DEVELOPING PRODUCTIVITY OF PRINTING LINES

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SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS Abstract**

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Abstract

The purpose of this thesis was to scout and find solutions how to develop productivity and efficiency of the printing line at CompanyX by increasing active printing time in each shift.

The first task was to study the operational principles of the printing lines. The printing lines were divided to three parts: feeding half made products, printing where half-made-product is lead through the printing units and picture is attached, and packaging where palletizing, wrapping and labeling is made. Half made products have right shape but they are lacking the printing.

The second task was to analyze the current situation in printing line. The current availability, performance, quality, overall equipment effectiveness and productivity were determined.

The third chapter of the report shows different solutions and the best combination of solutions to develop effectiveness and productivity. The first developing solution introduced was the rearrangement of breaks where printing line operators replace each other breaks. The second solution was to hire third employee in printing. The automation of wrapping, labelling and logistics to storage was studied in solution three. Solution four and five analyzed the production planning, training and decreasing changeover time by the use of washing machine. The fifth chapter introduces current situation of packaging and its automation proposal more closely.

The results and feedback of the study were excellent. Some of the solutions will be applied to practise as presented and others need more studying before decisions and investments can be made.

Keywords

Productivity, Efficiency, Automation, OEE, Overall Equipment Effectiveness

CONTENTS

1 INTRODUCTION

This study was carried out for CompanyX's developing needs. In this study two reports were made, public and confidental for CompanyX's own use.

The target of CompanyX's production strategy is constant improving and developing of production operations. In this study, printing lines, which include printing, palletizing, and wrapping, were observed. The goal was to find solutions to improve efficiency of the printing lines by increasing printing time in a certain time period.

The operational principles of the printing lines are studied in Chapter 2. The third chapter of the report covers current situation on the printing lines and the time usage of printing line operators. The fourth chapter consists of different solutions, which would improve efficiency in printing. Chapter 5 takes a closer look to automation as one solution to improve efficiency and quality. The last chapter includes summary and conclusions of the study.

1.1 CORE OBJECTIVES AND IMPLEMENTATION

Activity analysis, observing and interviews were chosen as a study method. These methods were seen to fulfill the purpose of the study and they could be implemented to available resources. The writer who carried out the study had approximately one year experience as an employee in the factory.

The main objectives of the study were to analyze current situation of the printing lines, including operational principle of the lines, and time usage of the operators. The goal was to find solutions to increase the efficiency of the printing. Automation of wrapping was studied as a part of the LEKA project. Besides efficiency, changes for printing lines were analyzed also from the quality point of view.

1.2 COMPANYX

CompanyX was founded in 1917. Today CompanyX is one of the biggest producers in own business area. CompanyX has activities in six European and one Canadian production units and it has sale units and agencies in over 20 different countries over the world. The unit of Finland's main market area is Finland but there is some export to Sweden. (Production manager, 2012.)

In 2011 the turnover of CompanyX Ltd was 1.2 million Euros and production volume was 800 tons. The company employed approximately 43 persons in 2011. CompanyX has ISO 14001 enviroment, ISO 9001 quality and OHAS 18001 standards. The standards cover producing and marketing in the unit of Varkaus. (Safety-, quality- and environment manager, 2012.)

2 OPERATIONAL PRINCIPLE OF PRINTING LINES

There are two printing lines located inside the CompanyX facility but the operational principles of both lines are identical. The printing lines share one palletizer robot which palletizes finished products to pallets. The printing line can be divided into three different sections: feeding half made products, printing, and packaging, which includes palletizing, wrapping and labeling.

2.1 FEEDING HALF MADE PRODUCTS

Half made products are products which have got their final shape, but are lacking printing and packaging. Half made products are in storage units which each contains from 3 480 to 5160 pieces of half made products, depending on the type of products. The printing line operator refills feeding conveyor depending on the printing speed.

The feeding device is located at the end of the feeding conveyor. Half made products pile to the feeding device where a denester-screw rotates and separates products from each other. The denester-screw drops half made products down to the chain track which goes to printing units.

2.2 PRINTING

The chain track goes through the printing units where half made products get their final looks. Colors will be pushed on the surface of the products by printing rubbers. Colors will be transferred to pushing rubbers from a metal plate, where printing picture or pattern is made by a relief. It is possible to make printings on different surfaces for customers needs. There are possibilities for side, top and inside printings. After the product has got its final look, its barcode will be checked automatically by the barcode reader.

2.3 PACKAGING

The chain track ends to a stacker. There is a sensor before the stacker which calculates correct amount of products for each bundle. The stacker piles up the products to

bundles. The bundle picker transfers bundles to press which presses bundles to correct length. The bundle with right length will be pushed to the next conveyor. The conveyor leads to bundle wrapping units. The bundle will be collar or fully wrapped depending on the customer needs. Wrapping is made automatically and thin foil is used for it.

The conveyor takes finished bundles to the palletizer robot which palletizes bundles to pallets automatically. The palletizer takes bundles from both two printing lines. Own pallets and conveyors are reserved for both printing lines. After there are right amount of bundles on the pallet, the pallet moves forward making room for the next pallet. Three pallets can be made for both lines until conveyors get full.

The printing line operator gets the pallets manually from the end of the conveyor using the electric hand pallet truck. The pallet will be carried one at a time to the wrapping machine where the operator wraps the pallet and makes the quality check.

Labels will be printed from label printer which is located next to the wrapping machine. A label will be attached on the side of the pallet and the pallet is left to be picked up for storage.

3 PRODUCTIVITY AND EFFICIENCY

It is necessary to define productivity, efficiency and difference between those before a closer analysis of the current situation. It has to be clearly understood, which factors effect on efficiency and productivity, before improving solutions can be developed.

Productivity is the quotient obtained by dividing output by one of the factors of production. In this way it is possible to speak of productivity of capital, investment, or raw materials, according to whether output is being considered in relation to capital, investment or raw materials etc. (David J. Sumanth, 1998, 4.)

There is slight difference between productivity and efficiency. Where productivity can be measured to any input factor of production, efficiency is measured with expected or standard value. Efficiency measures actual output to standard value. Efficiency is ratio of actual output generated to the expected (or standard) output prescriped. (David J. Sumanth, 1998, 12.)

3.1 CURRENT PRODUCTIVITY AND EFFICIENCY OF THE PRINTING LINES

Following the production and productivity from the right angle is important. The knowledge of own production and its potential is vital for production and sales planning. The efficiency of production is reported in many cases as a percentage but in CompanyX the most followed indicator of printing lines is pieces per man-hour. Pieces per man-hour indicator is one way to measure productivity and it bases on theory of partial productivity.

Partial productivity is the ratio of output to one class of input. For example, output per man-hour (a labor productive measure) is a partial productivity concept. So are output per ton of material (a material productivity ratio) and interest revenue generated per dollar of capital (a capital productivity ratio) and so on. (David J. Sumanth, 1998, 5.)

The man-hour includes all working hours of the printing line operator, not just running hours of printing machine. It includes all the breaks, packaging and product changes. Pieces include only finished products which mean it takes waste in consideration.

Table 1. Productivity of the printing lines calculated as pieces per man-hour.

Type of package	Finished pieces	Labor hours	Labor productivity pieces/labor hour	Sec/piece
PRODUCT1	6 109 602	1 138	5 368	0,67
PRODUCT2	3 675 030	908	4 047	0,89
PRODUCT3	1 111 180	366	3 040	1,18
PRODUCT4	658 474	171	3 856	0,93
TOTAL	11 554 286	2583	4 474	0,80

The data from 2011 is used to define current productivity of the printing lines. Both average and individual productivities for all current product types are calculated as pieces per labor hour (Table 1). There are big differences in labor productivity between the different product types.

An individual theoretical printing speed is defined for each type of product, which has to be taken consideration, when standard values are defined. Standard values are needed for determination of efficiency (Table 2). Limits in printing speed are one factor which explains differences in productivity between the product types. The main issues of printing lines will be discussed later stage of the study. Pieces per man-hours as an indicator is easy to obtain and compare the current situation to the past but efficiency shows how much there are potential left.

Table 2. Individual and total performance and quality of the printing line defined.

Type of package	Printed pieces	Finished pieces	Printing hours	Actual pcs/h	Standard pcs/h	Performance	Quality
PRODUCT1	6 236 725	6 109 602	404	15 423	18 000	85,7 %	98,0 %
PRODUCT2	3 764 056	3 675 030	309	12 185	15 000	81,2 %	97,6 %
PRODUCT3	1 153 491	1 111 180	101	11 372	15 000	75,8 %	96,3 %
PRODUCT4	680 054	658 474	57	11 931	15 000	79,5 %	96,8 %
TOTAL	11 834 327	11 554 286	872	13 576	16 392	82,8 %	97,6 %

In this case performance means how efficiently the printing line is actually running. It takes into consideration only the running time of the printing machine, not all labor hours. The average printing speed in 2011 is compared to the standard speed. In this

case the theoretical maximum printing speed of the printing line is used as the standard speed and printed pieces to define actual speed. Printed pieces consist of all feeded half made products. From finished pieces poor quality products are removed. The printing speed was approximately 13 576 pieces per hour and it could be theoretically 16 392 in 2011. It gives the average efficiency of 82.8 % for the printing line.

Waste has to be separated when actual running speed of the printing line will be defined. If poor quality products would be excluded from output the running speed of the printing line would be slower. Quality means ratio between printed and finished pieces. The quality of 100% would mean no waste at all.

The performance of the printing speed is rarely obtained but it has to be defined for overall efficiency.

3.2 TIME USAGE OF PRINTING LINE OPERATOR

The greatest effect on printing line productivity and efficiency has the running time of the printing machine. That for current printing time has to be defined.

Table 3. Printing hours in a shift and efficiency of the man-hour in printing defined.

Type of package	Man hours	Amount of shifts (8h)	Printing hours	Printing hrs/shift	Efficiency
PRODUCT1	1 138	142	404	2,84	35,5 %
PRODUCT2	908	114	309	2,72	34,0 %
PRODUCT3	366	46	101	2,22	27,8 %
PRODUCT4	171	21	57	2,67	33,4 %
TOTAL	2583	323	872	2,70	33,8 %

In this table efficiency means time available on printing. In current situation approximately 33.8 % of maximum 8 hours in a shift can be used for printing products. The rest of the time is used for many other tasks.

The tasks of the printing line operator were to be broken down (Table 4 and Figure 1) and re-evaluated to gain bigger efficiency in printing.

Table 4. The breakdown of time usage on printing. Minutes are used as a unit for breakdown. Full shift consists of 480 minutes.

Type of package	Printing	Breaks	Wrapping	Other
PRODUCT1	170	40	43	227
PRODUCT2	163	40	41	236
PRODUCT3	133	40	31	276
PRODUCT4	160	40	39	241
TOTAL	162	40	41	237

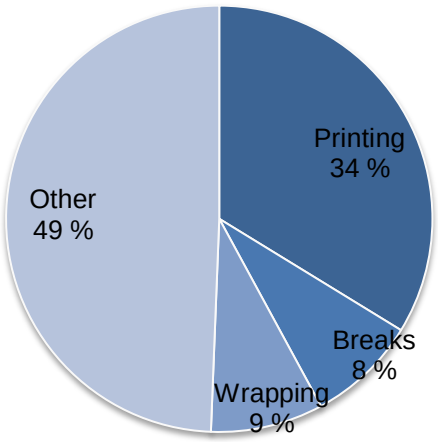

Figure 1. Average time usage of the printing line operator broken down with percentages.

The average production in pallets per shift was calculated and the wrapping time of the pallet was measured. These two factors are needed for defining the wrapping time in a shift. The wrapping of one pallet took 5 minutes. The time includes wrapping, moving of the operator to wrapping area and back to printing area. Approximately 8.2 pallets were produced in a shift (Table 5). Approximately 9 % of the printing line operator's time is used for wrapping the pallets, 8 % for breaks, and 49 % is used for other tasks. Other tasks consist of changeovers of product type or printing face, adjusting printing line, cleaning the printing plates, changing printing rubbers, unofficial breaks and other minor tasks.

Table 5. Average pallet production in a shift and wrapping time per shift.

Type of package	Pieces	Pieces on pallet	Pallets	Wrapping time
PRODUCT1	10 735	1238	8,7	43
PRODUCT2	8 095	990	8,2	41
PRODUCT3	6 080	980	6,2	31
PRODUCT4	7 713	980	7,9	39
TOTAL	8 948	1097	8,2	41

The rearrangement of the tasks has to be done to increase the actual running time of the printing machine. In Chapter 4 solutions for improvements will be introduced.

3.3 OVERALL EQUIPMENT EFFECTIVENESS

Overall Equipment Effectiveness (OEE) can be used effectively to measure efficiency of the manufacturing unit. The printing line efficiency of CompanyX is observed in this study.

True OEE multiplies factors that represent availability, speed and quality. The results can be expressed as a percentage of effectiveness that directly correlates with actual floor output, and can be reconciled 100 percent. (Robert C. Hansen, 2002, 11.)

In Hartman-Varkaus OEE is defined directly from productivity which takes into consideration all man-hours and waste as well (Table 6).

Table 6. OEE defined directly from actual productivity with standard productivity.

Type of package	Actual pcs/man hrs	Standard pcs/man hrs	OEE
PRODUCT1	5 368	18 000	29,8 %
PRODUCT2	4 047	15 000	27,0 %
PRODUCT3	3 040	15 000	20,3 %
PRODUCT4	3 856	15 000	25,7 %
TOTAL	4 474	16 322	27,4 %

As it is seen there is a lot of potential left for developing the effectiveness. For that a classic formula should be used to separate three main parameters: availability, speed and quality. All three variables are defined in the previous chapters. The parameters are collected to the same table and multiplied to get OEE (Table 7).

Table 7. OEE Defined by using a classic formula: Availability x Performance x Quality.

Type of package	Availability	Performance	Quality	OEE
PRODUCT1	35,5 %	85,7 %	98,0 %	29,8 %
PRODUCT2	34,0 %	81,2 %	97,6 %	27,0 %
PRODUCT3	27,8 %	75,8 %	96,3 %	20,3 %
PRODUCT4	33,4 %	79,5 %	96,8 %	25,7 %
TOTAL	33,8 %	82,8 %	97,6 %	27,4 %

The average performance of 82.8 % is in tolerable level, but there is still room for small improvements. In this study the main focus will be set to increase availability which is dramatically behind from the target level. Availability points out that printing machine is used approximately 33.8 % of its possible maximum time, 8 hours in a shift.

4 DEVELOPING SOLUTIONS

4.1 MAJOR ISSUES

The major issue found for improvement was the availability of the printing line operator. Only 33.8 % of the printing line operator's time was used for printing which had a great decreasing effect on overall equipment effectiveness. The multiple tasks of the printing line operator had to be re-evaluated and rearrangements had to be made. Because of that the main focus is set to increase availability of the printing which means increased printing time in each shift.

The effect of production planning to overall equipment effectiveness is evaluated. The estimations of increases are difficult to make because changes will play minor part in printing processes and the gain will vary in different situations. The batches are also produced in short notice, which forces to do quick changes on production planning.

4.2 SOLUTION 1: OPERATORS REPLACE EACH OTHERS DURING BREAKS

It was found that breaks are one great factor decreasing the printing availability. Statutory rest breaks in a shift are 40 minutes; two times 10 minutes breaks and one 20 minutes lunch break. Since no one is replacing an operator who is having his break, the line stops for that time. Because of independent work and lack of control, breaks will be extended easily. In reality approximately 60 minutes are used for breaks in each shift. Extra 20 minutes is included in other section on calculations.

The breaks of the printing line operators are kept at the same time. It is possible to separate breaks to keep both printing lines running during the breaks. The feeding conveyor should be filled and full pallets removed from the palletizer before the operators' break. With those procedures it is possible for one operator to keep both lines running while other operator is having a break. With these arrangements the running time of the printing line is increased by 60 minutes, from 40 minutes rest breaks and 20 minutes break extensions. Significant improvements can be seen in availability and productivity (Table 8).

Table 8. New availability of printing machine calculated. Official 40 minute-rest breaks and 20 minute-break extensions from other column are transferred to printing time.

Type of package	Printing	Breaks	Wrapping	Other	New Availability	Current Availability
PRODUCT1	230	0	43	207	47,9 %	35,5 %
PRODUCT2	223	0	41	216	46,5 %	34,0 %
PRODUCT3	193	0	31	256	40,2 %	27,8 %
PRODUCT4	220	0	39	221	45,8 %	33,4 %
TOTAL	222	0	41	217	46,3 %	33,8 %

If average printing time is observed, the availability was raised from 33.8 % to 46.3 %. The change is then 12,5 percentage units. The raise means approximately 37% increase in availability. With this increase greater productivity can be accomplished (Table 9).

Table 9. New productivity and OEE defined. Average printing speed of 2011 is used. Waste is taken into consideration by using finished products for defining the printing speed.

Type of package	Printing min/shift	Printing pcs/min	New pcs/man hrs	New OEE	Current pcs/man hrs	Current OEE
PRODUCT1	230	252	7 239	40,2 %	5 368	29,8 %
PRODUCT2	223	198	5 527	36,8 %	4 047	27,0 %
PRODUCT3	193	183	4 405	29,4 %	3 040	20,3 %
PRODUCT4	220	193	5 295	35,3 %	3 856	25,7 %
TOTAL	222	221	6 130	37,6 %	4 474	27,4 %

Approximately productivity would increase from 4 474 pieces per man-hour to 6 130 pieces per man-hour which signify 37 % increase in productivity and 10.2 percentage units in overall equipment effectiveness. The improvement could be achieved without any investments or adding extra hours to the printing line. The printing line operator's work description should be changed to include replacing each other during breaks. Training for new arrangements and working methods should be introduced and practiced to accomplish fluent transition to a more efficient working method.

This solution can be applied only if both printing line operators are present. If the shift is lacking a printing line operator, then there is no one to replace during breaks. The lack of printing line operator leads back to the current situation.

The savings and possible increase of production are estimated for whole year in Table 10. In this estimation year 2011 is used as an example.

Table 10. In this figure it is calculated both possibilities, the increase of productivity is used either to increase production volume or reduce man-hours to achieve target production.

	2011				
Type of package	**Finished pieces**	**Man hours**	**New pcs/man hrs**	**New production**	**New hours**
PRODUCT1	6 109 602	1 138	7 239	8 240 181	844
PRODUCT2	3 675 030	908	5 527	5 018 755	665
PRODUCT3	1 111 180	366	4 405	1 609 904	252
PRODUCT4	658 474	171	5 295	904 118	124
TOTAL	11 554 286	2583	6 130	15 772 958	1 886

If the amount of man-hours and ratio between the products remain the same it is possible to gain approximately the increase of 4 218 672 products in a year. This is approximately increase of 37 %. If it is assumed that production volume remains the same, it can be reached by 1 886 man-hours. Man-hours would be decreased by 697 which is a decrease of 27 %.

4.3 SOLUTION 2: THIRD EMPLOYEE IN PRINTING

This solution includes adding one extra employee in printing who would be responsible for wrapping and breaks. This solution adds four man-hours to both printing lines, which leads to a total of twelve man-hours per printing line in each eight hour shift. It would increase printing availability by adding breaks and wrapping time to printing (Table 11).

Table 11. The 40 minute-rest breaks, 20 minute-break extensions and wrapping times added to printing time. Wrapping time varies between 31-43 minutes. Average wrapping time is 41 minutes.

Type of package	Printing	Breaks	Wrapping	Other	New Availability	Current Availability
PRODUCT1	273	0	0	207	56,9 %	35,5 %
PRODUCT2	264	0	0	216	55,0 %	34,0 %
PRODUCT3	224	0	0	256	46,7 %	27,8 %
PRODUCT4	259	0	0	221	54,0 %	33,4 %
TOTAL	263	0	0	217	54,8 %	33,8 %

In Table 11 breaks and wrapping time is marked as zero minute. Breaks and wrapping take the same amount of time than before, but tasks are rearranged with the third employee in printing. Zeros show that breaks and wrapping do not consume printing time. The average availability of the printing machine would increase from 33.8 % to 54.8 % when wrapping and breaks are handled by the third employee.

Table 12. Printing speed in 2011 is applied to define increased productivity and overall equipment effectiveness.

Type of package	Printing min/shift	Printing pcs/min	New pcs/man hrs	New OEE	Current pcs/man hrs	Current OEE
PRODUCT1	273	252	5 729	31,8 %	5 368	29,8 %
PRODUCT2	264	198	4 362	29,1 %	4 047	27,0 %
PRODUCT3	224	183	3 408	22,7 %	3 040	20,3 %
PRODUCT4	259	193	4 156	27,7 %	3 856	25,7 %
TOTAL	263	221	4 842	29,7 %	4 474	27,4 %

The use of the third employee for wrapping and running printing machine during the breaks has only an effect of 2.3 percentage units increase on OEE and an increase of 368 units per man-hour from 4 474 to 4 842 units per man-hour (Table 12). It is only possible to run printing line eight hours per shift and additional four man-hours make the most of the benefits of increased printing time get lost. The impact of the third person on a year level is introduced in Table 13.

Table 13. The possible increase of production and decrease of man-hours defined.

	2011				
Type of package	**Finished pieces**	**Man hours**	**New pcs/man hrs**	**New production**	**New hours**
PRODUCT1	6 109 602	1 138	5 729	6 520 491	1 067
PRODUCT2	3 675 030	908	4 362	3 960 990	843
PRODUCT3	1 111 180	366	3 408	1 245 660	326
PRODUCT4	658 474	171	4 156	709 596	159
TOTAL	11 554 286	2583	4 842	12 436 737	2 394

If there is an increase in sales compared to the last year, increase of 7.6 % is possible which is approximately 882 000 units. It is assumed that same amount of man-hours is available than in 2011. If production volume remains the same it is possible to reduce 7.3 % of the man-hours which is total of 189 hours.

4.4 SOLUTION 3: AUTOMATION OF WRAPPING AND LABELING

The wrapping and labeling of the pallets is done manually by the printing line operator. Approximately 5 minutes is used to handle one pallet, and as it was defined earlier, approximately 8.2 pallets are produced per printing line in a shift. A total of 41 minutes is used for wrapping and labeling the pallets by each printing line operator. With automation, time used on wrapping and labeling could be released for running the printing machines. The printing line operators just have to refill foils and empty labels for automated units. The automation would have a positive effect on availability (Table 14).

Table 14. Wrapping time is added to printing. Wrapping time varies between 31-43 minutes within average of 41 minutes per printing line in a shift.

Type of package	**Printing**	**Breaks**	**Wrapping**	**Other**	**New Availability**	**Current Availability**
PRODUCT1	213	40	0	227	44,4 %	35,5 %
PRODUCT2	204	40	0	236	42,5 %	34,0 %
PRODUCT3	164	40	0	276	34,2 %	27,8 %
PRODUCT4	199	40	0	241	41,5 %	33,4 %
TOTAL	203	40	0	237	42,3 %	33,8 %

The printing time would be increased approximately 41 minutes per printing line in a shift. The availability in printing would increase approximately 8.5 percentage units from 33.8 % to 42.3 %. The automation would have an effect to productivity by increasing it from current 4 474 pieces per man-hour to 5 606 pieces per man hour (Table 15). The increase of productivity means approximately 7 percentage units increase in OEE.

Table 15. The new estimated productivity and OEE due to the automation of wrapping machine calculated.

Type of package	Printing min/shift	Printing pcs/min	New pcs/man hrs	New OEE	Current pcs/man hrs	Current OEE
PRODUCT1	213	252	6 704	37,2 %	5 368	29,8 %
PRODUCT2	204	198	5 056	33,7 %	4 047	27,0 %
PRODUCT3	164	183	3 743	25,0 %	3 040	20,3 %
PRODUCT4	199	193	4 790	31,9 %	3 856	25,7 %
TOTAL	203	221	5 606	34,3 %	4 474	27,4 %

On a year level, automation of wrapping and labeling would make possible increase in production by approximately 2 853 804 units which would cause the increase of 24,7 % if same amount of man hours were used. If improved productivity would be used for reducing man-hours, the hours would decrease from current 2583 to 2073 (Table 16).

Table 16. The new production and OEE defined by using the new estimated productivity achieved by automation.

	2011				
Type of package	**Finished pieces**	**Man hours**	**New pcs/man hrs**	**New production**	**New hours**
PRODUCT1	6 109 602	1 138	6 704	7 631 125	911
PRODUCT2	3 675 030	908	5 056	4 591 148	727
PRODUCT3	1 111 180	366	3 743	1 368 002	297
PRODUCT4	658 474	171	4 790	817 816	138
TOTAL	11 554 286	2583	5 606	14 408 090	2073

One of the best points of this solution is that it is not dependent on presence of co-workers. The new improved productivity takes place in every minute the printing machine is running. The printing line operator or anyone else had not to use their time for wrapping or labeling the pallets because processes are handled by machines. The automation is discussed more closely in Chapter 5.

4.5 SOLUTION 4: DECREASING CHANGEOVERS AND BUYING A WASHING MACHINE

There is one matter which affects directly two factors of overall equipment effectiveness. They are changeovers of printing face or product type. There was total of 162 changeovers of printing face and 14 changeovers of whole product type (Table 17) in 2011. If the whole product type is changed the printing face will also be changed. The changeovers have an effect on availability and quality.

Table 17. Amount of changeovers in 2011. Average batch size calculated in pallets.

Type of package	Changeovers		Production in pallets	Average batch size
	Face	Type		
PRODUCT1	77	3	1 234	16,0
PRODUCT2	54	4	928	17,3
PRODUCT3	22	4	284	13,0
PRODUCT4	9	3	168	19,2
TOTAL	162	14	2 614	16,2

In availability, the time of the printing line operator is used for changeover, adjusting a new setup up and cleaning the previous one. Time used for changeover of printing face is from 20 minutes to 60 minutes depending on the degree of difficulty and amount of work. The changeover of the whole product type takes from 1 to 5 hours and extra help is needed from a senior employee of the printing line who works in day shifts. Added man-hours decrease productivity even more. Increasing batch sizes would reduce changeovers. Decrease in changeovers would leave more time for printing. The cleaning, washing, and drying of previous setup is made manually. It would be possible to find a washing machine which would save approximately 15 minutes in each changeover. The time could be applied directly to printing time which would improve productivity. If 162 changeovers of printing faces are done in a year and a 15 minute gain is estimated using washing machine, it would increase running time in a shift approximately by 8 minutes (Table 18).

Table 18. The increase of availability defined. The increase of availability means in this figure the increase of printing time in minutes in each shift.

Type of package	Changeover of face	Amount of shifts	Increase of availability
PRODUCT1	77	142	8
PRODUCT2	54	114	7
PRODUCT3	22	46	7
PRODUCT4	9	21	6
TOTAL	162	323	8

With time gained by using the washing machine better availability will be achieved. The gain would be an increase from 33.8 % to 35.4 % (Table 19).

Table 19. The new availability defined for all product types due to the time gain by using washing machine for cleaning previous set up in changeovers.

Type of package	Printing	Breaks	Wrapping	Other	New Availability	Current Availability
PRODUCT1	178	40	43	219	37,1 %	35,5 %
PRODUCT2	170	40	41	229	35,4 %	34,0 %
PRODUCT3	140	40	31	269	29,2 %	27,8 %
PRODUCT4	166	40	39	235	34,6 %	33,4 %
TOTAL	170	40	41	229	35,4 %	33,8 %

The productivity would increase from 4 474 pieces per man-hour to 4 694 pieces per man-hour. In overall equipment effectiveness this would give approximately an increase of 1,4 percentage units (Table 20).

Table 20. The improved productivity and OEE calculated by using increased printing time.

Type of package	Printing min/shift	Printing pcs/min	New pcs/man hrs	New OEE	Current pcs/man hrs	Current OEE
PRODUCT1	178	252	5 603	31,1 %	5 368	29,8 %
PRODUCT2	170	198	4 214	28,1 %	4 047	27,0 %
PRODUCT3	140	183	3 195	21,3 %	3 040	20,3 %
PRODUCT4	166	193	3 995	26,6 %	3 856	25,7 %
TOTAL	170	221	4 694	28,8 %	4 474	27,4 %

With average gain of 220 units per man-hour, it would be possible to increase production from 11 554 286 to 12 053 145 units, which is approximately 498 859 units and 4.3 % (Table 21). If same production than 2011 is produced, it is possible to reduce hours by 107.

Table 21. The new possible production volume or reduction of hours defined due to the use of washing machine in changeovers.

	2011				
Type of package	**Finished pieces**	**Man hours**	**New pcs/man hrs**	**New production**	**New hours**
PRODUCT1	6 109 602	1 138	5 603	6 377 184	1 091
PRODUCT2	3 675 030	908	4 214	3 825 957	872
PRODUCT3	1 111 180	366	3 195	1 167 806	348
PRODUCT4	658 474	171	3 995	682 198	165
TOTAL	11 554 286	2583	4 694	12 053 145	2 475

Only the effect of getting a washing machine is evaluated in availability. It is still possible to increase availability even more by production planning. Increasing batch sizes would reduce amount of changeovers. The matching colors and part of the printing pictures can save time in changeover, because, if planned well, only a part of the set up has to be changed. Time gained from production planning is difficult to evaluate, because there are so many factors affecting on it, but those matters should be kept in mind during the production planning, and compared to previous time periods occasionally.

A changeover always causes waste. Approximately 350 pieces of waste is made during each changeover of printing face or changeover of product type. Approximately 20 percentage of total waste came from changeovers in 2011. Decreasing changeovers would directly affect positively to quality of production by decreasing waste.

4.6 SOLUTION 5: PRODUCTION PLANNING AND TRAINING

Improvements can be achieved in all areas of OEE: availability, performance and quality by production planning and training. The sales quantities should be evaluated closely and storage levels increased for products which have great sales. The products should be sold almost out of storage before starting to produce new batches. These principles would make it possible to increase batch sizes in production. The increase of batch sizes would lead to the reduction of changeovers which has posi-

tive effect on waste and availability. On the other hand, the size of the storage would be increased which increases the value of storage. The big storage adds pressure to sales because products can get old.

The printing program should be planned closely considering the colors. Same types of printing faces should be planned to produce after each other. Not necessary all the printing plates have to be changed then which again increases printing time and decreases waste. The matching colors from previous batch speed up the changeover. It also decreases the cleaning time of the cassettes. Training should be arranged to practice which colors can be easily changed without cleaning the cassettes. With these procedures changeover could be made more efficient in availability and waste wise.

With production planning it is difficult to improve performance. The performance is 82.8 % (Table 2) which is in tolerable level. The printing speed is in comfort zone which means it is relatively easy to achieve. The quality is good and waste is small. As it was mentioned before, the biggest problem is availability so there is not much resource invested in increasing the performance. One factor effecting on performance of printing is the quality of the half made product. The shape and weight of the half made products vary a little. The current printing speeds work well with all half-made products in tolerance. With training it should be possible to encourage operators to find optimal rate without decreasing the quality and increasing the waste.

The effects of production planning and training should be followed in longer time period, for example in every quarter or a year, when the real average situation can be evaluated. The sales situation may force poor decisions in productivity wise, which appears as a poor productivity in short evaluation periods. The customer might have a campaign of a product and the storage runs out quicker than predicted, or a machine breakdown in production causes reprioritization of tasks.

4.7 THE BEST COMBINATION

The best combination would be the automation of the wrapping and labeling and the printing line operators replacing each other during breaks. The washing machine should be acquired to speed up the changeovers on printing line. With these improvements extra man-hours are not needed, and great progress on availability would be achieved (Table 22).

Table 22. New availability achieved due to the combination of solutions. Rest breaks, break extensions, wrapping time and time used for washing set up after changeover in printing line added to printing time.

Type of package	Printing	Breaks	Wrapping	Other	New Availability	Current Availability
PRODUCT1	281	0	0	199	58,5 %	35,5 %
PRODUCT2	271	0	0	209	56,5 %	34,0 %
PRODUCT3	231	0	0	249	48,1 %	27,8 %
PRODUCT4	265	0	0	215	55,2 %	33,4 %
TOTAL	271	0	0	209	56,5 %	33,8 %

The availability would almost double and it would increase by 22.7 percentage units, from 33.8 % to 56.5 %. The improvements would increase productivity from current 4 474 pieces per man-hour to 7 483 pieces per man-hour. Overall equipment effectiveness develops by 18.4 percentage units from current average of 27.4 % to average of 45.8 % (Table 23).

Table 23. The new productivity and OEE estimated.

Type of package	Printing min/shift	Printing pcs/min	New pcs/man hrs	New OEE	Current pcs/man hrs	Current OEE
PRODUCT1	281	252	8 845	49,1 %	5 368	29,8 %
PRODUCT2	271	198	6 717	44,8 %	4 047	27,0 %
PRODUCT3	231	183	5 272	35,1 %	3 040	20,3 %
PRODUCT4	265	193	6 378	42,5 %	3 856	25,7 %
TOTAL	271	221	7 483	45,8 %	4 474	27,4 %

The combination of solutions can cause an increase of 7 628 022 units in a year from current 11 554 286 units to 19 182 308 units (Table 24). It means approximately 66 % increase in production. If the higher productivity was used to decrease man-hours in printing, the volume of 2011 could be made with 1 552 man-hours. It would reduce hours by 1 031 man-hours.

Table 24. The new estimated production volume and decreased man-hours defined.

	2011				
Type of package	**Finished pieces**	**Man hours**	**New pcs/man hrs**	**New production**	**New man-hours**
PRODUCT1	6 109 602	1 138	8 845	10 067 352	691
PRODUCT2	3 675 030	908	6 717	6 099 025	547
PRODUCT3	1 111 180	366	5 272	1 926 880	211
PRODUCT4	658 474	171	6 378	1 089 051	413
TOTAL	11 554 286	2583	7 483	19 182 308	1552

The production planning and training should not be forgotten. The production has to be planned well to speed up changeovers, and reduce waste. By training the working methods can be uniformed for all printing line operators, so that co-operating, including replacing each other during breaks, becomes easier. With the proper training and production planning the work atmosphere can be made less stressful and positive effects will be noticed there as well.

5 AUTOMATION OF WRAPPING AND LABELING

Automation is a necessity in the modern industrial world, and lacking automation gives great advance for competitors. In many cases it is possible to achieve better productivity and stable quality with automation. The automation means that machine or any apparatus or process is controlled automatically by electric or mechanical devices. The human labor can be transferred to other tasks. It is possible for one employee to control bigger amount of devices through the controlling units, because the controlling units of devices can be installed in the same location.

We define automation as " the creation and application of technology to monitor and control the production and delivery of products and services." (Automation Federation, 2012.)

Using our definition, the automation profession includes "everyone involved in the creation and application of technology to monitor and control the production and delivery of products and services"; and the automation professional is "any individual involved in the creation and application of technology to monitor and control the production and delivery of products and services." (Automation Federation, 2012.)

In this study automation would be used to free more printing line operator's time for printing itself.

5.1 CURRENT SET UP OF WRAPPING AND LABELING

In the current situation printed bundles are transferred automatically to the palletizer by conveyors and palletized also automatically, but wrapping, labeling and logistics to storage is handled manually. In Figure 2, the set up of current situation is introduced as a block layout.

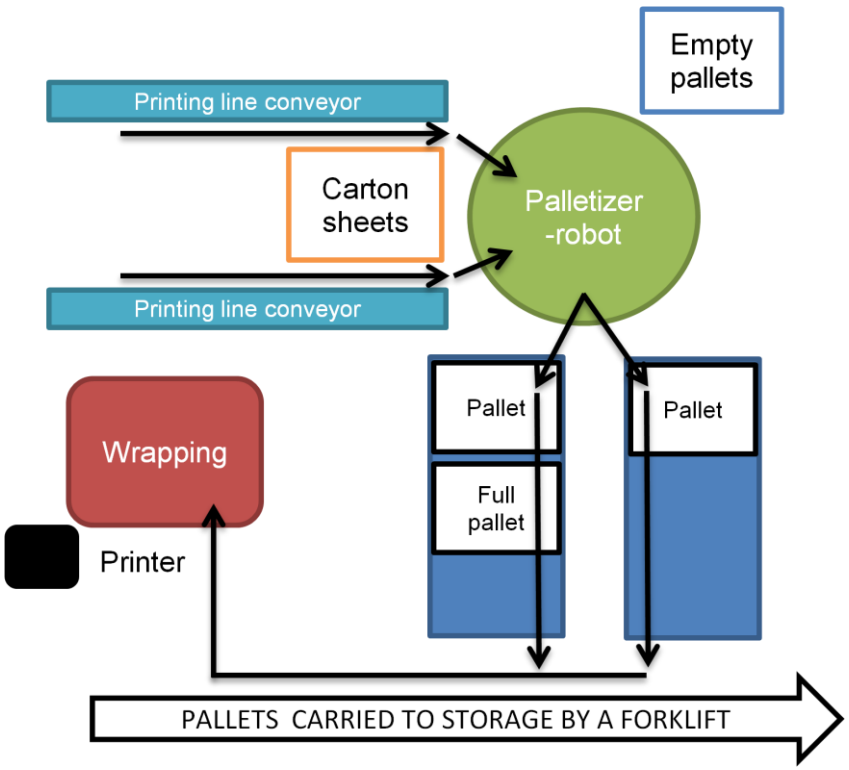

Figure 2. The current set up of palletizing, wrapping and labeling. The arrows demonstrate the flow of the bundles.

The palletizing, wrapping, labeling and logistics to storage are handled in the following way:

1. An empty pallet is lifted from an empty pallets slot to the pallet slot on the conveyor by the palletizer.
2. A carton sheet is put on the pallet by the palletizer.
3. Bundles are picked up from printing line conveyors and palletized to the correct pallet by the palletizer.
4. Full pallets will be moved automatically forward when they are done.
5. The full pallet is moved manually from the end of the conveyor to wrapping by an electric hand pallet truck by a printing line operator.
6. The wrapping machine is operated manually and the cover foil on the top is set manually by the printing line operator.
7. The labels are printed and attached to wrapped pallets by the printing line operator.
8. The finished pallet is left next to the printer to wait picking up for storage.

5.2 AUTOMATED WRAPPING, LABELING AND MOVEMENT TO STORAGE

In a automated set up the rest of the printing line processes are made automatically. Printing line operators have to only follow that machines do not run out of foil and empty labels. The block layout proposal of automated set up is introduced in Figure 3.

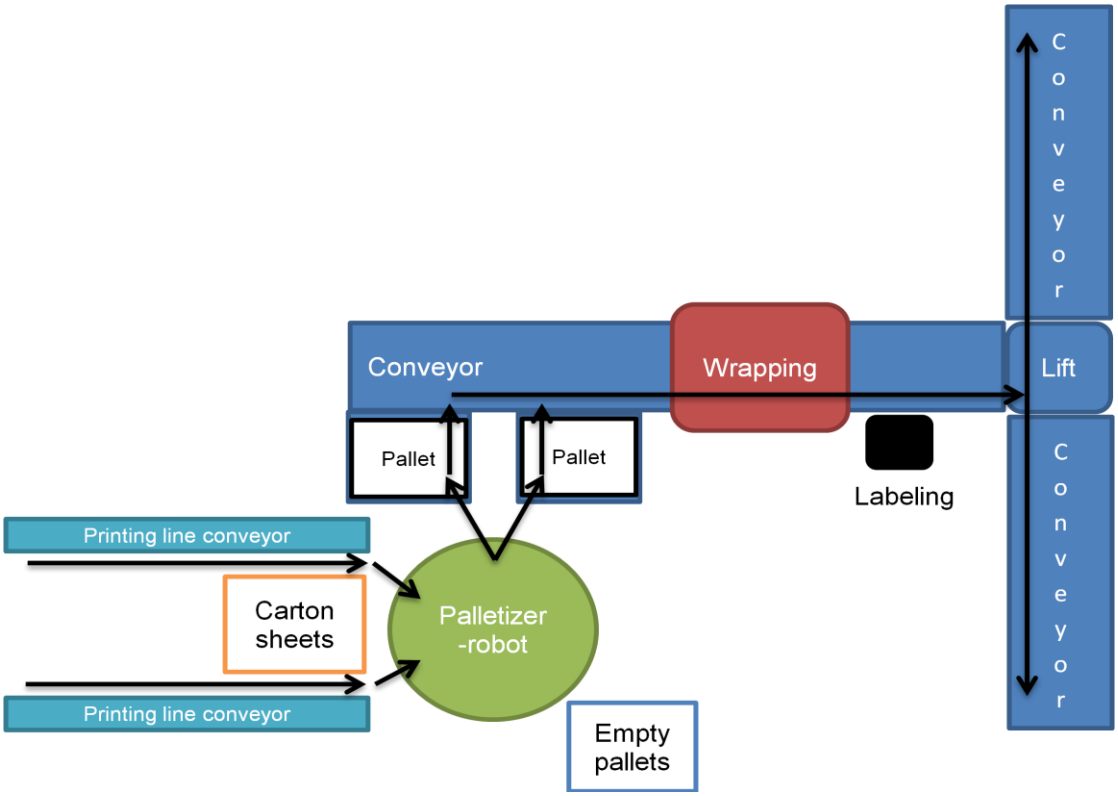

Figure 3. The set up of automated palletizing, wrapping, labeling and logistics to storage. The arrows demonstrate the flow of the bundles.

The automated set up operates the following way:

1. An empty pallet is lifted from an empty pallets slot to the pallet slot on the conveyor by the palletizer.
2. A carton sheet is put on the pallet by the palletizer.
3. Bundles are picked up from printing line conveyors and palletized to the correct pallet by the palletizer.
4. Full pallets will be moved automatically forward to the next conveyor.
5. The conveyor is run through the automated wrapping and labeling units where the cover foil on the top, wrapping and labeling is made.
6. The pallet will be moved to storage automatically by the conveyor.
7. The surface height difference is handled by the lift.
8. The pallet is middle stored on the conveyors in storage and is ready to be picked up on its correct place.

Due to the automation stable quality and safer work environment are achieved. Wrapping, labeling and logistics to storage is executed exactly the same way all the time. Human errors and small differences in quality can be removed by automation. The forklift traffic will be decreased around the printing line area which increases the safety. The last conveyor can be built for middle storage. The loader is in responsible for the storage and its order. Currently the truck driver of the shift moves the pallets in the storage. With a long enough, conveyor pallets can be middle stored, and the loader can organize pallets to correct places in the morning. It also reduces forklift traffic in the storage.

6 CONCLUSIONS

The main objective of the thesis was to find different options to improve CompanyX's productivity and efficiency on the printing lines.

From the first solution it was learned, that great improvements can be achieved basically without any investments by rearrangement of the rest breaks. This type of scheduling requires that both printing line operators are present.

In the second solution it was pointed out that better availability can be reached with added man-hours, but the increase of productivity was killed by extra man-hours. With this solution, the goals of the company could not be achieved.

A good result can be accomplished with automation, which was studied in Solution 3. The time was set free from wrapping and labeling by automation. The time can be directly added to printing time. The automated system is not dependable on the presence of both printing line operators. The investments are needed for automation. The payback time is from two to three years, depending the combination of rearrangements of tasks in printing lines. The automation would also free truck driver's time of the shift and the loader can handle storage at the morning, because middle storage is built. More stable quality can be achieved by the case of automation.

Also production planning and training were studied. Some ideas for making changeovers more fluent were introduced as possible solutions. With these ideas it is possible to increase availability and decrease waste. The effect of better production planning is difficult to estimate because situations can change quickly which forces the production planning to make unproductive decisions. The positive effects should be followed during longer time period.

The best solution was found by combining replacing each other during breaks, automating the wrapping, labeling and logistics to storage, buying a washing machine and taking production planning better into consideration.

The company feedback on the results was good and the main objectives were accomplished. The rearrangements of the tasks in printing line will be launched as soon as possible and a closer study for investment of automation is going to be started.

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