Warehouse assessment in a single tour

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Abstract

This paper presents an assessment method for warehouses based on a single facility tour and some Q&A. The method helps managers and students that visit a facility to get more information from tour visits through a simple and rapid assessment form. Since its inception, it has been applied to a number of cases, successfully identifying weak and strong points of the operations.

INTRODUCTION

Over the last decades, many companies have offshored manufacturing activities to Asia Pacific and Eastern Europe. Since the consuming markets have not moved, this has put an increasing burden on the distribution operations of such companies. Companies have centralized warehouse operations in few, but often large facilities responsible for distributing products over a large region. Managing efficiency and effectiveness (service) is a great challenge for managers of such facilities. As a result, they feel a great need to benchmark warehouse operations, not only their own, but also their competitors'. However, assessing the performance of a distribution facility is a tricky business. Even after having visited a large number of them, it is still difficult to tell after a visit, whether this was a best-in class operation, just above-average, or even relatively poor performing. Nevertheless, even short tour visits can reveal a lot of information to the trained eye. This paper proposes a method to help managers getting more information from tour visits, through a simple and rapid assessment form. The form should be filled out immediately after the visit. The evaluation has been inspired by the ideas of Gene Goodson in Harvard Business Review on rapid plant assessment (Goodson, 2002). Since its development, the method has been successfully applied in several visits, with different groups of managers (with and without warehouse experience), and students.

The major functions of a warehouse are to store products in order to make an assortment for customers, to assemble customer orders, sometimes to add value to the orders by customization activities, organize transport to the customers, and ship orders timely, in the way desired by the customer. Warehouse performance therefore, has multiple dimensions. Often, performance is measured in terms of ratios of output and input factors. Output factors include production (shipped orders, lines and units), quality (for example, order completeness, error-free and on-time delivery), flexibility (possibility to cope with changes in customer demand), agility (process adaptation to changed environment), and innovativeness (use of new supply-chain concepts yielding competitive advantage). Inputs are the resources used to achieve the outputs. These include the number of full-time equivalents (work hours used per year), investment in systems, buildings and IT infrastructure, process organization (i.e. the management), or the assortment carried.
Some researchers have tried to develop benchmark tools for warehouses (McGinnis et al, 2002; Hackman et al., 2001; De Koster and Balk, 2008). One such tool is DEA (data envelopment analysis), which expresses the warehouse efficiency as a ratio of weighed output and weighed

input factors, normalized on a 0 to 1 scale. Although DEA is a powerful tool, it is usually difficult to obtain the necessary data at the required accuracy level. Also, for every factor that is included in the efficiency analysis, more cases are needed in order to have statistically meaningful results. Furthermore, the warehouses should be comparable, which in practice may be difficult to realize. It is also difficult to compare warehouses in different countries, even when they operate in the same industry branch (think of cultural differences, or just of the number of working hours per full-time employee). Finally, it is difficult to include factors in DEA that are not measured on interval scales, or more subjective assessments (like teamwork, motivation, safety, cleanliness).

As an alternative, or addition, to more quantitative analyses, this tool is based on a single facility tour and can be carried out in a few hours, including some Q&A. It is not necessary to have deep insight in the operations. The main objectives of the tool are to discern the warehouse’s strengths and weaknesses after some elementary training on how to use the tool. The tool can also be used to evaluate operations of logistics service providers, operating public or dedicated warehouses. This is not to say that the tool can be a substitute for due diligence and care when analyzing company performance. In particular, financial performance is not part of the tool. However, all too often managers ignore visual signals that can be easily acquired in favor of seemingly objective data, like quantities processed, inventory turns or company profits (which are rarely directly attributable to a warehouse).

THE ASSESSMENT METHOD

The tool is based on a factor-rating method (see, for example, Heizer and Render 2004) and consists of 11 areas that have to be assessed, each on a six-category scale (see Exhibit 3). Seven areas (1 to 5, 8 and 10) are more or less generally applicable to industrial facilities and have been adapted to warehouse environments from Goodson (2002). Areas 6 and 7 (storage and order picking systems) form the heart of any warehouse (Tompkins et al., 2003) and must therefore be included in an assessment. Areas 9 (level and use of IT) and 11 (managing efficiency and flexibility) are equally important in an assessment. To aid filling out the assessment form, a number of yes/no questions have been formulated (Exhibit 2), which serve the purpose of conveying the opinions on the area and aiding area scoring. A score is measured on a 6 category ordinal scale and ranges from poor (1 point) to excellent (9 points) with an additional category ‘best in class’ (11 points). Best-in-class means that there is no better. We first discuss the areas in more detail and then discuss results as well as further validation of the method.

AREA 1: CUSTOMER SATISFACTION

Customer satisfaction is difficult to rate in a facility visit. However, all people in the facility – and particularly workers - should clearly know who the customers are, both internal and external. Management can take care of this by explicitly showing external quality performance indicators to the workers. Signboards with picking or shipping errors, customer complaints and returns over time, quality guidelines for workers, and so on, indicate sensitivity to wishes of customers and quality assurance. Try asking an order picker, packer or dispatcher: “What is the impact for customers when you make an error?” When this person answers that it will result in a complaint (or return, or a customer credit note), it should lead to a higher score than when the employee has no idea at all, or when she or he deems there are no clear consequences.

Even when products are picked by article (batched over multiple customer orders), the person should have an idea of the customers' wishes, whether there are deadlines for the (batch) order to be shipped (many large warehouses work with fixed departure schedules in order to reach their customers timely) and what the consequences are for not finishing the work in a timely manner. Questions 1, 4, 14 and 21 are related to this area.

AREA 2: CLEANLINESS, ENVIRONMENT, ERGONOMICS, SAFETY, HYGIENE (HACCP)

This is an area that is relatively easy to assess. If a facility is clean, it usually indicates that management organizes the processes well. In clean facilities, items do not get lost, inventory accuracy is higher (as well as order fulfillment accuracy), and there is an overall sensitivity to orderliness. Order picking warehouses (where case and item picking occur) typically generate much waste (pallets have to be unwrapped, boxes have to be opened) and workers have to be able to get rid of it in an easy way. In well-run warehouses, one can find waste baskets in front of the racks, where waste can be separated immediately at the source by type (which is compulsory in the EU). In a well-run facility, the air is clean, noise levels are low, and it is well-lit. In short, it is comfortable to work in. All location codes are easily readable (also from a distance) and barcoded, such that there is no confusion as to which code refers to which location (particularly for the lower beams in a pallet rack, or in a shelf area where location sizes are often tiny). Worker positions should have been designed with attention for ergonomics. As much of the work is repetitive, or strenuous, ill-designed work positions lead to high absence rates and labor turnover.

In many warehouses, pickers do not have fixed work positions, because they drive trucks or walk with pick carts. Even in such cases ergonomics pays off. The use of tiny screens and buttons on mobile terminals leads to low productivity and even to errors (reduction of which often was the main reason for the use of such terminals). In the European warehouse of a large Japanese manufacturer of consumer electronics, pickers use mobile terminals to receive pick instructions and confirm the picks. When they were asked about the contents of their work, it appeared that for a single order (of a few units) about 20 entries had to be made to confirm this. If 20 cases of the same product had to be picked from a pallet, labeled, scanned and put on a conveyor belt, it might take minutes to confirm this via the RF-terminal/scanner in the information system. Workers obviously find workarounds (do first and confirm when convenient), which may compromise the system integrity.

Safety is of utmost importance in many warehouses, especially where heavy pallet lifting or order picking trucks or cranes are used. Order-pick and forklift trucks may weigh up to several tons and can drive at considerable speeds. Warehouses should have safe travel paths for pedestrians and safety collision protection devices. Workers on foot should not work in narrow aisles together with heavy order-pick trucks. Unsafe working conditions can be discerned from the amount of damage at the racks, at the trucks or signboards indicating the number of accidents, or if people smoke in a battery charging area. Unsafe working conditions should lead to a low score on this criterion.

Hygiene (based on hazard analysis and critical control points) is of particular importance for warehouses which process (pet) foods, drugs, or raw materials for such products. If deep-frozen products wait for a considerable time in an insufficiently conditioned receiving or shipping area, the condition of the product may deteriorate. Questions 2a, 2b, 3, 17 and 21 relate to this area.

AREA 3: USE OF SPACE, CONDITION OF BUILDING AND TECHNICAL INSTALLATIONS

Although (particularly in distribution warehouses) labor is the most important ingredient of operational cost (in particular the order pickers, see Tompkins et al., 2003), facility cost (including technical installations) is a close second. Whether buildings and technical installations are owned, rented or leased is irrelevant. Therefore, space should not be wasted. Excessively large warehouses do not only lead to high cost, but often also to inefficient processes, due to long travel times for storage, order picking or cross-dock. In case of storage of large numbers of loads of slow-moving products, high-bay stacking is preferred. There is, of course a difference between countries in the costs of land and labor. If labor and land are relatively cheap (USA), buildings are usually lower. If land is expensive (Japan), buildings are higher.

On the other hand, insufficient space may prevent a process from being executed effectively and efficiently. If products have to be dropped at temporary locations because of lack of space in the proper area, if products have to be dug up because they are stored at wrong locations, or if much waiting and delays occur because maneuvering spaces are used by other workers, this area receives a low score. It may be necessary that multiple persons work in the same area (for example order pickers and replenishers in a pallet storage area); nevertheless blocking and congestion should be avoided. This can be enforced by having one-directional traffic or distribution of fast-moving articles over multiple storage zones.

Many facilities have undergone natural expansion: gradually, more and more buildings and systems have been added. In many cases this leads to suboptimal logistic processes. Warehouses spread over multiple locations lead to necessary transport movements between the parts. How is this process organized? Can inventory get lost while in transport? If not handled properly it should lead to a low score for this area.

The technical state of buildings, doors, floors, dock levelers, dock shelters, sprinkler installation, heating, cooling installations is fairly easy to asses during a visit. The quality of floors (i.e. flatness, and absence of pits and ramps) is particularly important if forklifts, reach trucks and high-bay trucks are used for discrete transport.

The basic facility layout is important for achieving top performance. U- shaped layouts, where dock doors are mainly located along one façade, usually lead to better performance (greater expansion possibilities, more flexible use of dock doors and receiving/shipping personnel, less crossing flows, shorter average travel distances) than layouts with dock doors on opposite sides of the buildings (I-shaped layout).

Questions 5a, 5b, 6a, 6b, 15, and 21 support the assessment of this area.

AREA 4: CONDITION AND TECHNICAL STATE OF MATERIAL HANDLING EQUIPMENT

Although it may seem wise at first sight to use a special truck for every different type of work, multiple brands of material handling equipment lead to less flexibility, higher risk of unavailability and higher maintenance cost. Material handling equipment that breaks down frequently or batteries that do not charge sufficiently may lead to an inefficient operation and missed deadlines. Even old trucks can work properly, if well maintained. You might try to ask a driver whether (s)he experiences any problems with the trucks. While asking this in a warehouse of a Serbian food retailer, it appeared that the batteries of one of the narrow-aisle pallet trucks charged insufficiently. This made the truck unavailable for a substantial part of the day, leading to orders that could not be filled completely on time.

Proper working material handling equipment shows from maintenance recorded on the equipment, the looks of the equipment and few failure records or performance obstructions in the operation. Question 16 supports this area.

AREA 5: TEAMWORK, MANAGEMENT AND MOTIVATION

As Bartholdi and Eisenstein (1996) and Bartholdi et al. (2000) showed, bucket brigades, a teamwork order-picking concept, can lead to substantial performance (particularly throughput) improvements in picker-to-parts order picking systems. Although the bucket-brigade concept is only applicable under special circumstances, people working as a team will perform better than as individuals. This is particularly true in order picking, receiving and shipping. If people are multi-skilled and rotate in different areas of the warehouse, this might be an indicator of team spirit. If people are proud of their work and the company, this is a positive indicator. One might try to discern this factor by asking questions to the employees and management.
Questions 1, 12, 21 support this area.

AREAS 6 AND 7: STORAGE AND ORDER PICKING METHODS

Storage and order picking form the heart of most warehouse operations. Warehouse efficiency depends to a large extent on the methods used for storing products and picking the orders. The question is whether the appropriate methods are used. This is probably difficult to assess, particularly for inexperienced visitors. Also, great varieties of storage and picking technologies are available on the market. The choice of these also depends on the volume to be picked, the variety in the assortment and quantity to be stored and the labor cost rate. Higher labor costs and larger throughput volumes justify more automated storage and picking systems, and a higher level of order picking aids, like scanners, mobile terminals, or voice-recognition equipment. In low volume warehouses, i.e. with few orders, the preferred way is picking by order. Although multiple workers can work on the same order, the order is kept intact: it does not have to be split and sorted, but can, after possible order assembly, immediately be packed for shipping. In very high throughput volume warehouses, picking by order is impossible. Instead, orders are picked by article (in batch) after which the items are sorted and grouped by order.

AREA 6: STORAGE SYSTEMS AND STRATEGIES AND INVENTORY MANAGEMENT

In order to assess the methods used the visitor might pay attention to the following elements.

- Are products stored at their appropriate locations? This includes storage based on physical properties (conditioning, dimensions, weight, and theft-proneness) and turn-over speed: fast-moving items should be located on easily accessible locations at short distances from the dispatch position (Q7a).
- Are locations used dynamically? In many warehouses fixed locations are used, from which products are picked. Even when products are initially assigned to these locations on turnover frequency (to reduce travel time), such an assignment will be far from optimal if not regularly maintained (like reassignment every month). Few companies do this. Companies that use dynamic locations, taking into account dynamic turnover frequency, score better than companies with fixed locations and little reassignment (Q7b).
- Is the number of different storage systems (with different racks, material handling systems and storage logic) justified? Warehouses often store large numbers of products. The idea is to

create the highest throughput efficiency possible, with the fewest systems used. These are often contradictory requirements, but a balance between the two should be struck. In case many different storage systems are used consideration should be given to merging two of them, without decreasing order picking efficiency or where few storage systems are used part of the assortment could be taken from a system and stored separately to increase efficiency and homogeneity of handling (Q7a, Q7b, Q8).

- Is the inventory of certain products split into bulk storage and forward pick storage? If items are picked in a condensed forward storage area, the order picking lead times are reduced considerably and storage activities can be decoupled from order picking. Such systems can be designed for box picking (bulk stored on pallets, lower pallet locations used for picking the boxes), or item picking (bulk stored on boxes on pallets, shelves used for item picking). Particularly if bulk quantities tend to be large and order pick quantities are small, splitting inventory pays off and outweighs the replenishment efforts (Q9a).
- Is family grouping applied in storage with the objective of making processes efficient? Many forms exist, such as grouping items that are frequently ordered together. Grouping methods that do not immediately lead to higher efficiency (such as products of the same supplier together, or products of the same owner together) score lower (Q7a, Q7b).
- Is inventory managed appropriately? Are inventory levels appropriate? It may be difficult to answer these questions, but clear visible signals should not be ignored. For example, in a company with short product life cycles, there should be an explicit program to get rid of “old” products. Look for a corner in the warehouse where seemingly non-movers are stored. These can be recognized by little pick activity, great product inhomogeneity, and sometimes small quantities stored per product. Inventory levels (ask for inventory turnover rate) depend on product properties, where suppliers are located and on the degree of supply chain cooperation. If suppliers are located further and products are cheaper, higher inventory levels are justified. Expensive products with short life cycles should have low inventory levels (Q9b, Q19).

AREA 7: ORDER PICKING SYSTEMS AND STRATEGIES

Before making an assessment, the order picking methods used (often more than one!) should be classified. A typical classification and explanation of methods can be found in Exhibit 1. Have the weak points of the order picking systems used been addressed adequately and sufficiently? Every order picking system has strengths and weaknesses. The strengths are usually immediately visible in a visit (apparently, the system works); weaknesses are more difficult to discern. Batch picking, followed by sorting on an automated sorter, requires that all items (including the last items, which usually are missing) are picked in time for the sorter to start. Is this handled adequately? Order throughput times in picker-to-parts systems can sometimes be very long. Is this controlled sufficiently? For example in Océ’s parts warehouse (Océ is a manufacturer of professional copiers and printers), which supplies parts overnight directly to technicians in Western Europe, orders are picked in batches (of orders for technicians in the same country) of about 60-120 order lines per order picker. The throughput time can be very long and is difficult to predict. Also, pickers can decide themselves on the number of lines they want to work on. This makes it difficult to guarantee that the fixed departure times of the trucks can be realized, requiring extra control effort (regular progress checking and emergency help) to guarantee this. The European warehouse of Yamaha Motor Parts uses a zoned pick-by-order system. A conveyor passes the order bins between the zones. As there are many zones (about 60), and orders can sometimes be large, orders queue before every zone, making order throughput times close to

unpredictable at busy moments. Yet, Yamaha has a fixed truck departure schedule for all customer destinations. The problem was solved by batching multiple small orders into the same order bin, thereby strongly reducing queuing. In C-Market's warehouse (a supermarket chain) pickers on order pick trucks travel long distances in a large pallet warehouse to pick orders for a single supermarket. In competitors' warehouses, pickers on long-fork trucks pick two or three stores simultaneously in roll containers in one warehouse zone only, which leads to a large increase in productivity.
The following questions (see also questions 10, 11a, 11b, and 20) might guide the evaluation of the order picking process:

- Are throughput times sufficiently controlled?
- Does avoidable double handling occur?
- Are obvious improvements possible in the picking process? You might think of some improvements and ask the pickers for their evaluation.
- How is the progress of the order picking process monitored and controlled?
- Are the used picking aids (order lists, labels, RF terminals, scanners, picking carts) well designed and of help to increase quality and efficiency?
- Have measures been taken to make the picking process sufficiently ergonomic?

AREA 8: SUPPLY CHAIN COORDINATION

The degree of supply chain coordination is visible at the shop-floor in several areas. At the yard, inbound trucks may be waiting to be allocated to a dock door, due to inability to properly coordinate arrival times. In the receiving area, trailers and containers must be unloaded and goods must be processed. Is this a rapid, well-organized process, or very time-consuming because the product carriers are wrong and products have to be restacked, information cannot be found or is incomplete, boxes of the same product are spread over multiple pallets or over the entire container? In case much paperwork is necessary to check incoming shipments, this is also not a sign for well-tuned processes. You might also ask what happens in case of wrong, under or over receipts. Does this happen often? Does it delay the process? Attention also has to be paid to the frequency of supply and the drop size. Drop size might be identified at a visit, frequency not without asking. If you see small drop sizes, ask the receivers the frequency of supply of these suppliers. At some warehouses, powerful customers try to reduce their inventories by JIT policies: frequently ordering small quantities. Although this leads to inventory reduction at the customer's facility, it leads to high handling and transportation cost for the supplier, which might retaliate against the customer.
In an extreme case, we asked a US wholesaler where the customer returns were handled. In response to that question we were taken to a warehouse at the other side of the street, where an endless heap of mostly damaged boxes were waiting to be processed. These were the returns of mainly one customer, who returned "suddenly" a few dozen truckloads of excess stock. This was representative for the company's entire receiving process.
Even if products are loosely stacked in sea-containers, it is still possible to have an efficient receiving process if adequate agreements have been made with suppliers. In the warehouse of Zeeman, a textile hard-discounting retailer mainly receiving products in sea containers from East-Asian suppliers, the boxes are grouped by product in the container, and box-sizes are standardized. This allows rapid manual unloading of the containers using extendible conveyors,

after which the boxes are automatically counted, labeled and palletized. Conversely Schuitema, a franchise retail organization, has to restack all of Unilever's pallets (a main supplier), because they do not fit into the storage slots.

The level of supply chain coordination is also visible in the shipping area. An abundance of paperwork needed to ship products is an indicator, as well as the carriers on which products are shipped. If products are shipped on product carriers that return (for example pool pallets, or closed-loop bins), this often indicates an efficient distribution and collection process, coordinated with the recipients. It saves one-way packaging materials which, particularly in Europe, are expensive, not only because of material cost, but also because fees have to be paid to green-dot systems in different countries to organize proper recycling of these materials. If products are shipped in sea containers on slipsheets (loads on flat carton 'pallets' that can be pushed into the container by 'push-pull' trucks) this saves space in the container and it suggests advanced coordination with the receiving customer (who also needs such a truck).

Question 19 refers to this area.

AREA 9: LEVEL AND USE OF IT

Nowadays, warehouses do not run without a sufficient level of information systems. Best-in class warehouses use systems for electronic information exchange with suppliers, customers, carriers, customs authorities, and brokers in the supply chain. They use a warehouse management system for managing the warehouse processes and they use appropriate tools and aids to support important warehouse processes. Warehouse management systems come in a great variety, varying from simple spreadsheet applications, to standard modules of ERP software packages, specialized WMS packages or tailor-made applications. In general, the more complex the operation (mainly measured in number of order lines, assortment size, different processes and uncertainty in demand and supply, see Faber et al., 2002), the more justified or even necessary specific or tailor-made software becomes. A warehouse management system is necessary to find the best location where an incoming load can be stored, the best location from which an order line can be picked, the right person to pick an order line (in the right sequence, minimizing travel time), the regular update of article-to-location assignments (based on turnover frequency) to internally move products to make sure that articles are cycle counted regularly without disturbing the main work flows, and so on.

Tools that can be used to speed up processes and reduce errors include pick-to-light and put-to-light systems and use of the right communication means with drivers and pickers to guarantee real-time monitoring of work progress. Bakker, a mail-order company which specializes in flower bulbs, uses a put-to-light system for distributing bulbs that have been pre-picked over the right customer order bins. A graphical screen helps the picker, as it shows visually which bins have to be addressed. These aids increase productivity significantly.

Question 20 reflects this area.

AREA 10: COMMITMENT TO QUALITY

Commitment to quality can be derived from a number of factors in a facility. First, from the design itself, at which points is it easily possible to make errors? If an operator can determine where to store an incoming load and later provide confirm, this is an obvious source for errors. Storage errors are very serious, as they potentially impact multiple customer orders. The same is true for picking: can an operator easily pick the wrong item or the wrong quantity? Best-in class

operations do not ensure quality by building in additional checks of the picked orders. Instead, they take measures that prevent people from making obvious errors (‘poka-yoke’, or fool proofness principle). In the previously mentioned warehouse of Yamaha, pickers at a miniload workstation have to pick a unit from a compartmented bin containing multiple products. In order to prevent errors, the computer screen is divided in the same way as the bin, with the proper part illuminated. On top of this, a battery of spotlights illuminates exactly the right compartment of the bin.
Second, is continuous process improvement actively propagated in the facility? Are workers stimulated to improve their processes and can proof be found for this? Indicators for this can be an idea-box, implementation of six-sigma improvement projects or the number of master black-belts, or the number of process improvements recently realized. You might try and ask about this. In a recent tour of the European distribution center of a US manufacturer, we were told that people could be promoted to management level only if they at least owned a six-sigma green-belt.
This area is addressed with questions 4, 11a, 11b, 12, 13, 14, 17 and 20

AREA 11: MANAGING EFFICIENCY AND FLEXIBILITY, AS A FUNCTION OF VOLUME, ASSORTMENT AND VARIETY

It is very difficult – if not impossible - to manage a large number of orders, together with a large assortment and a variety of customer wishes efficiently, in a manner that is flexible enough to accommodate late changes. Process automation and mechanization, with multiple solutions for different storage areas can help for efficiency, but usually bring down flexibility. Logistics service providers with public warehouses and short-term contracts usually opt primarily for flexibility and sacrifice efficiency to some extent. Flexibility is expressed as the ease to which different customer order patterns (large versus small orders), different customer wishes (product and order customization) can be accommodated, the processes expanded or shrunk, assortment changes handled. During a visit attention can be paid to what extent any of these principles have been sacrificed. If processes seem very efficient you might ask whether the above-mentioned flexibility features can be accommodated. In case an operation seems very flexible, it is interesting to estimate whether customers are really willing to pay for the inefficiency. If a right balance seems to have been struck a company scores higher than when there are obvious flaws. This is addressed with question 18.

RESULTS AND VALIDATION

The assessment has been carried out with several groups of managers and students. Within a group the areas are divided over different group members. Immediately after the visit, each group filled out the warehouse rating sheet as a team effort. Exhibit 4 shows the outcomes of some assessments carried out in 2004 and 2005 with different groups of international people (in total 96 persons from 22 countries participated, about 30-40 people per visit, with and without warehousing experience). For every facility, the maximum score is 121. The results show a clear distinction between high and low-ranking facilities. Low ranked facilities nearly always score

‘NO’ on question 21; high-ranked facilities ‘YES’. The outcomes of area ratings are quite varied as well, although “Customer satisfaction” (area 1) obviously scores fairly high in general.

In order to validate the method, basically three different methods were used. First, we independently benchmarked the warehouses using data envelopment analysis (DEA), based on a database of 71 warehouses. Second we compared the standard deviations of area and total scores among groups. If these standard deviations are moderate, we can at least say that the scoring is reliable. Third, we asked the managers method for feedback on the scores per area (the method was mailed to them prior to the visit).

In order to benchmark the warehouses with DEA, we asked the warehouse or logistics manager to fill out a questionnaire, addressing performance in the areas of shipment quality, production (volume and variety) and flexibility (for a full description of the method see De Koster and Balk, 2008). The resulting efficiency scores (the maximum efficiency to be obtained is 100%) can be found in Exhibit 4. Although the factor rating and benchmarking methods look at different indicators, the correlation between the two scores is quite high: 64% for the companies listed in Exhibit 4, indicating that the assessment method is a good forecaster of performance (albeit the number of included warehouses is still small).

Exhibit 4 also displays the standard deviation of total and area scores. The maximum standard deviation of the total score is within 16% of the average. For individual area scores, the average standard deviation varies between 1.4 and 1.7 (less than 25% of the average area score). Usually there are 1 or 2 areas of some disagreement between groups, with standard deviations up to 2.6. No areas consistently showed a higher standard deviation in the scoring. The score reliability improves when the assessment is done with more experienced people: having seen more facilities obviously helps in calibrating one’s judgment. However, it should be emphasized that all facilities were also visited by such inexperienced people, leading to the above-mentioned moderate standard deviations of scores.

After every visit, the warehouse manager was confronted with the area scores. In all cases, they agreed with the relative ranking of their scores. Obviously, warehouse management is often aware of weak points, but it is not always easy to improve. For example a weak layout cannot easily be changed by the management; such a conclusion should serve as input for the company’s facility development staff.

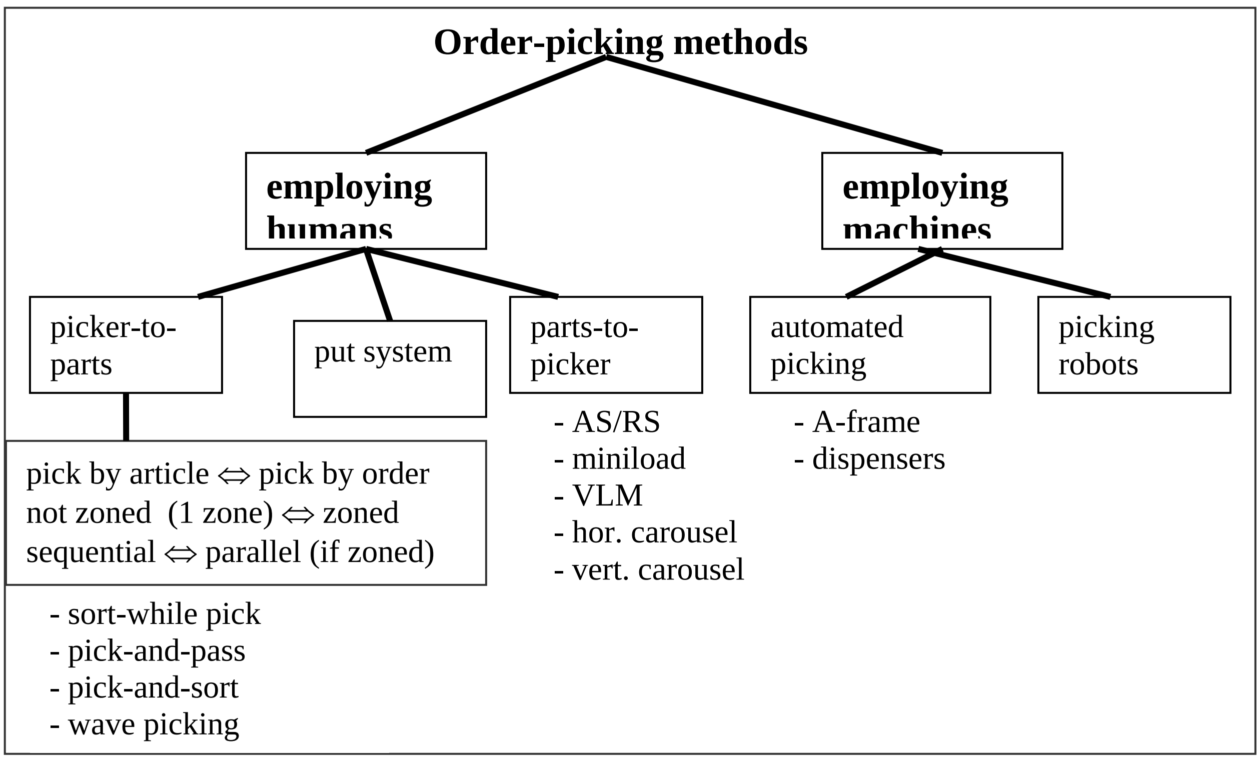
CONCLUSION

The method presented in this paper may help managers and students to rapidly assess warehouse facilities. The method serves as an addition to more quantitative methods, like financial analysis. We have validated the method with DEA benchmarking. Although the number of warehouses benchmarked with both methods is still small, first results indicate that indeed the method shows some value in an assessment. Total and area scores are reasonably homogeneous among the different groups (although every warehouse so far shows one or two areas with standard deviations higher than 2, which may be as much as 40% of the average area score). It is helpful, in this respect, that the assessors have applied the method more than once.

In conclusion, if a warehouse appears to score well, based on the visual information and Q&A, it usually is. If it scores poorly, there definitely is room for improvement, particularly in the low-ranked areas.

EXHIBIT 1 ORDER-PICKING METHODS

The next figure shows different order picking methods that can be found in warehouses (for a description of some of these methods, see Tompkins et al., 2003). In many warehouses multiple methods are used. The large majority employs humans for order picking. Among those, the picker-to-parts system, where the picker walks or rides along the items, is most common. Parts-to-picker systems include automated storage and retrieval systems (AS/RS), mostly using aisle-bound cranes that retrieve one or more unit loads (bins: miniload system, or pallets) and bring it to a pick position. At this position the picker takes the number of pieces required by the customer order, after which remaining load is stored again. Other systems use vertical lift modules (VLM), or carousels that also offer unit loads to the picker, who is responsible for taking the right quantity. Put systems are positioned between the picker-to-parts and parts-to-picker systems, because they often combine the two principles. First, inventory has to be retrieved, which can be done in a parts-to-picker or picker-to-parts manner. Second, the carrier (usually a bin) with these parts is offered to a picker who distributes the items over customer orders. Put systems are particularly popular in case a large number of customer order lines have to be picked in a short time window (for example at the Amazon German warehouse) and can result in about 500 packages on average per picker hour (for small packages) in well-managed systems.



Picker-to-part systems are the most common. The basic variants include picking by article (sometimes called batch picking) or pick by order. In the case of article picking, multiple customer orders (the “batch”) are picked simultaneously by a picker. Many in-between variants exist: picking multiple orders followed by immediate sorting (on the pick cart) by the picker (“sort-while-pick”), or “pick-and-sort” in which case the sorting takes place after the pick process has finished. Another basic variant is zoning, which means that a logical storage area (this might be a pallet storage area, but also the entire warehouse) is split in multiple parts, each with different pickers. The pickers can work sequentially, traveling along the locations in their zone and pass the product carrier with pick instruction to pickers in the next zone, or they can work in parallel, and work on the same orders. If this is the case, the order parts have to be assembled before they can be packed and shipped. Parallel and batch picking speed up the picking process, at the cost of additional sorting and order assembly work. The term “wave picking” is used if orders for a common destination (for example, departure at a fixed time with a certain carrier) are released simultaneously for picking in multiple warehouse areas. Usually it is combined with batch picking.

EXHIBIT 2 QUESTIONNAIRE

The total number of yeses on this questionnaire is an indicator of the warehouse's overall performance. The more yeses, the better the performance. A question should be answered a yes only, if the warehouse obviously adheres to the principle implied by the question. In case of doubt, answer no.

Warehouse Group:	***: Date visit:***	***Yes***	***No***
1	Are visitor welcomed and given information about warehouse operation, customers and products?	☐	☐
2a	Is the facility clean, safe, orderly and well lit? Is the air quality good and noise level low?	☐	☐
2b	Is the environment attractive to work in?	☐	☐
3	Are the work processes ergonomically well-thought over?	☐	☐
4	Do the employees appear committed to quality?	☐	☐
5a	Is the warehouse laid out in a U-shape, rather than an I-shape?	☐	☐
5b	Does the layout prevent major crossing flows?	☐	☐
6a	Is material moved over the shortest/best possible distances?	☐	☐
6b	Is double handling prevented and are appropriate product carriers used?	☐	☐
7a	Are products stored on their right locations? Do storage strategies lead to operational efficiency?	☐	☐
7b	Are locations used dynamically?	☐	☐
8	Is the number of different storage systems (with different racks, material handling systems and storage logic) justified?	☐	☐
9a	Is appropriate (non-)splitting of inventory in bulk and forward pick stock applied?	☐	☐
9b	Is there an effective process management for introducing new products, getting rid of non-movers, and internal relocations?	☐	☐
10	Is the organization of the picking process well-designed without obvious improvement possibilities?	☐	☐
11a	Are storage and receiving processes monitored and controlled on-line?	☐	☐
11b	Is the response to mistakes and errors immediate?	☐	☐
12	Are work teams trained, empowered and involved in problem solving and ongoing improvements?	☐	☐
13	Are up-to-date operational goals and performance measures for those goals prominently posted?	☐	☐
14	Are ratings for customer satisfaction and shipping errors displayed?	☐	☐
15	Are the buildings, floors and technical installations in good quality and well-maintained?	☐	☐
16	Are the material handling systems used, the racks and the product carriers in good operating condition and well-maintained?	☐	☐
17	Are inventories accurate?	☐	☐
18	Has a right balance been struck between order customization, process flexibility and efficiency?	☐	☐
19	Are receiving and shipping processes, and inventory levels tuned with suppliers and customers?	☐	☐
20	Is the level of IT, picking and storage technologies adequate for the operation?	☐	☐
21	Is this a warehouse you would like to work in?	☐	☐
	Total yes/no		

EXHIBIT 3 WAREHOUSE RATING SHEET

Warehouse:	
Date visit:	
Group:	

	Area	Related questions	Poor (1)	Below average (3	Average (5)	Above average (7)	Excellent (9)	Best in class (11)	Total
1	**Customer satisfaction**	1, 14, 21							
2	**Cleanliness, environment, ergonomics, safety, hygiene**	2a, 2b, 3, 17, 21							
3	**Use of space, condition of building and technical installations**	5a, 5b, 6a, 6b, 15, 21							
4	**Condition and maintenance of material handling equipment**	16							
5	**Teamwork, management and motivation**	1, 12, 21							
6	**Storage systems and strategies, inv. management**	7a, 7b, 8, 9a, 9b, 19							
7	**Order picking systems and strategies**	10, 11a, 11b, 20							
8	**Supply chain coordination**	19							
9	**Level and use of IT**	20							
10	**Commitment to quality**	4, 11a, 11b, 12, 13, 14, 17, 20							
11	**Managing efficiency and flexibility**	18							
								Total score	

EXHIBIT 4 SOME EXAMPLES OF THE TOOL'S RESULTS. N=NUMBER OF GROUPS

Ware house	Description	Ave. total rating (N)	Std. deviation[1]	Average (max) std dev. per area	DEA efficiency score
A	Multinational interior-decoration retailer	65.9 (8)	10.8	1.6 (2.5)	58.8 %
B	Automotive manufacturer, spare parts	82.5 (8)	8.9	1.7 (2.6)	95.5 %
C	National wholesaler supermarket products	76.3 (6)	3.5	1.4 (2.0)	100 %
D	National food retailer	59.2 (9)	7.2	1.5 (2.1)	-
E	Multinational hard-discounting non-food retail chain	64.0 (6)	10.0	1.6 (2.5)	66.2 %
F	Multinational fashion products manufacturer/ wholesaler/retailer	73.0 (6)	3.1	1.4 (2.2)	44.2 %

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[1] In calculation, we interpreted the scores as measured on an interval scale.

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