LAPPEENRANNAN TEKNILLINEN YLIOPISTO
Teknillinen tiedekunta
Konetekniikan osasto
BK10A0400 Kandidaatintyö ja seminaari

FINDING THE POSSIBLE ADVANTAGES IN RECEIVING, WAREHOUSING AND PICKING UP GOODS

LAPPEENRANNASSA 13.12.2010
Jaakko Warén

1 INTRODUCTION

In this 21st century world competition in business world is extremely hard regardless of the exact field. Companies throughout the world are constantly trying to find better and more efficient ways of operating, keeping their different stock levels up to date and other operations visible to see potential ways to improve their procedures. Many companies have already implemented different ways of making warehousing operations faster and more accurate is necessary in every reasonable business.

This paper tries to find the possible advantages of implementing a bar code system in a large Finnish engineering company in its warehousing operations e.g. receiving and booking, shelving and inventorying and picking up goods. As discussed with the case company in the preliminary meeting operations that take place before goods arrive at receiving area and after they are delivered to the intermediate storage are touched upon only briefly though many of the savings come not from the operations them self but from the possibility for more accurate inventory levels, more accurate ordering etc.

1.1 Case company

The case company used in this paper is actually division of a larger enterprise but for simplicity reasons it will be referred to as the target company from now on.

The company has around 500 employees and around 100M€-200M€ sales per year. The company designs, engineers and manufactures products that are often unique and engineered-to-order. Products are often based on modules and have some modifications. There is also a large after sales market in service department.

1.2 Defining the subject and structure

This paper will act as an initiative to start a more in depth study, which is needed to successfully implement a barcode system.

We will first discuss different aspects of supply chain and supply chain management without going too much into details. We will also take a look at different warehousing operations. In the preliminary meeting with the case company the operations being looked at more closely are receiving, put-away, and picking and these will be examined a little bit more than the others. Once we have found out the functions in the warehouse we will look at automatic identification systems in general.

We will take also closer look at how the process of how implementing a barcode system should be conducted and in the results chapter suggest some potential subjects for research as the next step for the process.

Next we will take a look at some different types of barcodes and what should be considered when choosing a type of code to be used. We will also shortly discuss the hardware needed in the system. Software issues are touched upon only very briefly.

To be able to give at least some estimates on if the research should be carried out further we will next look at some financial metrics and calculations on possible savings made by implementing such a system.

2 SUPPLY CHAIN, SUPPLY CHAIN MANAGEMENT AND AUTOMATIC IDENTIFICATION SYSTEMS

The terms logistics and supply chain management have been defined in countless different ways but for the purposes of this paper we will use the “6Rs” listed by ten Hompel to describe the purposes and targets of both logistics and supply chain management in general. The 6Rs are (ten Hompel 2007, p. 14):

- the right goods at the
- right time at the
- right quantity at the
- right quality at the right location at the
- right price.

Enterprise resource planning (ERP) systems are used in companies around the world to answer to the global pressure for more control in material flows in both retail and manufacturing environments. ERPs can be used to control different financial, logistics and marketing functions based on the data gathered. To make the decisions optimal it is vital that the data concerning the location and the quantity is always up to date. Bar codes are a great tool for a company that wants to use its existing ERP system to its limits. (Gel 2010, p. 153)

Without a doubt one of the most important gains of using any automatic identification system is its impact in inventory management. In general, in today´s manufacturing environment the time span between an operation taking place on factory floor and it registering in the computer system is too long. The result often is that the company starts to build up safety stocks and using safety lead times in order to make up for this “blind spot”. Bigger warehouses tie up a lot of capital and the initial problem is still unaddressed. (Lindau 1999, p. 159)

The potential for inventory errors arises every time the information is updated. Studies have shown that human data entry has an error rate around 1/300 characters (Lindau 1999, p. 160). Errors occur in both entering faulty amounts and entering faulty part numbers. Entering similar data using barcodes the error rate can be reduced to less than 1/2 000 000 (Osman 2000, p. 53). Besides being near perfect accurate, they also enable workers to work faster without sacrificing accuracy. In addition to accuracy and faster input if barcodes are being used right they can enable real-time monitoring of warehousing operations which is substantially more difficult to achieve with manual data input (Bar Coding 101 2007, pp. 1-2).

2.1 Order picking

One of the most important tasks in any warehouse is order-picking or "the process of retrieving products from storage (or buffer areas) in response to a specific customer request" (de Koster, 2007, p. 481). Order picking is the most labour intensive tasks in the warehouse and thus often a high priority when trying to improve productivity in any warehouse. Order picker´s working time can be divided into different parts. The time required by each task is obviously different in different warehouses but a typical picker´s time distribution is shown in figure 1 from which we can see that there is definitely some time to be skimmed from the picking time. A typical warehouse goods flow and functions are shown in figure 2.

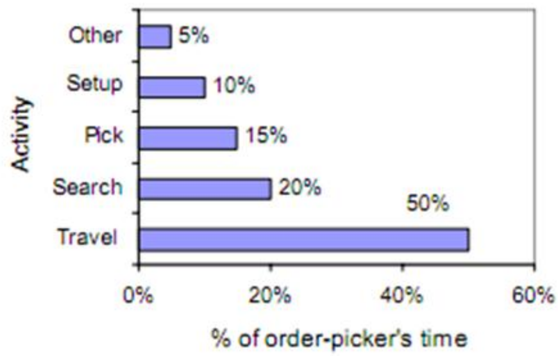

Figure 1. Typical distribution of order-pickers work time (de Koster 2007, p. 486).

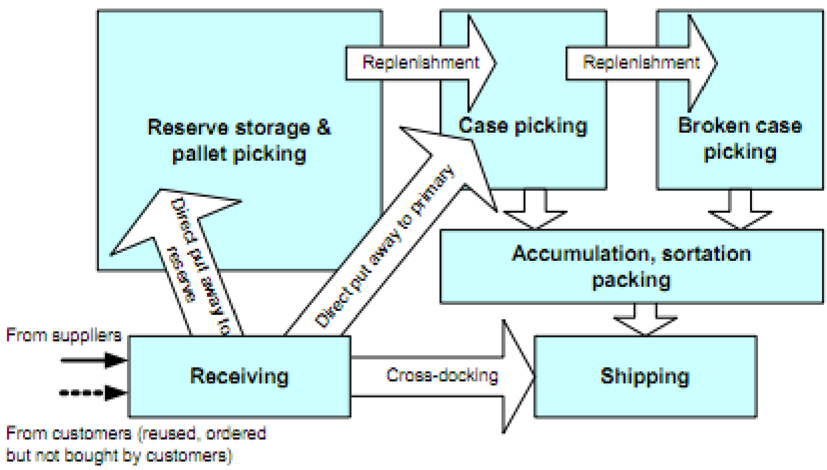

Figure 2. Typical materials flows and functions (de Koster 2007, p. 483).

2.2 Receiving

Receiving means unloading the products, checking for any quantity or quality inconsistencies and updating the inventory records accordingly. In transfer and put-away stages the incoming goods are taken to the correct warehouse locations. (de Koster 2007, p. 483)

2.3 The structure of an automatic identification system

An automatic identification system consists of the object to be identified, a machine readable code (bar code, silicon ship, etc.) the reading device & the decoder and from the computer software. The basic structure of a basic automatic identification system is shown in figure 3.

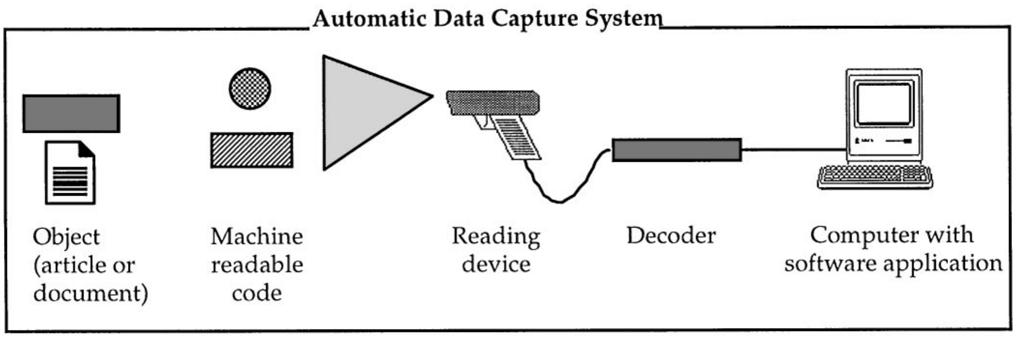

Figure 3. Automatic identification system (Lindau 1999, p. 160).

Even though technologies may vary in some ways (e.g. in the way that the data is transferred from the reader trough the reader to the computer) the basic structure remains the same. A list of features that a good automatic identification system has can also be crafted. ten Hompels list from 2007 is:

- an ensured reading reliability
- a sufficient reading speed
- possibility to generate a sufficient number of identification tags
- a reading distance adjustable to given conditions
- an ensured compatibility to other supply chain members
- cost efficiency of identification systems and operating means.

3 THE PROCESS OF IMPLEMENTING A BARCODE SYSTEM

Implementation of a barcode system consists of a few stages that can be used as a guideline when developing an existing system or when planning on implementing an all new system. The stages paraphrasing Manthou (2001) and Nabhani (2008) are:

- preliminary investigation
- mapping current state
- visualizing future state
- calculating costs and benefits of future state
- development
- implementation and evaluation.

The stages of implementing a barcode system according to Manthou (2001) is pictured more clearly in the appendix 1 and Figure 4.

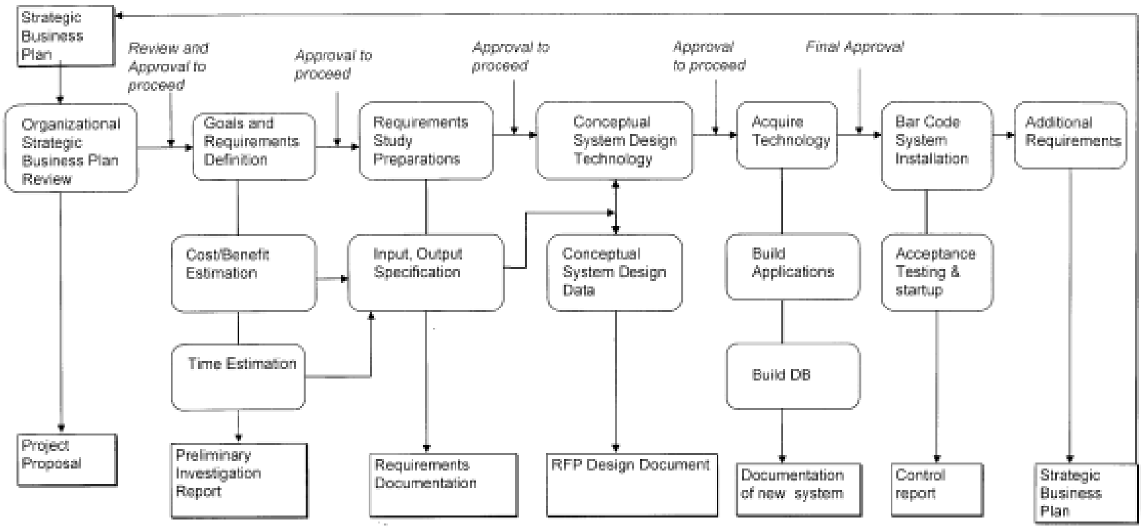

Figure 4. A model for developing and implementing of a barcode system (Manthou 2001, p. 160).

The first step of planning is to define company´s goals. Typical goals may be reduction of errors, timely data for inventory control, improving customer service etc. Setting goals early in the project will be of great help later when making decisions with critical important. In preliminary investigation stage a company can also for example study different vendors, attend trade shows and survey similar companies that already have implemented such system. .(Manthou 2001, pp. 159-161; Nabhani 2008, pp. 32-33)

Mapping of current state examines how and why the processes are currently carried out and helps to set correct goals. This can be done for example through direct observation, collecting live data from the shop floor and auditing persons involved in the process. The result should be a deep understanding of the process and a complete well documented process map with all the steps in the process timed divided into e.g. operational, transportation, delay, storage and inspection. As part of the preliminary investigations at least a preliminary budget as well as an investigation on software should be done with the vendor company.(Manthou 2001, pp. 159-161; Nabhani 2008, pp. 32-33

After completing review of the existing system as well as the desired state the vendors and the project team can start evaluating different hardware and software options. These stages are crucial and it is important that both the company and the supplier of the system understand what the goals are for implementing the system. After a decision of implementing a barcode system it is also crucial to train the workers well and to tell them about the goals. There are many moving parts in barcode systems (software, hardware, locations of the scanners etc.) and it important to evaluate and modify the operations after some time has passed from the implementation. (Manthou 2001, pp. 159-161)

4 BAR CODES

A bar code is basically a series of varying width vertical lines (bars) and spaces called elements. Different combinations of lines and spaces represent different characters depending on the type of code being used. These characters can be “read” with a scanner, decoded and passed on to a computer in a traditional data format. Bar codes are by all means all the same but can differ in a number of ways. Some can only represent numerals whereas some codes allow the use of full ASCII characters. There are more than 50 different types of barcodes but only a handful is in common use, the range from which to choose from is still quite large. Even more options open when one takes into consideration two-dimensional bar codes and optional technologies (e.g. RFID). (Bar Code Primer, pp. 1-2; Osman 2000, p. 52; ten Hompel 2006, p. 182)

An important feature of a barcode is the code length and the data density. Different barcode symbologies meet different requirements for maximum/minimum space in different ways.

4.1 Code 2/5

Code 2/5 might just be the simplest code available. It is a great code to demonstrate the principles of barcoding. A Code 2/5 character consists of five elements and two different element widths. Of the five elements two are always wide and three narrow. The code is basically a binary code in graphic form. Code 2/5 is limited in its use as it can only represent the numbers from 0-9 in addition to the start and end characters. The full set of characters represented by Code 2/5 is shown in figure 5. Code 2/5 uses a simple check digit to minimalize the number of errors in reading. The check digit is calculated based on the previous characters.

Character	Binary pattern	Barcode	Character	Binary pattern	Barcode
Start	110		Stop	101	
0	00110		1	10001	
2	01001		3	11000	
4	00101		5	10100	
6	01100		7	00011	
8	10010		9	01010	

= Start = Stop

Figure 5. The full set of characters represented by Code 2/5 (ten Hompel 2007, p. 183).

4.2 Code 128

A typical multi width barcode Code 128 is based on four different element widths and on three bars and spaces per character. Code 128 can represent the full ASCII characters from 0 to 127. Code 128 also uses three different character sets. Character set used in a specific barcode is recognised by different start characters for each of these set. The use of 3 character sets further adds the total number of characters to more than 200 characters by using 106 different barcodes. The full Code 128 is shown in Appendix 2. (ten Hompel 2007, p. 188)

4.3 PDF417

PDF417 (portable data file) is a widely used stacked barcode and a example of 2D barcodes. Each character is coded into a codeword with a width of 17 modules which consist of four differently widy spaces and bars. There are 3-90 rows and a maximum capacity of 1850 ASCII characters, 2710 numbers or 1108 data bytes. An example of PDF417 is shown in Figure 6. (ten Hompel 2007, pp. 211-212; Osman 2000, p. 55)

Two dimensional barcodes require different reading technology than normal barcodes i.e. camera systems.

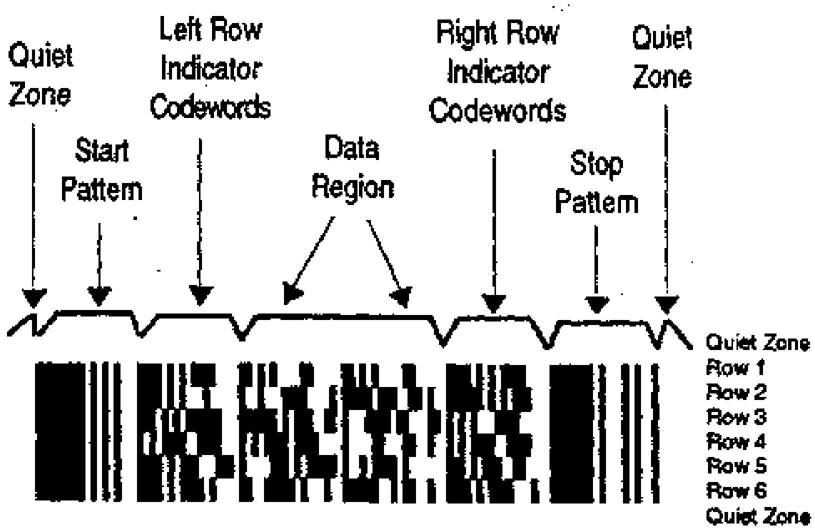

Figure 6. PDF417.(www.barcodemanufacturer.com)

4.4 RFID

RFID is not a barcode but an electronic device used in a similar way than a barcode. Typically, an RFID tag consists of a small silicon chip and an antenna. A radio frequency reader reads the tag and identifies the product in away pretty similar to barcode but the biggest difference in usage is that RFID does not require a direct line of sight. RFID tags differ a lot in data-storage capacity and in “smartness”.

The printing costs of an RFID tag cost around 10 cents per tag (in year 2006). When maintenance etc. costs are taken into account the cost of a RFID tag is around 20-30 cents (Twist 2004, p. 229; Pisello 2007, p. 40). Additional costs arise from readers which retail around a few thousand euros including installation and accessories. Labor cost savings in manufacturing industry have been estimated at 9 % after implementing a RFID system. (Pisello 2006, p. 4; Lee 2007, p. 40)

A comparison between RFID system and a barcode system is shown in figure 7 and a pros and cons list is presented in Figure 8. As we can see in any other category RFID tags are generally better than barcodes except for costs.

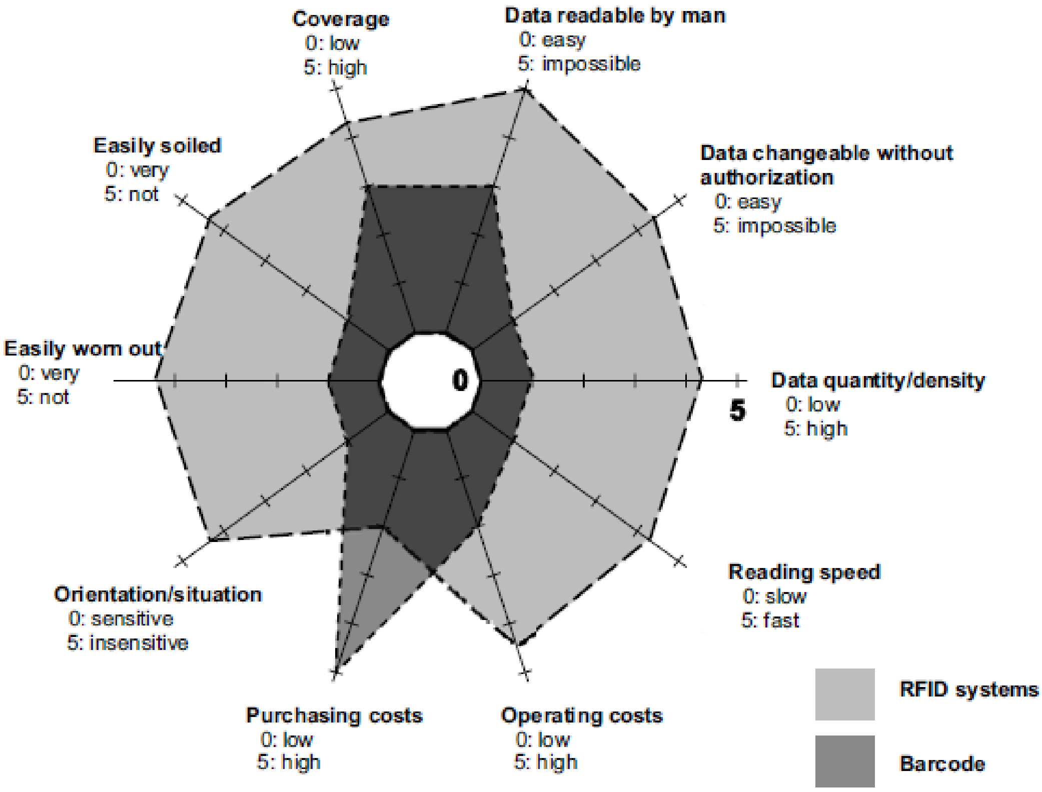

Figure 7. Comparison between barcodes and RFID (ten Hompel, 2006, p. 220).

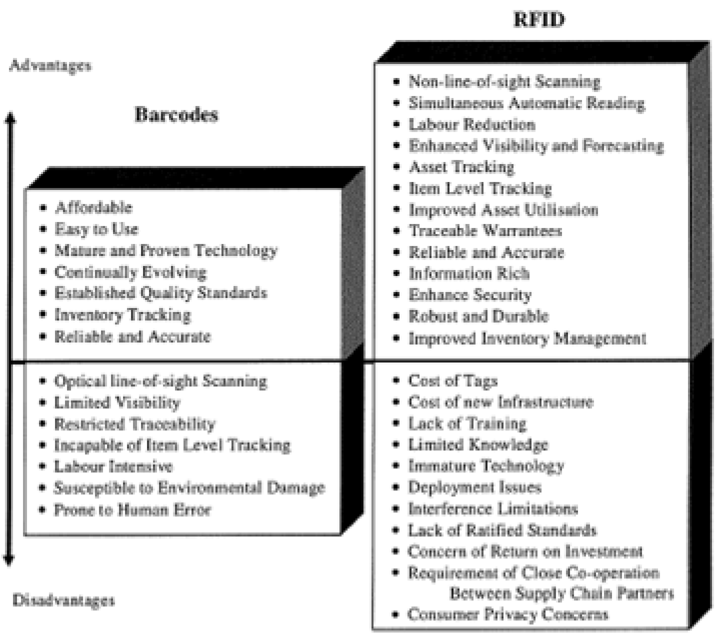

Figure 8. Comparing barcodes and RFID tags (McCathie 2005, p. 14).

4.5 Printing barcodes

To be read correctly a barcode has to be attached to the item. This labelling can be done with a number of methods which can be divided into two groups; direct labelling and indirect labelling. The most important quality criteria for printing barcodes are (ten Hompel 2007, p. 198):

- contrast between light and dark
- dimensional accuracy of the print
- contour sharpness
- congruence for black surfaces
- resolution (especially for very small codes)
- UV/scratch/smear/water/etc. resistant.

Direct labelling refers to techniques such as engraving or printing the code to the item itself. Indirect labelling means that the code is printed to a separate paper etc. While often being in poorer quality direct labelling can be a cost effective way to label items in the process of manufacturing them. When done right direct labelling also offers some possible cost reductions in removing printers and printing from the process direct labelling and ensures that the code is permanently attached to the item. Indirect labelling is used more often in logistics systems. (ten Hompel 2007, p. 198)
The quality of the data is an important, but not only, factor in choosing the printer technology. In tough choices the purchasing and operating costs often rise as criteria above others. In addition to quality and costs some of the aspects to be considered are (ten Hompel 2007, p. 198):

- printing speed
- barcode to be used
- changeability of the data contents
- space available for the bar code.

4.6 Reading barcodes

Barcode reader consists of a scanner and a decoder. To be read consistently without errors the print contrast signal of the code has to be at least 70 % for some older scanners and roughly half of that for newer devices. The equation for calculating the contrast signal is presented in equation 1, where rl is the reflectivity of the background and rs is the reflectivity of the barcode (ten Hompel, 2007, p. 208):

$$dk = 100\%(\frac{(\frac{rl}{rs})}{rl}),$$

where rl is the reflectivity of the background and rs is the reflectivity of the barcode.

Handheld scanners work by emitting light which is reflected from the code and converted into voltage in the diode. A digital signal is created and it is then decoded in either a built in decoder or with separate software into ASCII form. Scanners generally have an RS232 interface but some scanners can also be plugged to e.g. between the computer and the keyboard in which case the scanner works like computer keyboard (ten Hompel, 2007, p. 209)

4.7 Advantages, challenges and costs of barcoding

In 1998 UNOVA conducted a study about barcodes and their use in manufacturing industry especially in the U.S. 505 barcode (or some other automatic identification technology) using companys and 520 non-users answered to the survey and some of the results were:

- barcode users reported 10 % better ROIs
- barcode users reports decreased manufacturing times and decreased manufacturing cucle time.

Maybe more interesting than these were however the differences between companies that had extremely skilled/well trained users compared to those companies that had users with only some skill:

- extremely skilled users reported 19,7 ROI whereas users with some skill only 17,7%
- 89% of companies using barcodes reported decreased manufacturing costs in the last three years whereas only 81% companies with users of only some skill did.

It could be said that if barcodes bring more ROI and savings training of the workers should not be neglected.

Barcoding is generally considered a simple and inexpensive technology. Printing a barcode costs only around one cent per code (McCathie, 2005, p. 2). Scanners that are robust enough to be used in a manufacturing environment retail around 2000€ and the purchasing of software vary a lot but can be next to nothing depending on the code to be used.

5 FINANCIAL METRICS FOR ANALYZING INVESTMENTS

When trying to define potential for investments one has to make estimates of the benefits and costs from the investment. Benefits from installing a barcode system can be roughly estimated using equations

Process saving costs can be calculated if we can estimate the reduction in process time (in hours) and multiplying the time with orders handled (n) and hourly labor costs.

$$Process\ Savings\ per\ producs =$$
$$Reduction\ in\ time\ [h] \times items\ [n] \times labour\ costs\ [\frac{€}{h}]$$

There is a significant number of money tied up in safety stocks. Safety stocks exist because supply and demand don´t always match perfectly. According to Lindau (1999, p. 161) they serve five purposes, they:

- enable achieving economics of scale,
- balance supply and demand,
- enable specialization in manufacturing,
- provide protection against uncertain demand and order cycle,
- act as buffer between critical interfaces.

Accurate inventorying is crucial in trying to reduce safety stocks and as barcodes, when used right, help reducing safety stocks we can also take them into calculations. Savings from safety stocks are calculated (Nabhani 2008, p. 39):

$$Savings\ from\ safety\ stock$$
$$= Carryin\ cost\ \%\ \times Total\ Inventory\ Value\ x\ Safety\ Cost\ \%$$

Additional benefits can be found from the reduced inventory times. In studies it has been shown that the inventory times can be reduced up to 80 % using automatic identification systems (Nabhani 2008, p. 39).

Benefit cost ratio is one of the best simple financial metrics for analyzing if an investment is worth making. As the name indicates it is simply the financial benefits (earnings or savings) divided by the costs of the investment. Equation for BCR is:

$$BCR = \frac{Benefits}{Costs}$$

If we want to calculate how long it would take for the investment to pay itself back we can use payback period PP. Payback period is calculated:

$$PP = \frac{Costs}{Benefits}$$

6 CURRENT WAREHOUSING OPERATIONS - A ROUGH PROCESS REVIEW

The company has instructions concerning receiving and picking up goods and the instructions are followed reasonably well.

6.1 Receiving goods

The flow of goods starts from the moment they arrive in the warehouse. Goods arrive to the warehouses receiving area and a warehouse worker takes the list of goods from the pallet and inserts the order number to company´s ERP system. If everything on the delivery note is found on the pallet the status of delivery is changed to “received”. If there are items missing or items have been damaged during transportation this is noted in the delivery note. And the buyer responsible for this delivery is informed so that a claim can be done. According to the instructions the orders should be received within 24 hours of their arrival to the warehouse.

A list with storage locations is then printed out and the items are taken to their correct locations in the warehouse. If for some reason items can´t be placed to their assigned locations they are often placed in some available free space in the warehouse and a note is left to the “correct” place.

Arriving items can be assigned to a certain project already when they are purchased, in which case they are often left to the receiving area as they are going to be picked soon. This leads to the receiving area being disorganized and picking/stock level errors can happen.

Stock level errors also occur when assembly team members without being properly instructed take items from the shelves and often forgetting to tell the warehouse about it. Stock level errors make it much more difficult to keep the replenishment order levels at optimal levels.

6.2 Picking up goods

The picking process is guided by a manufacturing project schedule. Warehouse coach advices the warehouse team on each project according to this schedule. According to the instructions the workers should be instructed of every picking project at least a week before it is due to start. Manufacturing team coach instructs the warehouse if the schedule needs to be changed.

Warehouse workers print out picking lists according to the schedule provided and pick them from the warehouse often using a fork-lift. Picking for each project is usually divided into smaller parts and each of these is picked separately usually to one pallet. If any exceptions in the stock levels are noticed they should, according to the instructions, be corrected immediately.

After each item is picked and marked to the picking list the picked parts are taken to the assembly teams intermediate warehouse and a copy of the picking list is attached and marked as picked to the bulletin board next to it. The bulletin board is used to let the assembly team let know which items are ready to be installed into the assembly.

When picking is done picker enters the picked items into the ERP system and their status is changed to “delivered”. If there were some items that could not be picked (due to e.g. pallets being left in the wrong places or stock level errors) a different list is being kept in the warehouse for replenishment picking. This list is checked regularly by warehouse and the items that were missing are delivered to the pallet in the intermediate warehouse.

Currently it takes between 80-100 hours to pick up all the parts required to manufacture the product in case. There are some 1000 different parts and 5000 articles in the product.

7 PRELIMINARY BENEFIT-COST ANALYSIS

It is impossible to give any exact calculations but some rough estimates can be done even in this preliminary study.

In warehousing operations we will first concentrate on the working time. In receiving the items there won´t be big changes. Each item still needs to be labeled with company´s own labels. With some products it might be possible to use suppliers own barcodes. Since each arriving item is marked with its own label and this label furthermore has a barcode field already the time required to make necessary changes in the system are minimal and once the WMS is updated it will require not much more work.

Putting away of items can be faster because a worker can do all the necessary actions without manually having type in the information. Inventory should also with a proper training of workers be always up to date, which brings additional benefits in manufacturing planning.

7.1 Savings from picking-up

If we assume that the order pickers time distributes even closely to the diagram presented in Figure 2 and it takes 90 hours to pick all the parts in one of the products we are studying in this paper we can evaluate that:

$$90\ h\ \times (0{,}05 + 0{,}1 + 0{,}15) = (27\ h \div 5000) =$$
$$(1650\ \text{min} \div 5000) = (97200\ s \div 5000) = 19{,}44\ \text{s}$$

almost 20 s per part is spent on something else than picking itself. If we can reduce the time typing numbers, time spent searching for missing parts due to inventory errors etc. and estimate that this time is 1 second this would mean that,

$$18{,}44\ s \times 5000 = 25{,}6\ h$$

1 1/2 hours per product just in picking time would be saved. If we further estimate the labor costs at 20 €/h the savings from picking one product would be 35 €.

The savings made from reducing safety stocks, inventory time and other benefits from better guiding in e.g. purchasing can´t be estimated without further research.

8 CONCLUSIONS AND FUTURE RESEARCH SUGGESTIONS

In chapter 2 a list of a good automatic identification system and the 6R´s of supply chain management were presented. All of the components of a successful automatic identification system can be achieved with the use of barcodes. Barcodes also improve most of the 6R´s of supply chain management when used properly.

Barcodes are an excellent tool to manage the whole supply chain including purchasing and purchasing planning. Because it is clear that there indeed are some potential advantages in implementing such a system we would strongly recommend that the next stage of the barcode implementing process (to fully map the current processes in the warehouse and time them) should be started. Research should be conducted in co-operation with the purchasing, manufacturing departments to map all the potential problems caused by faulty inventory values and try to estimate those times and the costs as accurate as with reasonable effort possible. And to educate all the people involved.

Barcoding process and the reasons behind implementing it should be discussed with the whole staff during the process. People actually using the hardware are in the end responsible for a successful implementation of barcodes, if no-one uses them or no-one uses them correctly they can actually be harmful, slow processes down and confuse workers.

“Anybody with a warehouse should be using barcodes. Enough said” (Flott, 2002, p. 46)

REFERENCES

de Koster, R., Le-Duc T., Roodbergen, K., J. 2007. Design and control of warehouse order picking: A literature review. European Journal of Operational Research 182. p. 481-501.

Fametech Inc., 2004. PDF417 Barcode Symbology Introduction. [viewed 13.12.2010]. Available: http://www.barcode-manufacturer.com/barcode_scanner/pdf417_barcode_scanner.html

Flott, L.W. 2002. Bar codes. Metal Finishing, August Issue. p. 42-47.

Gel, E. S., Erkip, N., Thulaseedas, A. 2010. Analysis of simple inventory control systems with execution errors: Economic impact under correction opportunities. International Journal of Production Economics 125. p. 153-166.

ten Hompel Michael & Schmidt, Thorsten. 2007. Warehouse Management – Automation and Organization of Warehouse and Order Picking Systems. Springer.

Lindau, R., Lumsden, K. 1999. The use of automatic data capture systems in inventory management. International Journal of Production Economics 59. p. 159-167.

Manthou, V., Vlachopoulou, M. 2001. Bar-code technology for inventory and marketing management systems: A model for its development and implementation. International Journal of Production Economics 71. p. 157-164.

Nabhani, F., Klonis, A. 2008. Calculating the AIDC Return on Investment (ROI) within Small to Medium Size Enterprice. Conradi Research Review 1/08.

Osman K. A., Furness A. 2000. Potential for two dimensional codes in automatic manufacturing. Assembly automation, Vol. 20, No. 1. MCB University Press.

Twist, D.C. 2004. The impact of radio frequency identification on supply chain facilities. Journal if Facilities Management. Vol. 3. p. 226-239.

UNOVA., 1998. Bar code users and their performance – A report on information technology and manufacturing productivity.

Worth Data Inc. 2004. Bar Code Primer.

The stages of developing and implementing a barcode system. (Manthou 2001, pp. 161-162)

Table 1
Stages for the development and implementation of a bar code system

	Data/information Input	Source of data	Actions
Stage 1 Preliminary Investigation	Vendors of bar-code technologies	List of vendors	Problems definition
		Trade shows	Goals establishment Constraints determination of the proposed system Statement of expected benefits Cost estimation Time estimation Preliminary investigation report
	Technical characteristics of the proposed system	System's vendors	
		Firms which have already implemented similar systems	
	Surveys of similar installations (infrastructure, sectorial and environmental similarity, throughput, working procedures)	Vendors customers	
		Primary and secondary research	
	Initial feasibility study of the interested company (infrastructure, working procedures, change requirements)	Concerned company	
	Involved parties requirements and expected benefits	Users (i.e. marketing, inventory decision managers/controllers)	
	Cost of the proposed systems	Vendors Trade shows Company's infrastructure	
	Time needed	Vendors company's requirements and infrastructure	
Stage 2 Systems analysis	Host system summary reports, end users knowledge	End users/internal data	System boundaries definition
			Calculation of throughput Examination of efficiency of working procedures Reorganization of working procedures Documentation of information flows (i.e. data flow diagrams) Hardware and software interface specification Requirement's documentation
	External primary and secondary data	Internal and external environment of a business	
	Performed tasks (what, when, who, how, where, why)	End users, company's reporting stations	

Table 1 (*continued*)

	Data/information Input	Source of data	Actions
	Existing hardware technical characteristics	Vendors, personnel in charge of information systems, project team	
	Existing software characteristics		
Stage 3 Design	Hardware and software configurations of the proposed system	Project team, vendors	System design specification
			Request for Proposals (RFP)
	Interface configuration Response time of bar code system Data structure Duration time of transmission to the host computer		
Stage 4 Development	System Design specification	Project team, vendors	Program documentation System documentation Operations documentation End-user documentation
Stage 5 Implementation and evaluation	Performed tasks	End users	Integration (environmental, interfacing to other business IS) Testing Training
	New or modified business operations		

APPENDIX 2,1

Value	Code A	Code B	Code C	Pattern	Barcode
0	SP	SP	00	212222	
1	!	!	01	222122	
2	”	”	02	222221	
3	#	#	03	121223	
4	$	$	04	121322	
5	%	%	05	131222	
6	&	&	06	122213	
7	’	’	07	122312	
8	(	(	08	132212	
9	)	)	09	221213	
10	*	*	10	221213	
11	+	+	11	231212	
12	,	,	12	112232	
13	-	-	13	122132	
14	.	.	14	122231	
15	/	/	15	113222	
16	0	0	16	123122	
17	1	1	17	123221	
18	2	2	18	223211	
19	3	3	19	221132	
20	4	4	20	221231	
21	5	5	21	213212	
22	6	6	22	223112	
23	7	7	23	312131	
24	8	8	24	311222	
25	9	9	25	321122	
26	:	:	26	321221	
27	;	;	27	312212	
28	<	<	28	322112	
29	=	=	29	322211	
30	>	>	30	212123	
31	?	?	31	212321	
32	§	§	32	232121	
33	A	A	33	111323	
34	B	B	34	131123	
35	C	C	35	131321	
36	D	D	36	112313	
37	E	E	37	132113	
38	F	F	38	132311	
39	G	G	39	211313	
40	H	H	40	231113	
41	I	I	41	231311	

APPENDIX 2,2

Value	Code A	Code B	Code C	Pattern	Barcode
42	J	J	42	112133	
43	K	K	43	112331	
44	L	L	44	132131	
45	M	M	45	113123	
46	N	N	46	113321	
47	O	O	47	133121	
48	P	P	48	313121	
49	Q	Q	49	211331	
50	R	R	50	231131	
51	S	S	51	213113	
52	T	T	52	213311	
53	U	U	53	213131	
54	V	V	54	311123	
55	W	W	55	311321	
56	X	X	56	331121	
57	Y	Y	57	312113	
58	Z	Z	58	312311	
59	[	[	59	332111	
60	\	\	60	314111	
61	]	]	61	221411	
62	^	^	62	431111	
63	_	_	63	111224	
64	NUL	`	64	111422	
65	SOH	a	65	121124	
66	STX	b	66	121421	
67	ETX	c	67	141122	
68	EOT	d	68	141221	
69	ENQ	e	69	112214	
70	ACK	f	70	112412	
71	BEL	g	71	122114	
72	BS	h	72	122411	
73	HT	i	73	142112	
74	LF	j	74	142211	
75	VT	k	75	241211	
76	FF	l	76	221114	
77	CR	m	77	413111	
78	SO	n	78	241112	
79	SI	o	79	134111	
80	DLE	p	80	111242	
81	DC1	q	81	121142	
82	DC2	r	82	121241	
83	DC3	s	83	114212	
84	DC4	t	84	124112	

Value	Code A	Code B	Code C	Pattern	Barcode
85	NAK	u	85	124211	
86	SYN	v	86	411212	
87	ETB	w	87	421112	
88	CAN	x	88	421211	
89	EM	y	89	212141	
90	SUB	z	90	214121	
91	ESC	{	91	412121	
92	FS	|	92	111143	
93	GS	}	93	131141	
94	RS	~	94	131141	
95	US	DEL	95	114113	
96	FNC3	FNC3	96	114311	
97	FNC2	FNC2	97	411113	
98	SHIFT	SHIFT	98	411311	
99	CODE C	CODE C	99	113141	
100	CODE B	FNC4	CODE B	114131	
101	FNC4	CODE A	CODE A	311141	
102	FNC1	FNC1	FNC1	411131	
103	Start CODE A			211412	
104	Start CODE B			211214	
105	Start CODE C			211232	
106	Stop			2331112	