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A World Class Order Picking Methodology: an Empirical Validation

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Abstract. Order picking is the process of retrieving products from storage in response to a specific customer order. Although this process' design has significant impact on warehouse global performance, a practical-oriented design procedure is still lacking in literature. This paper presents a novel order picking system design methodology based on Design for Six Sigma approach, that aims to assist designers making decisions by suggesting the most effective operational and organizational policies and the equipment needed in order to fulfill customer's orders. A case research in a home appliances manufacturer is presented in order to demonstrate the effectiveness of this approach.

Keywords: order picking process, design methodology, design for six sigma, case research

1 Introduction

Picking is the process of retrieving products from storage in response to a specific customer order. It has been identified as a key warehouse activity due to its impact on operational costs and service level. An appropriate design can also directly improve global performance (De Koster et al. 2007). In addition, according to Rushton et al. (2006) and Errasti et al. (2010) the design of this process has become particularly important and complex due to recent trends in distribution centers: an increasing number of make to stock items in the warehouse, a reduction in delivery times to 24-48 hours, an increasing level of customization in orders, or a reduction in the number of minimum delivery units.

It has been pointed out that most of the research related to order picking focuses on a specific situation or design issue (De Koster et al. 2007, Manzini et al. 2007, Ekren et al. 2009). However, extrapolating methods developed for one particular situation to a different situation is not that simple. Even though some authors have identified the elements and alternatives (Goetschalckx and Ashayeri 1989) and other authors have

identified the tasks (Yoon and Sharp 1996), a general design procedure for the order picking process is still lacking in the literature (De Koster et al. 2007).

Gu et al. (2010) state that it would be worthwhile to carry out research that characterizes order picking alternatives in such a way that they could support design process. Moreover, these authors conclude that both applied design models and practical cases that show the value of bringing academic research results to real situations are necessary. More case studies and computational tools for warehouse design and operation will help bridge the significant gap between academic research and practical application.

We propose a novel order picking system design methodology that aims to fill the following gaps: (1) the lack of a flexible order picking design framework, (2) the misuse of tools and techniques that allow the modeling and simulation of operative processes in the design or redesign phase of a operative process to be incorporated and (3) the scarcity of empirical investigations that allow the applicability of new procedures and technologies to be evaluated.

2 State of the art

Yoon and Sharp (1996) outlined a procedure for analyzing and designing order picking systems with three steps: a) input stage, b) selection stage, and c) evaluation stage. After this last stage, different subsystems are compared, and overall performance is evaluated. These authors only suggested that these steps need to be taken; however they did not specify how these steps could be performed, nor how to select the most suitable picking configuration according to the complexity of the process. In this context, Baker and Canessa (2009) highlight that there is no consensus on the exact nature of the tools and techniques to be used for each design step. The same authors also state that great reliance is put on the knowledge of the designer in deducing which tools need to be used, and final design decisions are made based on intuition, experience and judgment.

Dallari et al. (2009) improved Yoon and Sharp (1996) design procedure with the development of a new taxonomy based on the analysis of 68 warehouses located in Italy. We believe that this has been an important step into bridging the existing gap, but a major degree of detail regarding to order picking alternatives is still needed in order to support effectively the design process.

We propose a novel order picking system design methodology for use in warehouses and distribution centers. This procedure assist designers making decisions, by suggesting the most effective operational and organizational policies, as well as the equipment needed in order to fulfill orders considering their typologies.

This procedure is based on the Design for Six Sigma (DFSS) approach (Yang and El-Haik 2003; Brue 2003). It has been developed for achieving Six Sigma process capabilities on the design side. In design, opportunities are virtually unlimited since most of the costs of a product are determined in the design stage (Montgomery 2005). We decided to adapt DFSS due to its focus on design or redesign products/processes right the first time, by integrating tools and methods that look for robustness. The

DFSS approach with four stages ICOV (Identification of requirements, Characterization, Optimization and Verification) was followed, although there are varieties in literature such as DMADV, IDOV, etc.

Six Sigma is, by definition, analytical and profoundly rooted in statistical analysis. It was defined by Linderman et al (2003) as "an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates". A key difference between Six Sigma and other approaches is the integration of a highly disciplined process (such as IDOV) with one that is very quantitative and data oriented. This is a winning combination as evidenced by the results of the companies that have used it (Hahn 2005).

DFSS is one of the drivers of research and application of experimental design techniques. So is the expanding deployment of Six Sigma in general, where it is broadly recognized that Design of Experiments is the most powerful and important of the Six Sigma tools (Montgomery 2006). Therefore, the order picking system design methodology developed incorporates elements from the Design of Experiments (DoE) (Box et al. 2005) and the Discrete Event Simulation technique (Banks 2010) when selecting the most suitable design strategy from those suggested in a previous stage. A simulation model is developed, considering the external and internal factors that influence picking performance identified by Goetschalckx and Ashayeri (1989) and Frazelle (2002).

3 Order picking design methodology

The proposed methodology takes the procedure proposed by Yoon and Sharp (1996) and fit its three steps (Input, Selection, and Evaluation) into a DFSS approach with four stages (Identification of requirements, Characterization, Optimization, and Verification). It also details how each stage is to be performed and what tools and techniques need to be used.

3.1 Identification of Requirements Step

According to Frazelle (2002), the factors that have to be considered when categorizing this process are:

- Order type (lines per order, items per line)
- Picking volume complexity (orders/t, lines/t, or items/t)
- Product characteristics (shape, volume, weight) and heterogeneity
- Storage unit vs. order unit
- Number of make to stock items

The first stage of the proposed methodology takes these factors into account in order to establish the order picking complexity. The characterization is performed employing a priority matrix that assigns a discrete level of complexity: medium, high or extreme picking (Errasti 2011). This matrix has been gauged after a Delphi study carried

out among 40 world class companies with different order picking complexities. Table 1 shows the valuation ranges and the weighing that have been given to the five factors previously mentioned.

Table 1. Priority matrix for determining order picking complexity level

FACTOR	Valuation Ranges			Weighing
Picking Volume (lines/t)	Lines<100	100<Lines<1000	1000<Lines	3
	1	2	3	
Storage unit vs. order unit	Ratio>75%	25%<Ratio<75%	25%>Ratio	3
	1	2	3	
Number of make to stock items	Number<100	100<Number<1000	1000<Number	2
	1	2	3	
Different order type	Number=1	Number=2	Number>3	1
	1	2	3	
Different Product characteristics	Number=1	Number=2	Number>3	1
	1	2	3	

The order picking complexity level is determined by calculating a value obtained after multiplying the valuation range and its corresponding weighing (see Table 2).

Table 2. Order picking complexity levels

Order Picking Complexity Level	**Value**
Extreme Picking	Value>=25
High Picking	20<=Value<25
Medium Picking	10<=Value<20

Once this characterization has been carried out, a group of possible designs are suggested in the following step.

3.2 Characterization of the Design Stage

This second step aims to delimit the large variety of solutions and parameters considered according to the process complexity, reducing the time required to find the most appropriate solution in the next phase. With this aim in mind, several charts of alternatives are proposed. Order picking processes design is highly complex owing to the high number of existing possibilities (Baker and Canessa 2009), thus this is an important contribution because it helps designers choose from among the most appropriate alternatives. The suggested designs are the result of a Delphi study carried out among 40 world class companies with different order picking complexities. In this phase, the designer needs to select the two or three designs they consider the most suitable according to their experience.

The alternatives suggested include the classic factors that influence picking performance identified by Goetschalckx and Ashayeri (1989): mechanization level (automated, semi-automated, mechanized or manual), order realize mode (wave-picking or continuous), zoning (one zone or multi-zone), batching (pick-by-order or pick-by-article, and pick-and-sort or sort-while-pick), storage (random, class-based, family grouping, or dedicated), and routing (heuristic or optimal), but also incorporate the new operational or technological options implemented by companies nowadays. Figure 1 shows the huge range of possibilities that warehouse managers face when designing order picking process.

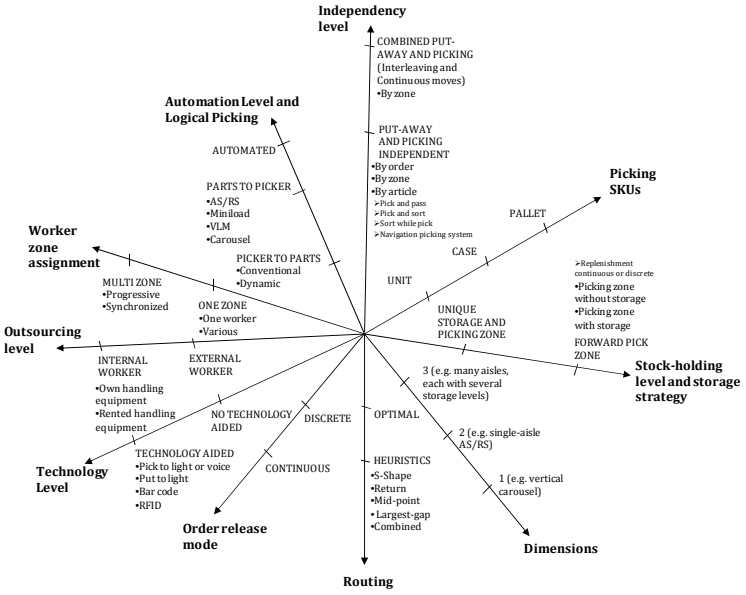


Fig. 1. Order picking design possibilities

Figure 2 exemplifies the alternatives proposed in view of the different order picking complexity levels.

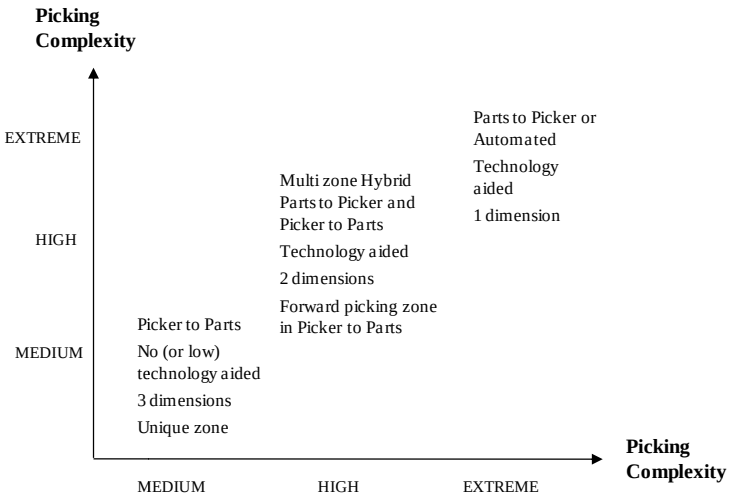


Fig. 2. General alternative chart

Three new charts with a higher degree of detailed of handling systems and equipments have been built in order to extend the information shown in Figure 2 (see Figure 3). Further information could be found in Errasti (2011).

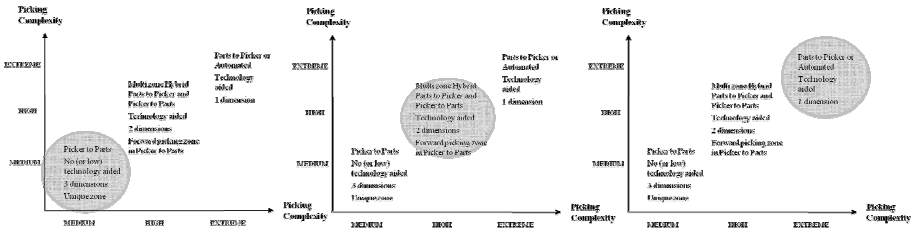


Fig. 3. Alternative charts according to order picking complexity level

3.3 Optimization of the Design Stage

In this step the most suitable alternative is selected. This selection is performed according to Frazelle's (2002) Key Performance Indicators KPIs (cost, utilization, productivity, quality and time), and a priority matrix is suggested in order to weight those metrics according to the business's characteristics.

The development of a Discrete Events Simulation model is suggested in order to compare the chosen alternatives during Characterization of the Design Stage. Chackelson et al. (2011) had verified the effectiveness of combining those techniques.

DoE is proposed with the aim of detecting interrelation between factors, and in order to be aware of how operational and organizational policies are affected by different demand characteristics. In other words, based on DoE approach, the methodology proposed in this paper involves a series of tests in which changes are made to the

input variables of the process or system in order to observe and identify the impact of these changes on the output response(s) (Montgomery 2008).

The experiments are carried out in the simulation model, which allows for the comparison of the maximum number of input and output variables, identifying the most significant effects and discarding the variables with less influence on performance. This technique can be adapted to a variety of situations as well as to fluctuating business needs.

It important to highlight that warehouse processes design is highly complex and it may not be possible to identify what is the *optimum* solution, owing to the high number of existing possibilities (Baker and Canessa 2009).

3.4 Verification Stage

A Verification Stage is needed in order to corroborate that the simulation computer program performs as intended and that it is also an accurate representation of the system under study. The obtained results can be used to support decision making process only after the simulation model has been subjected to this verification and validation process (Law and Kelton 1991).

With this aim in mind, different techniques could be used such as Animation or the Comparison of Simulated and the Real data (Kleijnen 1995, Sargent 1996).

4 Case research

In this study, we use a Case research carried out in the small appliances warehousing order picking process of a home appliances manufacturer in order to test the utility of the proposed methodology. The whole design procedure has been followed during the design of the order picking process, and at the moment the implementation is taking place successfully.

A description of the results obtained after the four steps of the order picking design methodology are described in this section.

Table 3. Case research priority matrix

FACTOR	Valuation Ranges			Weighing
Picking Volume (lines/t)	Lines<100	100<Lines<1000	1000<Lines	3
	1	2	3	
Storage unit vs. order unit	Ratio>75%	25%<Ratio<75%	25%>Ratio	3
	1	2	3	
Number of make to stock items	Number<100	100<Number<1000	1000<Number	2
	1	2	3	
Different order type	Number=1	Number=2	Number>3	1
	1	2	3	
Different Product characteristics	Number=1	Number=2	Number>3	1
	1	2	3	

According to Table 3, it is a Medium Picking situation because the value that determines the order picking complexity level is 19 = 2x3 + 2x3 + 2x2 + 2x1 + 1x1. Figure 4 shows the chart of alternatives that corresponds to that complexity level.

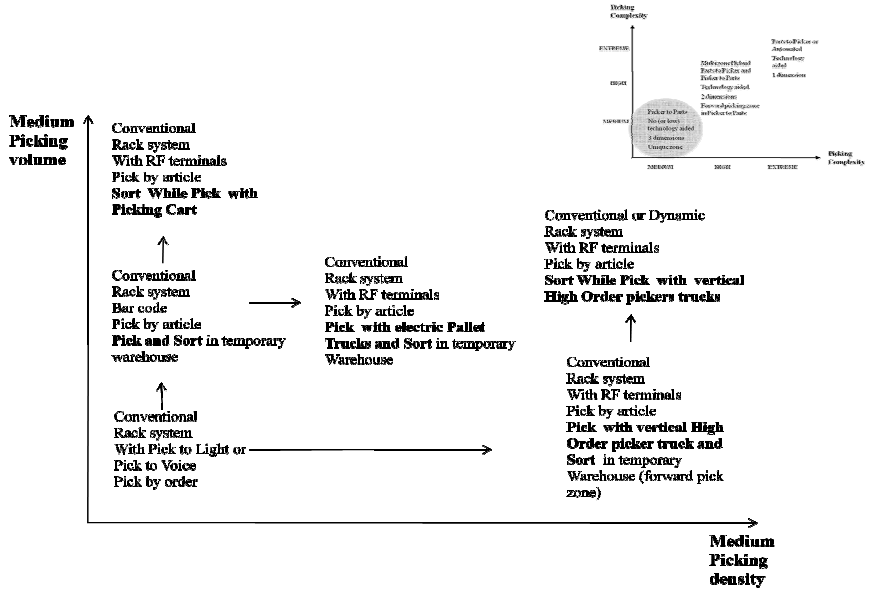


Fig. 4. Medium picking alternative chart

The warehouse designer selected a conventional rack system with electric pallet trucks. A discrete event simulation model using AnyLogic 6.6.0 University was built in order to analyze the following picking operational alternatives:

- Class-based storage strategy vs. family grouping
- Within-aisle vs. across-aisle storage implementation strategy
- Pick by-article vs. pick by-order

The criteria selected in order to determine the most suitable alternative was the travel distance (m/day). The following table shows the comparison between the analyzed possibilities:

Table 4

Storage strategy	Implementation policy	Batching	Travel distance	Improvement
Family grouping	-	By-order	46.191 m/day [2]	-
ABC class-based	Within-aisle storage	By-order	45.570 m/day [2]	1,4%
ABC class-based	Across-aisle storage	By-order	40.561 m/day [2]	14%
ABC class-based	Across-aisle storage	Combined [1]	39.724 m/day [2]	16%

[1] Combined: A-items by article and B and C items by order

The final design included an ABC class-based storage policy across-aisle, combined with a mix picking policy (A-items by article and B and C items by order) in a conventional rack system with electric pallet trucks.

5 Conclusion and future work

The present work is focused on order picking design. A novel methodology is proposed with the aim of filling: (1) the lack of a flexible order picking design framework, (2) the misuse of tools and techniques that allow the modeling and simulation of operative processes in the design or redesign phase of a operative process to be incorporated and (3) the scarcity of empirical investigations that allow the applicability of new procedures and technologies. Based on the Design for Six Sigma approach, this procedure assists the designer suggesting the most suitable picking alternatives according to the process complexity level (medium, high or extreme). The preferred alternatives are suggested to be compared according to according to Frazelle's (2002) Key Performance Indicators KPIs (cost, utilization, productivity, quality and time), and utilizing a discrete event simulation model. A Design of Experiments approach is also proposed with the aim of detecting interrelation between factors, and in order to be aware of how operational and organizational policies are affected by different demand characteristics.

A case research was carried out, where the warehouse designer admits to being satisfied with the support this methodology has provided him, and highlighted the power of visualizing the possible designs in a simulation model when selecting the final configuration.

Many authors state that *a comprehensive and science-based methodology for the overall design of warehouses does not appear to exist* (Baker and Canessa 2009, Gu et al 2010). This important concept is being taken into account while improving the recommended order picking design approach, while looking at a modular point of view that allows it to be easily incorporated into a generic methodology.

In addition, the proposed methodology only addresses design aspects from a material flow point of view. In future studies, sizing and dimensioning of order picking process from a stock perspective will be included.

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