PIECE PICKING TECHNOLOGY SELECTION

Dragan B. Đurđević [a,*], Momčilo D. Miljuš[a]

[a] University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia

Abstract: *Order picking is process that is realized in warehouses of unitize goods and includes all the activities that follows picking of demanded assortment of goods according to its kind and quantity in order to fulfill customers' demands. Order picking is known to be the most labor-intensive and also one of the most costly functions among all the warehouse functions. Depending on the types of retrieval units, types of order picking can be classified into pallet picking, case picking and piece (broken -case) picking. We focus our research on piece picking technologies. In order picking area piece order picking process could be realized on different and nowadays numerous technical solutions. During warehouse design process, selection and involvement those technologies for defined requirements, limits and functions is hard task. In this paper one approach of solving this problem is presented.*

Keywords: *piece picking, order picking, warehouse*

1. INTRODUCTION

Order picking (OP) is process that is realized in warehouses of unitize goods and includes all the activities that follows picking of demanded assortment of goods according to its kind and quantity in order to fulfill customers' demands. OP is known to be the most labor-intensive and also one of the most costly functions among all the warehouse functions. Depending on the types of retrieval units, OP can be classified into tree basic categories [Park (2012)]): (i) pallet picking, (ii) case picking and (iii) piece picking (Figure 1.1).

- (i) Pallet picking is present when the order concerns on homogenous pallet units picking;
- (ii) Case picking is realized when ordered quantities is less then whole quantity in homogenous pallet unit (few case units). This process is typical when pallet with mixed content is needed;
- (iii) Piece picking (PP) is also known as 'broken-case picking' or 'split-case picking' and involves an picking order, where the picking quantity is less than a full case or is in pieces. Here individual items are picked from crates or open cartons. On this occasion, dispatch units are formed, usually in the form of mixed cases. PP is

* d.djurdjevic@sf.bg.ac.rs

characterized with large number of item types, small quantities per pick, and short cycle times.

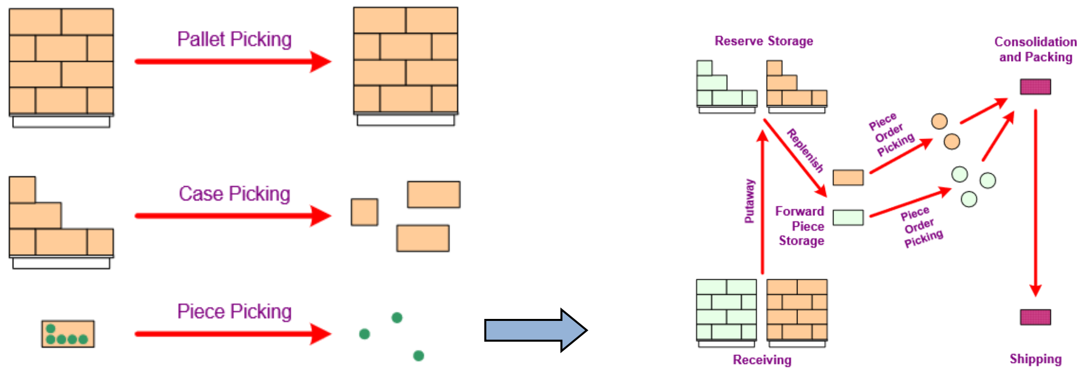


Figure 1.1. Trees basic categories of OP [Kay (2009)]

The picking operation has changed significantly over the past 20 years [Gwynne (2014)]. Nowadays present approaches (Just-in-time methods, increasing internet sales and initiatives such as efficient consumer response (ECR) and quick response (QR)) are resulting in smaller, more frequent orders. This again necessitates changes in warehouse operations, with a move away from full-pallet picking to case picking and PP. PP form of OP will be more dominant type of logistics activities in the future. All mentioned resulting that PP is the most complicated, costly, and most effort-intensive types of Order Picking System (OPS).

The designers of OPS therefore face great challenges, including: increasing labor costs, less available space and more frequent small orders with shorter delivery times. Consequently, there are constant research efforts devoted to new innovations that aim to reduce operational costs, generate higher productivity, optimize the space utilization rate and enhance service levels. Multiple and complicated requirements results that a lot of handling/equipment types are developed and present in technologies of PP processes.

OP technologies that could be applied in order picking area (OPA) are different and they are more numerous as the time passing by. During designing warehouse/OPA always is present dilemma which technology should be applied in real circumstances. Generally, problem of defining alternative technologies and decision which one to be selected is one of the hardest tasks during design process. This paper is focused on this problem and offers one possible approach to solve them.

The remainder of this paper is organized as follows. In chapter 2 some of basic alternative PP technologies are presented and classified. In chapter 3 one practical approach for generating and selection of technological conceptions piece picking (TCPP), with examples, is presented. Finally, in chapter 4 we conclude the paper and discuss opportunities for future research.

2. PP TECHNOLOGIES

The consideration of the OP process technology realization relates to the character of interrelationship, on the one hand, of technological requirements as parts of OP task, and on the other hand, on technological system elements [Vukićević (1995)]. Having in mind a wide range of OP tasks, an even greater set of OP solutions has been developed, based on the application of different technological elements - technologies for the realization of certain technological requirements in the OP process. They are characterized by different combinations of storage, handling, and transport technologies with different automation levels of these processes. Accordingly, it is possible from the technological aspect to apply the classification of piece picking system (PPS) to different criteria.

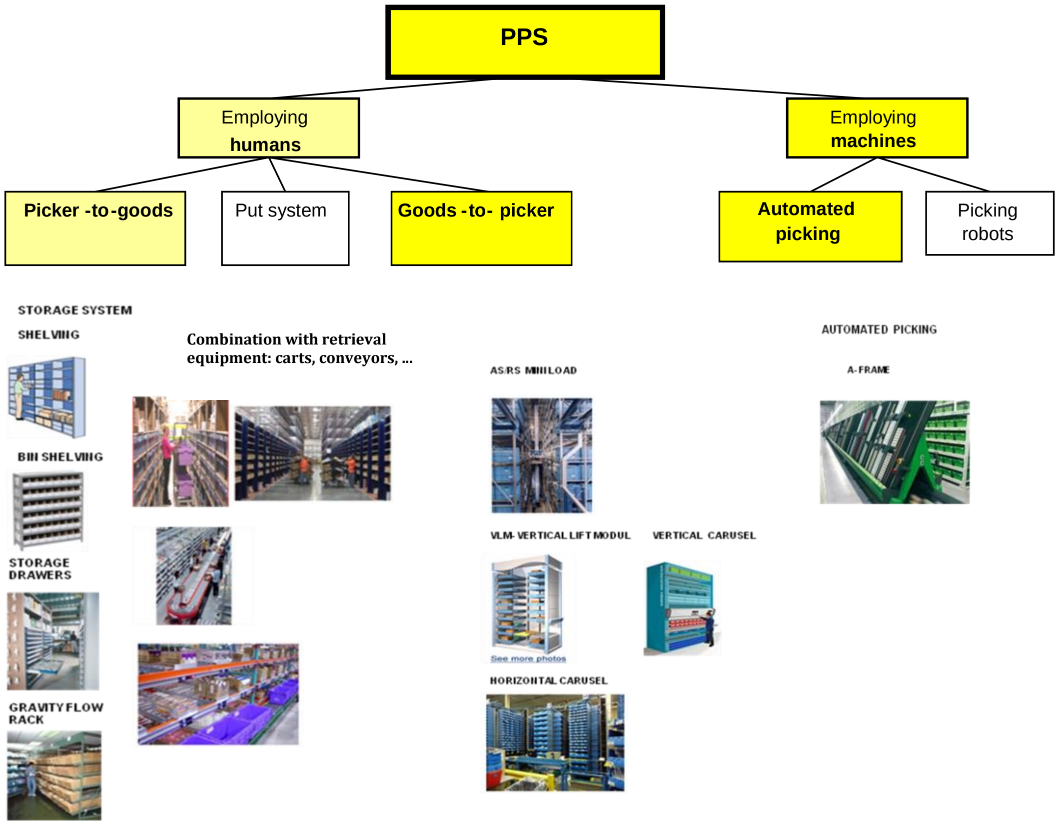


Figure 2.1. Classification of PPS (based on [de Koster et al. (2007)).

Technologies shown on the Figure 2.1 distinguishes PPS according to whether humans or automated machines are used [de Koster et al. (2007)]. The most of warehouses engage humans for OP. Among these, the *picker-to-goods* (PTG), where the order picker walks or drives to storage location to retrieve/pick items is typical. In PTG systems most popular storage equipment are: shelving, bin shelving, storage drawers and gravity flow rack. This equipment in typical technologies is often combined in various variants with retrieval equipments: picking carts, picking conveyors and order picker truck. In typical *goods-to-picker* (GTP) systems, the container or the storage location housing requested item is mechanically brought to the picker for retrieval. In GTP systems the retrieval equipments are typically integrated with storage equipments to become an automated storage/retrieval system. Consequently, usual GTP systems act as a modular subsystem of the whole warehouse system. In GTP systems, three popular storage/retrieval systems are: carousel systems, miniload systems, and vertical lift modul –VLM. An A-frame dispenser system is an *automated PPS* used for high-speed, high throughput OP of small and well packaged individual items with uniform size and shape. It consists of a set of dispensers in two rows configured as an A-frame. Typically, a conveyor runs through under the A-frame.

These various technologies suitable for different PP range from labor-intensive to highly automated. Each technology has its own set of advantages/disadvantages and compromises. They need to be analyzed first of all in terms of typical application, benefits, compromises (including the amount of space/footprint it requires, how easily it can be expanded, and the levels of throughput, productivity, accuracy, inventory control and ergonomics it supports), and general cost information. As the available space is limited, here will not be presented a more detailed description of these technologies. A good overview of PP technology is given in the literature: Gwynne (2014), Vukićević (1995), Hompel et al.(2011) and Frazelle (2002).

3. TECHNOLOGY SELECTION PROBLEM

The choice of OP technology is one of the most important decisions in warehouse designing with far-reaching consequences for its functioning. The designer have to choose the technology that will fully meet the set of defined goals. Some of the objectives a designer is required to optimize include maximizing throughput or minimizing cost, space, response time, or error-rate, or a combination there of. Technology selection problem, in literature, generally is solved using multi-criteria decision models [Pazour and Meller (2014)]. Research on material handling technology selection are relatively rare and three major approaches are distinguished [Gu and McGinnis (2010)]: (i) general frameworks for technology selection that are based on empirical experiences (e.g. Yoon and Sharp (1996) and Chackelson et al.(2012)); (ii) mathematical models and algorithms that are limited to selecting transport technologies (e.g. Noble and Tanchoco(1993)); and (iii) knowledge-based rules (e.g. Noble and Tanchoco(1993a) and [Dallari et al. (2009)).

None of these approaches gives full support for generating and selecting PP technology. It could be seen that the generation of variants is cited as an art part of the design process [Apple et al. (2010)] and hence it is not appropriately treated. An approach has been given in this paper, adapted for practical problem solving for the generating and selection of PP technology in the design process. Here, it will be presented in his basic steps and aspects.

3.1 Generating and selection of acceptable alternatives

The TCPP is defined over three basic components material handling (MH) technology, picker guidance and method of OP (Figure 3.1). Each of these components appears in a large number of functional forms, but only their purposeful/suitable/harmonized combinations, due to the high degree of interdependence, are feasible alternatives. From this set of feasible alternatives one a set of acceptable alternatives is defined, between which the final solution is chosen. It is clear that this is a very important design work - a decision with a high influence on the future functioning of the system. The selected alternative (technology solution) largely defines some global parameters that have a decisive impact on the cost and performance of the OP/warehouse that will be monitored for many years-often throughout its lifetime. Below is a methodological approach-procedure for obtaining acceptable alternatives.

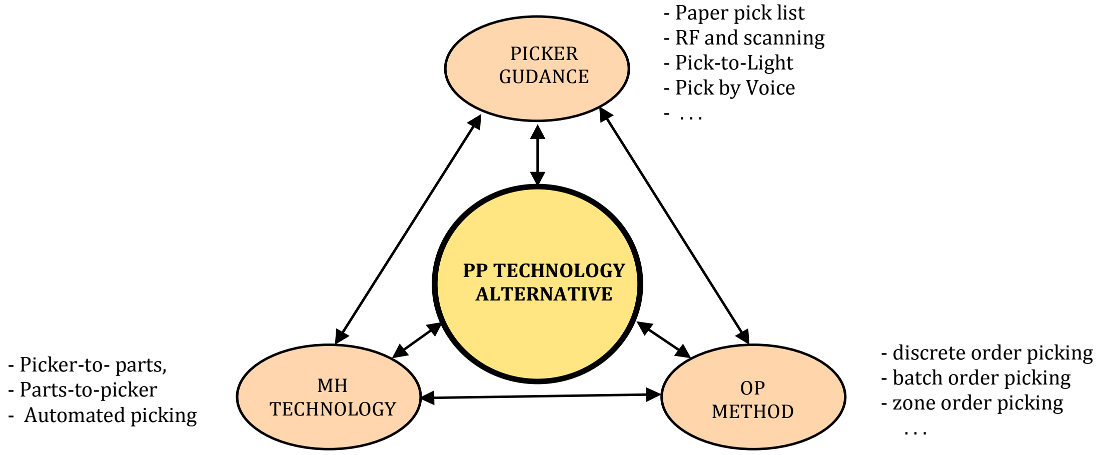


Figure 3.1. TCPP structure and interrelationship of basic components

3.2 Access to select alternative TCPP

Generating feasible TCPP alternatives is a creative act that involves knowledge of a large number of different variants of the partial components, their characteristics, as well as the possibility of combining them, or creating feasible alternative combinations. It could be described as a multiphase iterative process, where the basis of the solution - the concept - is chosen at the beginning, which is more precisely defined in each subsequent step of iteration, as the level of detail increases. In this way, there is a set of feasible alternative concepts, which number in some cases can be extremely large. This set of feasible variant concepts requires, for design purposes, the application of appropriate selection criteria to be reduced on 2-5 acceptable alternative concepts. Theoretically, it is necessary to carry out a two-step process which involves: (i) generating - developing feasible alternatives, and then (ii) applying the selection criteria to reduce this set to a set of acceptable alternatives. This approach requires significant time engagement so it is rarely applied in design practice. More often in practice, the choice of experience-based alternatives is applied when several types of alternatives (the most common ones applied in similar situations) are defined. This approach narrows the choice and carries the risk of omitting suitable alternatives from consideration. For these reasons, the approach is suggested to be faster than the theoretical and more effective in relation to practice.

The novelty of the proposed approach is to avoid the theoretical two-step approach (the first approach to the set of feasible and then the reduction to a set of acceptable alternatives) is avoided by introducing the selection criteria even in the process of generating alternatives, and in this way it allows shortening the time for determining acceptable alternatives.

In the shortest sense: in all phases of the process, those alternatives are chosen that correspond not only to the conditions of the task, but also to the relevant criteria (required performance and limitations). The choice of task parameters and the choice of relevant criteria have a particularly important place in this approach (more detailed in the examples in Chapter 3.3).

Setting and defining tasks in the general form, respecting all relevant parameters, their characteristics would not be a rational or convenient approach. A more favorable approach, from the aspect of designing and making certain project decisions, is the one that defines and adjusts the task in relation to the decisions that need to be taken. Selected parameters of the task and their characteristics direct the process of generating - the development of potential alternatives (Table 3.1), and at the same time the relevant criteria is included in this process and reduces the number of alternatives, which can sometimes be large, to a narrow set of acceptable alternatives (Figure 3.2).

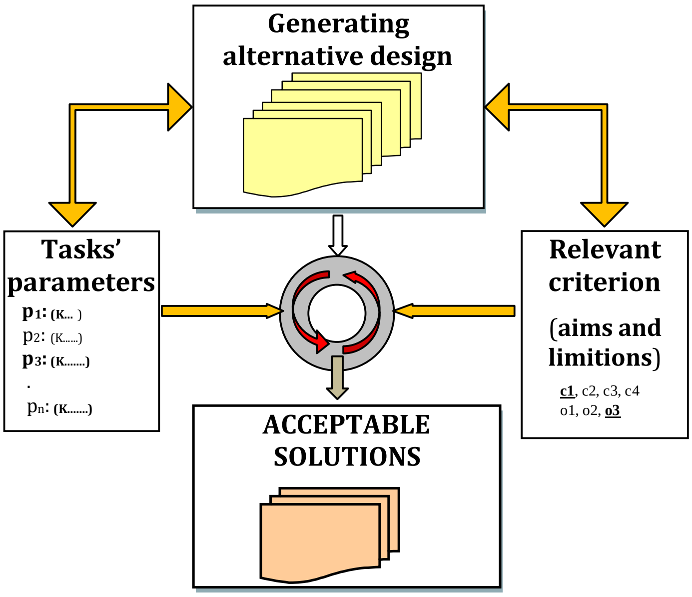


Figure 3.2 Relation of relevant factors of acceptable alternative selection

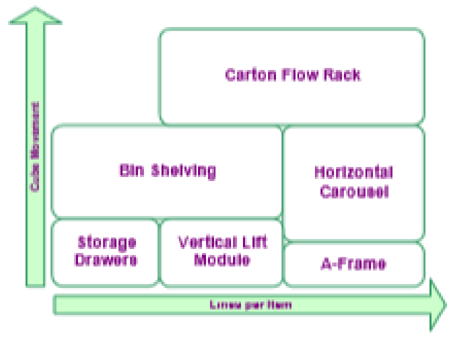
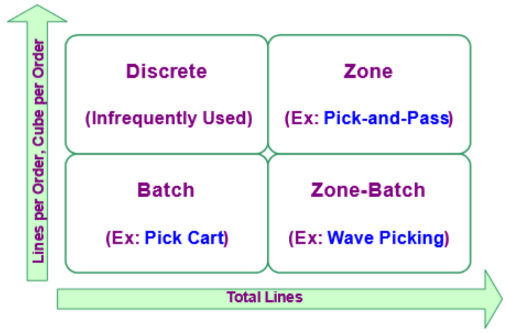
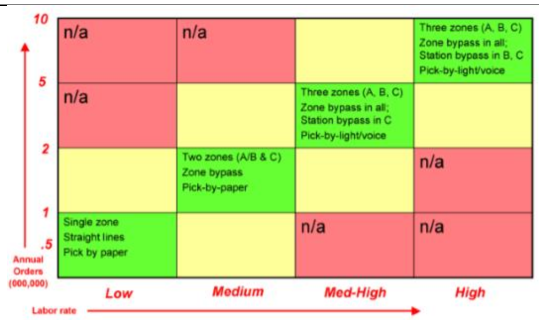
In this way, in all phases of the process of alternative generating, with the adjustment of the task (by selecting and introducing new parameters) and choosing the criteria, the selected acceptable alternatives from the previous phase are more closely defined to the final form. The time of favorable alternatives developing is significantly reduced, relative to the theoretical approach, for the purpose of reducing the search area and the necessary number of iterations. Alternatives selection and elimination processes are based on the application of logical and/or low-level quantitative analysis that allows the designer to decide in the early stages of generating alternatives whether any of them keep on into the analysis procedure or is rejected. A necessary assumption for their implementation and making valid decisions is the knowledge and/or assessment of the basic performance measures (eg: flow, service levels, costs, utilization rate, etc.) of individual alternatives.

Below are given recommendations for development and making decision on selection of variants TCPP. On one example, a selection of relevant task parameters was presented in the function of making certain decisions.

3.3 Recommendations for development and making decision on selection of TCPP

The recommendations for development and decision making on the selection of variants TCPP are demonstrated on one example. Selection of relevant task parameters was presented in the function of making certain decisions. In order to obtain relevant parameters / task information, it is necessary to carry out processing of data on goods, customer orders, system requirements and constrains using appropriate analytical procedures and methods [Frazelle (2002) and [Sharp et al. (2008)]. The obtained parameters and their quantitative characteristics (for different quantitative ranges), using the appropriate graphics, will serve as the basis for making certain project decisions (Table3.1).

Table 3.1- The selection of relevant task parameters in the function of making certain decisions [based on: Frazelle (2002) and Apple et al. (2010)]

What select_? (decision)	Relevant tasks parameters	Graphic
Appropriate type of ***MH technology***	***Cube Movement***—*the total unit demand of the item over some period of time times the cubic volume of each unit (representative of the cube in storage for the item);* ***Lines per Item*** *(a.k.a. popularity)—the total number of lines for the item in all orders over some period of time (representative of picking activity for item)*	
Appropriate ***OP method***	***Lines per Order***—*the average number of different items (i.e., lines or SKUs) in an order;* ***Cube per Order***—*the average total cubic volume of all of the units (i.e., pieces) in an order;* ***Total Lines***—*the total number of lines for all items in all orders over some period of time (representative of total picking activity);.*	
Appropriate **Picker guidance**	***Activity*** ***Labor Cost***	

Of course, they only allow for a coarse selection of technology, and for further steps in the process of generating alternatives it is necessary to include other auxiliary tools, e.g. matrix of compatibility. Compatibility matrices will allow you to identify the possibility of combining individual partial components into a feasible alternative. In addition, significant selection assistance provides information on the typical applications of particular alternatives (technologies, methods, etc.), their advantages and disadvantages. For example, for certain alternative technologies within the PTG system, the question of combining the storage and transport equipment, or the application of carts or conveyors, is raised. Defining the appropriate method is typically made based on the overall size of the OPA (travel requirements), throughput of goods (velocity) and pick density (e.g. in Table 3.2)

Table 3.2 Mode of Order Transportation [www.opsdesign.com]

	Commonly Used Operations	Benefits	"Draw Backs"
Pick to Cart	▪ Large number of items with low movement per item ▪ Full case and piece picks operations with little system support to split out the orders	▪ No conveyor cost ▪ Highly flexible ▪ Multiple pickers per zone, if required	▪ Low pick rate due to typically long travel paths
Pick to Conveyor	▪ Low number of items ▪ High volume items ▪ Large number of very small items (i.e. jewelry)	▪ High pick rate due to small pick zones	▪ Typically only one picker per zone ▪ Conveyor cost

Each of the alternatives is characterized by different potentials in terms of performance(s) (productivity, service level, flexibility, etc.), costs (different requirements in terms of resource recruitment (space, people, technology) and related investment and operational costs). In accordance with the methodology described in C hapter 3.2 it is necessary to include the selected relevant criteria in the selection of variants in all stages of the process. Criteria appear either as a goal or as a constraint. For example when they appear as a constraint, it is necessary to reach the target values without exceeding the given limits (e.g. the price of the system). As an example / help for roughly examining the performance of certain alternatives can be used by sources and data on productivity, initial costs, etc. (e.g. Table3.3 and Table 3.4).

Table 3.3 Summary Characteristics of Alternative PPS [Frazelle (2002)]

System Attribute	Unit of Measure	Bin Shelving	Gravity Flow Racks	Storage Drawers	Horizontal Carousel	Vertical Carousel	Miniload AS/RS	Automatic Dispersing
Gross system cost	Initial cost/ purchased Ft3	$5–15	$3–5	$25–30	$20–35	$40–70	$30–40	$300–600 per dispens
Net system cost	Initial cost/ available Ft3	$10–30	$9–15	$31–38	$40–70	$65–100	$38–50	
Floorspace requirements	Ft3 of inventory housed per Ft2 of floorspace	1–1.2	0.7–0.85	1.8–2.5	0.8–1.25	5.0–6.0	4.0–5.0	
Human factors	Ease of retrieval	Average	Average	Good	Average	Excellent	Excellent	Good
Maintenance requirements		Low	Low	Low	Medium	Medium	High	High
Item security		Average	Average	Excellent	Good	Excellent	Excellent	Average
Flexibility	Ease to reconfigure	High	High	High	Medium	Low	Low	Low
Pick rate	Order lines per person-hour	C: 25–125, T: 100–350, M: 25–250, W: 300–500	C: 25–125, T: 100–350, M: 25–250, W: 300–500	C: 25–125, T: 100–350, M: 25–250, W: 300–500	50–250	50–300	25–125	500–1,000
Key	T = Tote picking	C = Cart picking	M= Man-aboard ASRS	W= Wave picking				

Table3. 4… Key parameters for each pick technology types, including typical pick rates, low/medium/high ranges for SKUs, volume, order rates and product size, plus typical accuracy rates. [www.hksystems.com]

Attribute	Technology													
	Floor Shelving	"Man-up" VNA	Flow Rack	AS/RS (w/ Side Ports)	Horizontal Carousel	Vertical Carousel	Vertical Lift Module	AS/RS (End-of-aisle)	Case Sequen-cer	A-Frame	Robot	Tilt-Tray Sorter	Cross Belt Sorter	Dispen-sing System
Typical Pick Rate/Hr.	20-250	13-23	20-350	50-200	200-500	50-100	100-200	50-300	100-500	8,000-15,000	1,200-8,000	6,000-20,000	5,000-10,000	150-350
Number of SKUs	LM	L	LM	MH	LM	LM	MH	MH	LMH	LMH	LMH	H	MH	L
Cubic Volume	LM	LMH	LM	LM	MH	LM	LM	H	MH	L	LM	LMH	LM	M
Number of Orders	L	L	LM	LM	M	L	M	M	MH	H	MH	H	H	M
Item Size	LM	LMH	LM	LM	LM	L	LM	LM	LM	L	LM	LMH	LM	L
Accuracy (%)	90-95	90-95	99	99.9	99.9	99.9	99.9	99.9	99.99	95	100	99.8	99.5	100
Variable Unit Costs	$.07-1.25	$.87-1.92	$.06-1.25	$.07-.25	$.05-16	$.21-.56	$.10-.25	$.07-.50	$.01-.10	<$.01-.08	<$.01-.06	<$.01-.08	$.02-.10	<.$01-.06

LMH = low, medium, high

4. CONCLUSION

During designing a warehouse / OPS, the selection of technology is a significant and difficult task, especially expressed in the case of generating and selecting PP (probably one of the most complex tasks in the area of the warehouse design). In spite of its importance, this problem is not appropriately treated in the literature. Developed models and achieved results do not allow direct application and support in making project decisions that the practitioners / designers of these systems are involved. This paper represents an solution to correct this insufficiency in an appropriate way. The paper presents a methodological method adapted to practical problem solving generation and selection of acceptable variants. It enables the selection of the relevant project criteria in the process / process of generating alternatives (primarily guided by the parameters of the task and their characteristics) at the same time. In this way, quality and speed are ensured - the efficiency of the design process. The paper can be used as the basis for the development of a future ***decision support system*** (DSS) that would provide significant support in warehouse design processes.

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