OPERATIONS BY FORKLIFTS IN WAREHOUSES

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ABSTRACT

Nowadays the great attention has to be paid to logistics. Theoretical analysis shows the need to improve logistics system. This encourages the search for solutions during warehouse operations. Aiming to determine possible improvements, the operations of forklifts are examined in warehouses.

The study consists of two parts: in the first part of the study possible improvements are analysed, in the second part - the financial evaluation of suggested improvements are presented.

The application of simulation method is presented in the first part of the study, the use of the comparative and financial analysis methods - in the second part of the study.

Simulation results were compared with the results of companies, applying such solutions. This showed labor productivity increased from 27% to 37%. Continuing the investigation, the assessment of financial value is presented. The solution describing how to improve logistics system, gives time savings around 12.5% and cost savings around 9%.

The presented results resemble to the results reached in practise.

Keywords: routing, warehouse, simulation, forklifts, savings

1. INTRODUCTION

Warehousing is becoming critical activity in trade enterprises to outperform competitors on productivity, lead time and customers' service. So, short lead times and productivity are considered in many warehouses as competitive weapon. It becomes more and more difficult to realize short customers' orders throughput times because of factors such as increase in assortment and smaller, not frequent, orders. For the increasing assortment an increasing floor space is needed. This means in increased lead times per order. Smaller orders (less units per line) and higher frequency of ordering lead to some changes: less full pallets are picked and more single item picks are necessary. Also additional activities have to be performed within the short time frame available for handling the customers' orders.

For such activities forklifts are the most important and expensive machines. Requirements for forklifts and costs are crucial for the selection of such operations. Basically, forklifts are used for moving pallets inside warehouses. The movement of a pallet from point A to point B is not critical itself, but if the wrong pallet is moved or if the right pallet is put in the wrong place, an error will occur.

During the process, driver have to know where to go, how much to pick and where to place it. The construction of least-costs forklift routes can help to increase productivity.

Forklifts are used in environments and applications that require different performance characteristics than other equipments.

Forklifts retrieve products from specified storage locations on the basis of customer orders. The infrastructure needed for a firm to incorporate and handle all movements of forklifts has to be in place.

Forklifts are the most expensive machines due to investments into equipment and other assets, which are used to support their operations.

This shows the importance of such research. In addition, the analysis of scientific literature, which is published by Oxford University Press, Cambridge University Press, Harvard University Press, Springer, M.E. Sharpe, Routledge, etc. shows that only 1% of authors, which analyze logistics issues, give attention to forklifts. The authors that analyze the operations of forklifts mention that minimization of non-productive movements and the construction of less-costly routes can help to increase productivity.

In the paper author analyzes the application of forklifts in trading companies, business cases, the assessment of technology implementation by production companies, their attitudes and interests.

The target of the paper is to determine possible logistics systems improvements in forklifts operations.

To answer to the above mentioned question, study is presented in the paper.

The study is divided into two parts. At the beginning literature review is given, later on experimental study is presented. The literature review is short summary of the application of forklifts in trading companies, business cases, the assessment of technology implementation by production companies, their attitudes and interests. The first part of experimental study is dedicated for the identification of forklift and construction of least-costs forklift routes. The second part of experimental study is dedicated for the effect related to minimization of costs identification and time savings calculation.

The study is based on simulation, comparative and financial analysis methods.

2. THE SCOPE OF FORKLIFTS APPLICATION IN WAREHOUSES

When purchasing forklift, the purchaser must know, if it can meet handling needs of company. This is where productivity comes in. Speed limits are applicable and they have huge impacts. Usually manufacturers of forklifts can design governors on forklifts that only allow reaching the certain speed (Ryan and Ryan 2006). The speed limit in different warehouses is 10km/h.

A forklift is a powerful tool when used by well trained driver (or operator). It helps to move pallets (or other materials) by eliminating the need to lift and carry boxes by hands.

Forklifts can be classified by different methods including type of power source, driver position, and load engagement method. Electric motors powered by batteries are among the most common type of forklifts seen in industry (Ryan and Ryan 2006). Different manufacturers may offer different models of forklifts. Selection of forklift is often a several-step decision process. First characteristic is volume of material flow - the large volume will require buying the number of forklifts with similar characteristics. Second characteristic is the frequency and scheduling of movements - this relates to the time between movements. Usually, movements are performed due to different batches or continuous. Third characteristic is route factor - this includes distance, conditions along the route, the path of travel (Kasilinga 1998).

In addition, author Kasilinga (1998) mentions important forklift selection factors: purchasing price, operating costs, maintenance costs. The regulation require that a forklift be checked every day that the forklift is used. If forklift is used continuously, then it must be checked at the end of each shift.

Forklift operations require the floor space as well. Traditional wide-aisle pallet storage aisles must have corridors 3.3-3.6 m for forklifts operations. It is necessary to have also barriers that protect walls and racks against forklift damages.

The place of depot in front of aisles or between the two blocks is planned in Caron, Marchet, and Perego (1998) study. This is the position where forklift driver takes task and after which returns back for another one.

Various assignment policies may be used simultaneously within the area of warehouse. Consider, for example, picking and storage areas. The used assignment policy does not have to be permanent and could be switched to another one when conditions are changed. Dedicated storage policy can be used for fast moving products and random storage policy for slow moving items (Hassan 2002).

The number of locations available in storage area usually is smaller than the total number of pallets arriving to warehouse on daily basis. This means that first, pallets from storage places have to be removed to picking places and after this, new pallets can be placed to storage area. At the end this means increased throughput time per order.

According to De Koster, Roodbergen, and Voorden (1999), the travel time in a warehouse, in general, has a significant impact on throughput time.

The time, needed for forklifts operations can be split in travel time (travelling time), pick and place time, and remaining time. The travel time is required for the movement between locations that have to be visited (where the items are stored that have to be moved). The pick time is associated with stop, finding and picking right pallet. This includes search for the pallet, grabbing it, scanning it and storage location, reading the next location to be visited. Place time is related to the dropping of the pallet to pick location and scanning it. The remaining time is related to time needed to close the task and get next assignment, etc.

2.1. Time savings algorithms

50% of the total travel time spent on unproductive traveling (Dukic and Oluic 2007). Saving algorithms are based on the algorithm of Clarke and Wright (1964) for the vehicle routing problem: a saving on travel distance is obtained by combining a set of small tours into a smaller set of larger tours.

Time savings algorithms are based on the time savings that can be obtained if different tasks are combined instead of being executed separately. For combined tasks the time saving is calculated. Instructions for the next route are given via a computer terminal (De Koster, Le-Duc, and Roodbergen 2006). For reaching next assignment, radio data terminal is used by forklift driver. The forklift driver follows a route designated by reading instructions on a radio data terminal or following commands.

Each route is formed containing many tasks. This process is repeated until all tasks during day have been assigned to a route.

In the calculation of the time savings, a routing algorithm may be used. This may be one of mentioned heuristics: S-shape, Combined, Largest gap, return, mid-point, etc. or optimal (De Koster, Le-Duc, and Roodbergen 2006). Usually optimal method outperforms S-shape method by 7-33 % in single-block random storage warehouses (De Koster and Van der Poort 1998). Several types of the above mentioned algorithms are discussed in De Koster, Roodbergen, and Voorden (1999).

All articles discussed so far assume that the aisles of the warehouse are narrow enough allowing to retrieve pallets from both sides of the aisle without changing position. In Goetschalckx and Ratliff (1988) a polynomial-time optimal algorithm is developed that solves the problem of routing order pickers in wide aisles.

In practice, usually simple routing heuristics are used. No standard warehouse management system package consists that contains the Ratliff and Rosenthal algorithm. Methods that are used include the 'Largest-gap' return strategy, 'Mid-point' return strategy, 'S-shape' strategy. In the application of 'S-shape' algorithm, a distinction has to be made between single-side and double-side picking (De Koster, Roodbergen, and Voorden 1999).

In many labor-intensive warehouses, there is the constant pressure to reduce travelling time. One of such is Bijenkorf warehouse - warehouse of retail trade organization in Holland with the product assortment of 300 thousand stock-keeping units. Authors De Koster, Roodbergen, and Voorden (1999) have made the case study analysis. The delivered results are as follows: the reduction of total travel time means the reduction in the number of labor units.

Another problem with routing may arise if products are stored at multiple locations in a warehouse (De Koster, Le-Duc, and Roodbergen). In this case a choice by warehouse management system has to be made before directing the forklift to location from which the pallet has to be retrieved.

The travel time is an increasing function of the travel distance (study, for example, Jarvis and McDowell 1991; Roodbergen and De Koster 2001; Petersen and Aase 2004). Consequently, the travel distance is often considered for planning warehouse. Two types of travel distance are widely used in appropriate literature: the average travel distance of tour (or average tour length) and the total travel distance. For a given tasks list (a set of tasks), however, minimizing the average tour length is equivalent to minimizing the total travel distance.

Clearly, the minimization of average travel distance (or, equivalently, total travel distance) is limited for forklift operations. Usually, it is only one of many possibilities. Another important objective would be minimizing the total cost (De Koster, Le-Duc, and Roodbergen 2006) (that may include both investment in to forklifts and related infrastructure and operational costs).

In addition tracking system maybe used that will connected forklifts to the mobile device for the provision of routing information (Giaglis, Minis, Tatarakis, and Zeimpekis 2004).

Eastern Service Company - freight forwarding and logistics service provider in Hong Kong and South China. The company specializes in managing warehouses and providing other cargo logistics services. This company aims to achieve these major service goals to their customers: shorten the lead time; and maintain a higher visibility on the supply chain area. To ensure accuracy scanning is applied to check the right correctness of movement (Cathy, Lam, Choy, and Chung 2011).

3. EXPERIMENTAL STUDY

The objective of experimental study is to calculate how the identification of forklift will help for the construction of least-costs forklift routes; and what will be the effect related to minimization of costs.

The first part of experimental study is dedicated for the identification of forklift and construction of least-costs forklift routes. The second part of experimental study is dedicated for the effect related to minimization of costs identification and time savings calculation.

For the first part of experimental study the Interactive warehouse simulation model is used.

The Interactive Erasmus Logistica Warehouse Website model offers opportunities to discover more ways to perform tasks (Oudijk, Roodbergen, De Koster, and Mekern 2002) in the Microsoft Internet Explorer environment. There are different possibilities to compare different scenarios which depend from the number of aisles and cross-aisles, length of aisles, position of computer station in warehouse. The only limitation of the model is that the maximum number of locations per aisle is limited to 68.

The Interactive warehouse simulation model will be used for optimizing the way of forklift that is done between two transaction points. Each time forklift gets a task, an event (or task) row is recorded in the information system. An event row can include the starting and ending time of task, thus enabling its duration to be calculated. Each consecutive pair of transaction points represents costs of activity (Varila, Seppanen, and Suomala 2007).

The forklift driver starts route at computer station (Oudijk, Roodbergen, De Koster, and Mekern 2002), goes to the front of the particular aisle; drives inside aisle, takes pallet, delivers it to pick location at the same or other aisle in shortest way, and, finally, returns back to the computer station. For calculation of forklift travel distance the optimal route was used mainly (see Figure 1). Each pick and place point is served by only one forklift. In addition, the capacity of forklift is limited. It is possible to handle one pallet on its forks at the same time.

Three assumptions are used for experimental study. The first one is dedicated to optimal routing by assuming that order pickers do not create routes on their own. The next one is dedicated to the wide of the aisle. This means that the aisle has the least floor space where the forklift can pick pallets from both sides of an aisle without covering an additional distance. The third one is dedicated to path and time relationship by assuming that the linear relationship between forklift travel time and distance exists. For the calculation of traveling time the average speed 10 km/h is used (assuming that forklift is travelling in warehouse with the same speed).

This simulation model was used to perform pick and place tests, when:

1. Reserve (pick) and pick (place) locations were in different aisles (see the left side of the picture);
2. Reserve and pick locations were in the front of aisle;
3. Reserve and pick locations were in the end of aisle;
4. The above mentioned is combined (see the middle of the picture).

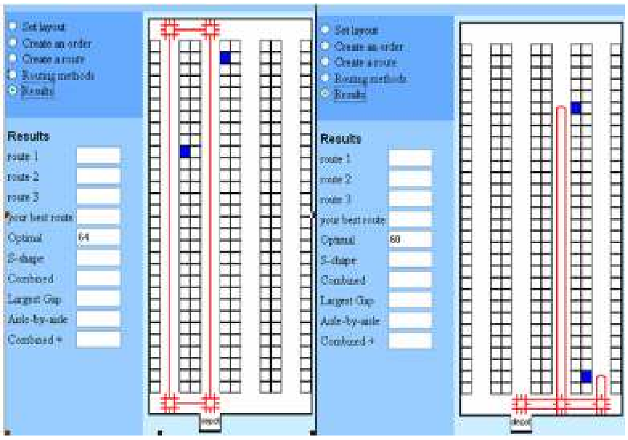

Figure 1: Interactive warehouse simulation model and different tests. Source: Oudijk, Roodbergen, De Koster, and Mekern (2002)

If forklift works according paper-based task list, at first forklift driver moves to depot (where all task lists are placed), then moves to storage location to pick pallet (according task list), takes pallet, delivers it to pick location, and, finally, returns back to the depot to confirm completeness of task and gets assignment for new task. The trip to depot takes some minutes.

If forklift has RF terminal, then new task list is placed on the screen (no need to drive to depot). In such case the driver of forklift has to be equipped with radio control device, such as RF terminal, which is located on the forklift. The terminal of forklift can have real-time communication with warehouse management system. And the portable computer can be used to map out the most efficient route. Operations performed by forklifts with RF terminal require a discrete signal that will ensure only that the desired pallet is identified. RF terminal is used to send messages (SME's) for the driver. The monitor on the forklift typically provides instructions associated with the given task. When the task is finished the driver gives confirmation to warehouse management system over local area wireless (WI-FI) network (see Figure 2, when several or multiple tasks are completed without return to depot).

By running simulation tests with interactive warehouse simulation model it was seen that the best travel distance is when RF-terminal is implemented. This means that the tasks are distributed to forklifts via SME's and forklift drivers don't need to go to depot to give confirmation and get new assignments. In such case, the way decreases by 27-37 % when travelling without depot is implemented and tasks are distributed to forklift drivers on-line.

Talking about costs, these results present the cases with and without RF-terminals. As there are several choices for warehouses - task lists distributed to forklift drivers at depot (computer station) or via SME's.

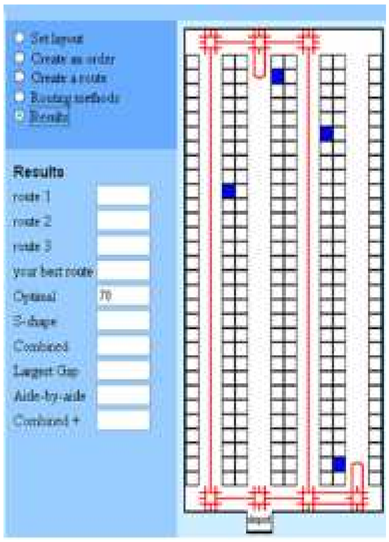

Figure 2: One return to depot for two tasks. Source: Oudijk, Roodbergen, De Koster, and Mekern (2002)

In addition, authors Gray, Karmarkar, and Seidmann (1992) propose to analyse savings in accordance with the components of warehouse operations. The time, needed for forklifts operations, can be split in travel time (travelling time), pick and place time, and remaining time:

- The travel time is required for the movement between locations that have to be visited,
- The pick time is associated with the number of stops, finding and picking right pallet,
- Place time is related to the dropping of the pallet to the right location,
- The remaining time is related to time needed to close the task and get next assignment at computer station.

After each above mentioned component is studied:

- Travel time component. Gray, Karmarkar, and Seidmann (1992) propose to calculate 1,5 minutes per performed task. On average during a day he spends an hour and a half for travelling in order to take a pallet and to place a pallet into new location. Comparing results of two scenarious (Figure 1 and Figure 2) it is seen that the total travel distance of forklift can be reduced by 27-37 %;
- Pick time component. Gray, Karmarkar, and Seidmann (1992) propose to calculate 1 minute per pallet taken from the old place (0.5 minute of this is needed for finding the right pallet and scanning location). If on average the driver of forklift picks 60 tasks, this means that during a day he spends around an hour to pick pallets;
- Place time component. Gray, Karmarkar, and Seidmann (1992) propose to calculate 1.5 minute per pallet placed to new place. On average during a day the driver of forklift spends one hour and a half to place pallets;
- Remaining time component. In paper-based process it takes some forklift driver's efforts to

handle the job at the depot (computer station). Gray, Karmarkar, and Seidmann (1992) propose to calculate 0.5 minutes per task (Gray, Karmarkar, and Seidmann 1992). If on average the driver of forklift picks 60 tasks, this means that during a day he spends around half an hour at the computer station.

The mentioned time components for the first and second scenario are mentioned in Table 1.

Table 1: The time needed for forklift operations

Components	1st scenario	2nd scenario	Effect
Travel time component	1.5	1.5	
Pick time component	1	1	
Place time component	1.5	1.5	
Remaining time component	0.5	0	
Total time	4	3.5	12.5%

The effect 12.5% related to minimization of costs is identified (see Table 1).

And finally, time savings calculation is presented. First, each line of investments is mentioned, later on the comparison for both scenarios is given.

Investments into forklift:
The forklift purchase price - 18113 Euro
The purchase price of 2 batteries - 2993 Euro
The purchase price for RF-terminal* - 5000 Euro
Total purchase price for forklift and its equipments - 26106 Euro

Investments into charging room:
The purchase price for charging room protectors - 23 Euro per sq. meter
The purchase price for battery change table - 1496 Euro
The purchase price for 2 battery chargers - 2860 Euro

Investments into warehouse floor:
The purchase price for walls and racks protectors - 2.5 Euro per sq. meter
The purchase price for WI-FI network* - 3.4 Euro per sq. meter
Increase of corridor space from 2.5 sq. meter to 3.3 sq. meter for forklifts operations
One sq. meter of charging room is requested for 135 sq. meter of warehouse floor

* - additional investments needed for second scenario.

The mentioned numbers are presented in Table 2.

Table 2: Total investments required for forklifts operations

Investments		1st scenario	2nd scenario
Investments into forklift	26106 Euro	21106 Euro	26106 Euro
Warehouse space (50 m x 20 m)	1000 sq. m		
Charging room space	7.4 sq. meter		
Investments into charging room	4526 Euro	4526 Euro	4526 Euro
Rent price per sq. meter	5 Euro		
Number of corridors with 3.3 m width and 20 m length	10.5		
Investments into warehouse floor	6740 Euro	3340 Euro	6740 Euro
Forklift driver costs a day	40 Euro	40 Euro	35 Euro
Total costs for 5 years		78372 Euro	80597 Euro
Savings in 5 years			
Savings of driver costs (when 247 working days a year)			6175 Euro
Savings of forklift costs (12.5%)			3263 Euro
Total savings			9438 Euro
Net total costs for 5 years		78372 Euro	71159 Euro

In addition, it should be mentioned that net total costs for second scenario are 91 % lower than for the first scenario. This means that if more forklifts will be included in such calculation, the reduction of travel distance effect would be much higher.

4. CONCLUSIONS

In many labor-intensive warehouses, there is the constant pressure to reduce travelling time. In the literature review short summary of the application of forklifts in trading companies, business cases, the assessment of technology implementation by production companies, their attitudes and interests. In addition, different time savings algorithms are presented.

In the second part of the study is dedicated to experiments. First, to construction of least-costs forklift route; and second, to effect, related to minimization of costs, estimation.

The experiments demonstrate labor productivity increase from 27% to 37% and reduction of time and costs. The comparison results of both scenarios shows that total time can be reduced by 12.5 % due construction of least-cost forklift routes. In addition, total costs can be reduced by around 9%.

In the paper the travelling of forklift is examined through simulation and experiments with simulation model are undertaken. For saving analyze, the time, needed for forklifts operations, is splited into travel time, pick and place time, and remaining time. The results of such analysis showed that the yearly savings for each forklift driver are 1235 Euros and for each forklift - 652 Euros.

In addition, it should be mentioned that net total costs for second scenario are 91 % lower than for the first scenario. This means that if more forklifts will be included in such calculation, the reduction of travel distance effect would be much higher. The study results show that the implementation of RF-terminals and related infrastructure is a priority in warehouses. By implementing this managers can have significant savings of warehouse costs, especially for forklifts, which are the most expensive machines used for manual operations in warehouses.

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