that they weren't 5 years ago?	*How are order picking systems likely to change in the future*	*What is the role of the workforce/ human in the picking process*	*Manual handling on site*	*Are any specific manual handling aids required with the current system?*	*What manual handling equipment is in use?*	*Additional comments about order picking, particularly manual handling/human involvement.*
	without damaging stock. Technologically software is looking at statistics to improve efficiencies and "*if we feel we can design jobs out that are causing harm to people…the job disappears and a robot takes over*".	forward pick station and it is all done by robotic pallet trucks. Fewer people are likely to be involved in the operation so people will have a more skilled role in keeping the operation moving.		conveyor which has a work platform so the workers do not raise or lower themselves, so they do not have to take items down from height.	a hanging garment warehouse they have hanging rails, overhead conveyor belts with jets that employees hang stock on and that can move the whole stock of hanging garments around without anyone carrying them.	the weight limit of the tub is 16 kg. Shrink wrapping machines are used, so pallets of plastic tubs can be wrapped which removes manual handling. Where there are no automated boom conveyors there are mobile conveyors.	

Table 6 The Specifier Perspective – Site and System Information

	Type of clientele	*Types of layouts used*	*Commonly used systems*	*Product most in demand by clientele*	*Order picking system recommended most frequently*	*Order picking system recommended least frequently*	*What are clients looking for in a new order picking system?*	*What compromises have to be made in recommending order-picking systems?*
Specifier A	Fast moving consumer goods.	Narrow aisle racking (2.4 m) and wide lane (3.5m) solutions. From 5 to 15 levels high (up to 15 m). Uses roll cages mostly in food/supermarket distribution centres. Also bulk distribution (bulk to pickface replenishment – picking systems).	Store/e-commerce order fulfilment picking (WMS) Warehouse Management Systems.	Clients demand the best in class WMS because this system gives them the management information they need to help them achieve stock accuracy and improve pick accuracy. They also demand this system to improve operative productivity.	Headsets are recommended for picking accuracy as multi-language systems can be used for non-UK workers, e.g., Polish. Wrist mounted systems were used but withdrawn by many operators due to injury claims from operators and their insurers. However, a new light-weight device has been introduced and is used in the industry by mainly narrow fork lift truck order pickers. Paper systems are rarely used in modern retail warehouses and are more of a manual backup system.	Bulk storage systems (without racking) and order picking systems using fork lift truck clamps (e.g., for domestic appliances and larger item storage). The reason they are recommended less frequently is because of health and safety issues related to products falling from height and ergonomic issues related to lifting and loading.	Clients are looking for: • A Return of Investment on capital expenditure within three years. • Improvements to operative productivity, picking accuracy and health and safety. • Ways to reduce damage usually through cubing systems that involve load and volume planning. • Improved space utilisation of 40% that can be achieved through a WMS. • A reduction in transport costs by improving load-planning functionality. Overall, the new order picking system can reduce labour costs, which is the main return on investment.	Compromises tend to be made for the sake of fire regulations, planning constraints and insurers recommendations.
Specifier B	Food, clothing and hardware are the three main areas.	The layouts vary customer by customer. The layout can be a goods-in area into bulk storage, out of bulk into picking and despatch.	More business is direct to the consumer with internet shopping. Stores pick and despatch straight to the customer rather than to a	The specifier provides a system to suit customer requirements so it is difficult to say what product is most in demand, as it could be anything from a mini-load to a	The specifier tailors solutions to meet the needs of the customer. However, examples were provided of portal gantry systems for bread-baskets, pallet rise systems for a clothing retailer. For the last three years voice has been chosen consistently as you can train	Pick-to-light has now been superseded by voice pick.	Clients are looking for a range of savings when investing in a new order picking system. Reducing labour costs is the biggest and easiest way of achieving savings as is footfall savings and picking accuracy. Space is also important as is damage reduction but for that you would need to be looking at a fully automated system. Damage to flat pack	Marketing requirements and keeping the management board happy tend to be why compromises are made. Sometimes clients need to take their own customers into consideration and the specifier provided an

	Type of clientele	*Types of layouts used*	*Commonly used systems*	*Product most in demand by clientele*	*Order picking system recommended most frequently*	*Order picking system recommended least frequently*	*What are clients looking for in a new order picking system?*	*What compromises have to be made in recommending order-picking systems?*
			shop.	pallet rise.	people to use it easily, it is hands and paper free so a versatile system. Paper systems still have a place if there is insufficient volume to justify the investment. It is still used within e-commerce to label items to go direct to the customer.		furniture is an issue because they can be difficult to handle. Overall customers are looking for reduced costs, efficiency savings and systems that have smaller footprints that deliver accuracy.	example of a traditional cheese maker who decided to continue to store cheese in wooden boxes rather than a system with plastic boxes because their customers would no longer see their product as 'traditional'.

Table 7 The Specifier Perspective – Site and System Information (continued)

	What improvements would you make to the OPS you currently provide?	*If you were designing a new system what factors would influence your selection criteria and why?*	*What are people asking for that they weren't 5 years ago?*	*How do you see order picking systems changing in the future?*	*What is the role of the workforce/human in most picking processes?*	*What can you tell me about the manual handling in order picking systems?*	*Are there any specific manual handling aids that need to be supplied with the order picking systems?*	*Is there anything else you would like to add about order picking systems?*
Specifier A	Improvements in the design of narrow aisle order picking trucks to avoid operator injury (stretching and lifting at height).	• Budget(spend) • Volume requirement • Replenishment/fulfilment requirement • Space requirement • Key performance indicators required. The cost of a warehouse management system (WMS) can cost between £50k for a basic system to between £2-5 million for a best in class system. Other influences include the cost of automated picking systems which can vary between £8 million to £75 million. Also the amount of volume daily, weekly, yearly, seasonal and peak time; the size of the storage facility and key performance indicators (KPIs). Stock accuracy would be around 99.8%, pick accuracy 99.2%. On time in full 98%.	Audio visual picking systems and employee engagement tools (visual productivity tools).	Foresees a change back to manual picking systems. Automated systems are extremely expensive to maintain and do not give the retail businesses the ability to flex cost against volume.	Manually unloading products, manual pick of products, manual labelling of products, manual packing of products, manual loading/despatching of products.	Covered in other questions	NIOPs (Narrow aIsle Order Pickers) allow pickers to be lifted up to 12 m to pick from high racking locations. Fork lift trucks need to be compatible with certain technologies. Most modern fork lift trucks and operator driven pallet trucks are compatible with most warehouse management systems.	Order picking systems are productivity driven and most warehouses use labour management tools to target individual productivity. This produces highly stressful working environments for order pickers/warehouse operatives. Warehouse management are focused on health and safety for their workers, especially the ergonomics of manual handling in the workplace but neglect the stress placed on order pickers by implementing 'unfactored' productivity targets. This not only leads to operatives cutting health and safety corners to increase productivity but have created a new 'hidden injury' to their workers' mental health.
Specifier B	Voice is a better technology than pick-to-light but if the latter works for a customer	The building you have to work with and its situation, the quality of the floor, the power that comes into the building and whether they need to build a new substation. These all have	Voice is the latest technology. Most retail companies are servicing an internet shopping system, each					

	What improvements would you make to the OPS you currently provide?	*If you were designing a new system what factors would influence your selection criteria and why?*	*What are people asking for that they weren't 5 years ago?*	*How do you see order picking systems changing in the future?*	*What is the role of the workforce/human in most picking processes?*	*What can you tell me about the manual handling in order picking systems?*	*Are there any specific manual handling aids that need to be supplied with the order picking systems?*	*Is there anything else you would like to add about order picking systems?*
	would not suggest they would get much better improvement by changing to voice systems.	to be built into the return on investment and this can significantly affect the design. Customers are aware of reducing packaging so that can become an important factor in designing packaging systems.	with different ways of picking small orders for despatch to customers. Some retail outlets pick from shelves for internet customers, others pick from distribution centres.					

Table 8 The Supplier Perspective – Site and System Information

	Clientele	*What is the most common use for the systems you provide?*	*What product is most in demand?*	*What order picking systems do you provide?*	*What type of information is provided to the picker?*	*What are clients looking for in a new order picking system?*	*What are the features, compromises and improvements to your current systems?*	*What are the benefits of your systems?*
Supplier A	Systems are traditionally aimed at retailers that have a chain of shops with a turnover of £50 million per year but they do not buy much. Supplier provides voice picking as an entry level system to companies with lower turnover e.g., warehouse with 6-7 operatives. The internet has also changed the market as most retailers have a web based business and other companies are exclusively internet based. Systems are placed within distribution centres and warehouses.	Voice picking is popular but radio frequency (RF) terminals (bar code scanner type) are still most common. The terminals you hold or wear are prone to damage by operatives forgetting they are wearing them when they reach into a shelf. Both voice and RF provide accuracy and most companies can afford an RF system. The most common automated system are mainly conveyor based, either split case picking where you pick individual orders to make up an order or in supermarkets where you find full case picking. Roll cages are found in supermarkets for bulk items, tote bins for smaller items as you have to move them around the store. Most do not have fork lifts. Internet goods are usually bagged or boxed. Items are generally consolidated into one package within the customer's preferred packing weight. Item weight varies from virtually zero weight to 15 kg which is the limit.	Client mostly demand voice picking but although they also looking for RF terminals as well. This is sold as an entry-level system.	The majority of systems provided are automated conveyor systems, pick-to- light with shelves that have a light to identify the quantity to pick and then put into a box. Paper systems are still used, as are RF, pick-to-light and goods-to-pick. Of the conveyor systems provided there is split case where people put things in a box and order-to-man systems. In the last 2-3 years multi-shuffle systems with goods in racking which are then pulled out for pickers (a goods-to-person system) have mainly been provided. From a health and safety perspective they are ergonomically better as operatives work from a workstation, noise is reduced and you can make the stand adjustable so the operative is more comfortable. Although there is an argument for operatives to move around otherwise the work becomes repetitive.	Operatives are usually provided with the item, quantity and location. If an item is 5 kg and the operative is told to pick six items there is a prompt to pick less to keep within the 15 kg weight limit. The weight of each item or SKU is provided along with its volume and instructions on packing. For example, if picking light bulbs the operatives will usually be instructed to pack something lighter on top.	Clients are looking at accuracy as well as improved productivity. Productivity is the key driver as that is what the return on investment calculation is usually based on. If you send an operative around with a piece of paper you might get 60 picks per hour. RF may increase it to between 60-110 per hour, a conveyor/ pick-to-light should increase picks to 300 per hour. Goods-to-persons systems can go up to 1,000 picks per hour.	Regulations inform what can or cannot be done in respect of reach with upper and lower quartiles. Systems are developed with those regulations in mind so compromises mean that the systems are engineered within limits. No compromises are made with health and safety. The aim is to try and get most items picked from waist height so fast movers [items] are placed at waist height to minimise the amount of bending and reaching. When a system is designed for a client it goes through both an engineering review and a health and safety review. Maintenance is also considered so machinery can be safely maintained. The supplier provides method statements for the maintenance of equipment. The industry is moving towards installing more goods to persons systems. Noise has dramatically improved although different countries request different levels.	Performanc e and reliability. You do not want the machinery breaking down so you want to build in redundancy . A multi-shuttle with mini-load cranes run down the aisle and with multi-shuttles you need to have access into the racking if they break down.

Table 9 The Supplier Perspective – Site and System information (continued)

	What factors would influence your selection criteria in designing a new system?	*What is the role of the workforce/human in the picking process?*	*What are people asking for that they weren't 5 years ago?*	*How do you see order picking systems changing in the future?*	*Manual handling in your systems?*	*Are there any specific manual handling aids required with your order picking systems?*	*Is there anything else you would like to tell me about your products with regard to manual handling/human involvement?*
Supplier A	It depends on what the customer wants, what is on the market and the customer's budget. Goods-to-person systems are more expensive than voice picking and conveyor systems. The factors that influence selection include how many items they move, (volumetrics) and replenishment needs. If a lot of items are being moved then pick from a pallet may be needed. There are a lot of factors but no fixed solution. Clients are usually shown bits of equipment that applies to them but everyone has a different requirement. Compared with the USA, space is limited in the UK and in the USA there are limits to how high you can build. Systems are usually designed to operate for 15-20 years. Some internet retailers want to increase the number of SKUs they offer in order to be seen as the website of choice. This involves knowingly stocking up on items that are not big sellers.	The workforce is used in Goods In to unload a lorry. Boom conveyors lift goods out of the truck and that is the most strenuous activity in the distribution centre. Goods then go into bulk store, which can be automated. It then goes into the pick-face which is a replenishment activity that can be done either automatically or manually. In an automated system you can reduce the role of the workforce to unloading the lorry and making the pallet good and then the picking operation so you pick into a box that can be automatically sent off. With internet operations around Christmas there is usually a sea of packing benches with operatives packing boxes all day long. Overall, the two most labour intensive activities are picking and packing.	Goods-to-man picking systems and voice picking systems are being asked for, mainly for reasons of accuracy and increased productivity. To have a goods-to-man station, items need to be picked frequently. Multi-shuffle can push 800-900 moves per hour from the aisle. Sortation systems have fallen by wayside including cross belt sorters although there is still a market for them. Industries tend to have their own preferred technologies and in apparel there are a lot of sortation systems that are not needed for general merchandise.	There will be more goods-to-person and less own picking systems with conveyors. It could look like a recently designed system that is like an airport check-in desk with a desk and a computer and the operator puts a label on the item. The operative does not see what is going on with the conveyor, as there is a sound proof layer between the conveyor and the operative. It becomes almost an office environment rather than a noisy warehouse environment	Decanting of pallets and handling cases. The supplier can produce clever decanting solutions using lifts but clients tend to want the pallet on the floor. If you try to make it ergonomically sound the cost goes up. Clients know what the rules are but they are happy for the operator to bend and pick up. A lot of manual handling is not automated but you can get sucking devices, vacuums to pick cases up.	Steps to reach items on trucks, vacuums, decanting system, scissor lift, weight scales to make sure tote bins are not too heavy and also to let the shop know the weight. Boom conveyors are used for unloading and can be equipped with suction devices where they can take full cases out of the back of the trailer. However, these things do not get used because items come in different shapes and sizes so not very practical.	Where there are automated stacker cranes or conveyors there is no human involvement and if there is then there are strict rules. The real danger is falling from height. In high bays you would not want to be working close to those machines. Health and safety rules are designed to stop you getting killed by machinery and with a package conveyor there are things that can go wrong but are not life threatening. The more unskilled the operator the safer the item being handled. All equipment is controlled by voltage, handling liquids requires more resistance around the controls but that is engrained in working standards.

Table 10 The Supplier Perspective – Site and System Information (continued)

	Clientele	*What is the most common use for the systems you provide?*	*What product is most in demand?*	*What order picking systems do you provide?*	*What type of information is provided to the picker?*	*What are clients looking for in a new order picking system?*	*What are the features, compromises and improvements to your current systems?*	*What are the benefits of your systems?*
Supplier B	Clientele tend to be companies in the retail, logistics, parts and components industries. The requirements of customers in the retail industry tend to be different to clients in other sectors, as they typically require fewer features in the equipment. Companies in the parts and components sectors often specify equipment that add 'value added' functions such as labelling, packing, standing and possibly temperature and weight controls.		Zone-picking systems and goods to man systems.	Zone-picking systems, goods to man systems and bench picking systems. Systems supplied can handle a maximum weight of about 3 kg. Average weight of items handled is just over 1 kg.	Information is provided to pickers via voice, monitor and paper. Information provided via monitors tells pickers where and how many to pick.	Clients are looking for functionality and performance from order picking systems. Performance is typically defined in terms of operator productivity, and is calculated using order and product profiles. Functionality is defined in terms of workstations being ergonomically optimal for the operator, as this affects the performance of the system. Optimising systems ergonomically supports maximal productivity. There has been an increased focus on ergonomics over the past two years.	The compromise is trying to get the customer to accept that they can have safe workstations if those workstations are set up in the right way e.g., the right layout, optimal lighting, ergonomic mats etc. These things add to the cost of the system and make the workstation more expensive. However, they also improve productivity, reduce sick leave, and reduce health risks in the future. Some customers are willing to listen to that, but others aren't. Improvements to systems are focused on specific warehouse functions e.g., order picking, packing. The company is striving to build a better ergonomic workstation for operators. But there is still a lot of work to do.	The two key perceived benefits are increased productivity/ efficiency and increased customer satisfaction. Both of these arise from improved ergonomics.

Table 11 The Supplier Perspective – Site and System information (continued)

	What factors would influence your selection criteria in designing a new system?	*What is the role of the workforce/ human in the picking process?*	*What are people asking for that they weren't 5 years ago?*	*How do you see order picking systems changing in the future?*	*Manual handling in your systems?*	*Are there any specific manual handling aids required with your order picking systems?*	*Is there anything else you would like to tell me about your products with regard to manual handling/human involvement?*
Supplier B	Factors such as increased energy efficiency, increased operator efficiency and improved levels of customer satisfaction.	The key role of the workforce is to pick orders as accurately and efficiently as possible. Failure to do so results in lower levels of customer satisfaction and increased costs.	More functionality and productivity in terms of operational manpower. However, systems may be approaching the theoretical limits of what is possible. In zone picking there seems to be a limit of four hundred order lines per operator per hour. In goods to man systems a thousand order lines per hour is about the upper limit achievable.	The key change on the horizon is increased levels of automation and mechanisation. They estimate that about 3-4% of warehouses in Europe have some automation or mechanisation and this is almost certain to increase over the next five years.	Manual handling aids are included as part of the system specification.	The most common aids are manual hand trucks, but not electric forklifts. The need for items to be positioned correctly makes manual equipment a more appropriate solution.	It is important to understand the ergonomic issues correctly. Unless an individual has a very good understanding of ergonomic issues and methods, they may reach the wrong conclusions. The right people need to be used in order to understand ergonomic issues, hence the need to involve subject matter experts.

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Factors in the design of order picking systems that influence manual handling practices

Order picking can be defined as the retrieval of stock keeping units from a warehouse according to a pick list generated from a customer order prior to the despatch of the completed order to the customer.

There is a variety of order picking systems that are used in warehouses and distribution centres and the choice of system will determine the amount and type of manual handling that occurs within those locations. In order to understand the factors that influence the design of order picking systems a literature review was undertaken and telephone interviews were conducted with six industry stakeholders. The stakeholders included were two retailers with distribution networks operating across the UK, two specifiers who design order picking systems of different types and complexity for the end users, and two major suppliers of order picking systems.

The factors that influence the amount of manual handling within warehouses and distribution centres are complex and inter-locking. The key factor is the design of the order picking system, particularly how much automation is used and whether pickers travel between pick slots or whether items are automatically delivered to them. It also depends on the nature of the goods that the warehouse handles. There are financial trade-offs between high capital costs of automated systems, and increased labour costs in manual systems.

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