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MATERIAL FLOW OPTIMIZATION THROUGH MODELLING AND SIMULATION IN THE SOFTWARE TOOL TX PLANT SIMULATION

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Abstract: The article is oriented on the optimization of material flow through modelling and simulation in the software tool Tx Plant Simulation. The company in which optimization was realized is engaged in production of plastic and aluminum windows and doors. The aim of optimization was to propose production disposition which would provide the production productivity increase, since company expands its activity portfolio also to foreign markets. Part of the proposal is evaluation and return on investment of the proposed production disposition, specifically, the calculation of economic efficiency of investments through indicators: net present value, index present value, discounted payback period, discounted economic value added DEVA. The estimated values of these characteristics are further used for the economic evaluation of investment costs and benefits of these proposals.

1 Introduction

The company which is the subject of the case study is a company engaged in the production and sale of plastic windows and doors. It focuses mainly on the Slovak market, but in recent years it began to work also with foreign countries. The main objective of the company is to deliver quality products at a reasonable price and in time. The products are made of quality materials and compliance with technological processes, allowing them to ensure high quality products with minimal complaints.

The company has one production hall, which produces plastic and aluminum windows and doors. The offices are in the hall. Warehouses are directly in the production hall. Great attention is paid to assembly work, since improper installation of the most common causes the reduction of product quality and comfort of use.

The company has one production factory (Fig.1), which produces plastic, and aluminum windows and doors. The offices are in the hall. Warehouses are directly by the production hall, but also inside of it (Fig.2). Materials storage works on electronic customer's orders, which are processed by software. This software is not connected with production. After that, process engineer create the technological procedure. Storekeeper orders the material which is necessary for processing the contract.

Company disposes with production hall, where plastic and aluminum windows and doors are produced. Parts of the production hall are also warehouses and offices (Fig. 1). is a plan view of the hall. There are shown the different workplaces, warehouses, locker rooms, and offices.

A flow chart elaborated in Tab. 1 shows the sequence of technological operations of the manufacturing process for the production of plastic windows. It is important for the analysis of material flow to monitor:

- individual transactions in the context of production activities in terms of type and time,
- handling activities and methods of transportation, storage,
- control quality and quantity,
- organizational provisions for the particular motion, waiting, idle time, etc.

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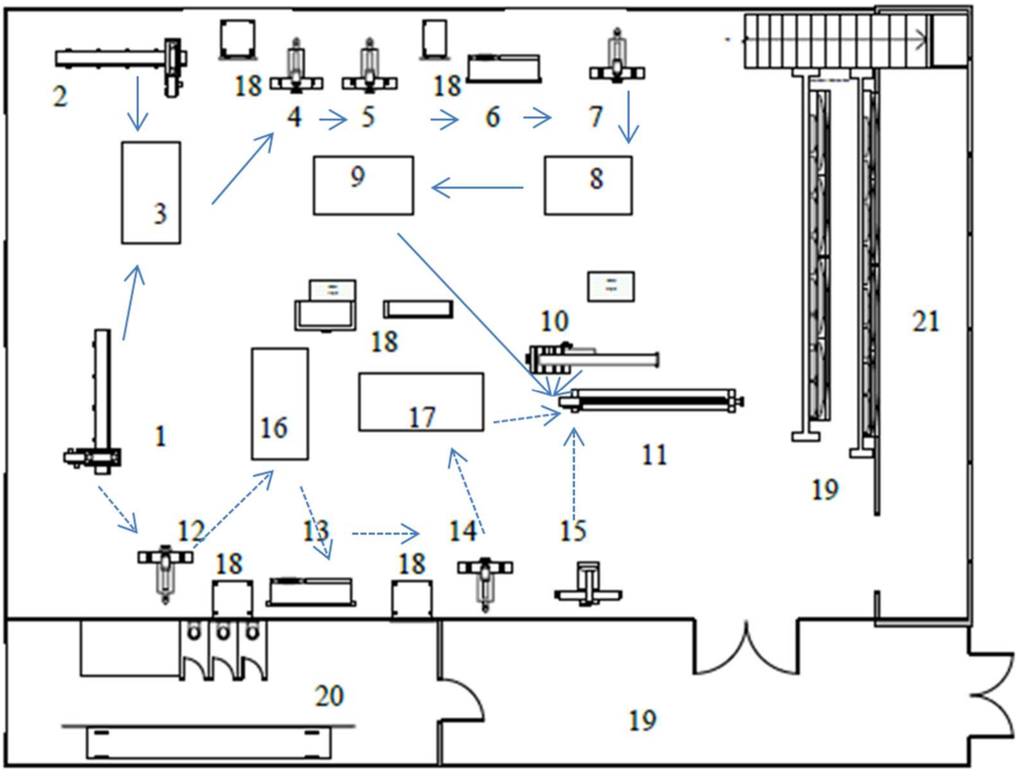

Legend: 1. CNC saws, 2. belt hacksaw, 3. work desk with drill, 4. cutter, 5. drill, 6. welder double-barreled, 7. cutter, 8. work desk with neatening cutter, 9. work desk with drill, 10. saw on glazing bars, 11. roller track, 12. saw on metal, 13. cutter, 14. the single-press, 15. saw on glazing bars, 16. workbench with neatening cutter, 17. workbench with drill, 18. tool cabinets, 19. warehouses, 20. dressing rooms, 21. Offices, 12. saw on metal

Figure 1 Ground plan of the production hall of the company

Figure 2 Production hall and warehouses of the company

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Table 1 Flow chart of window production

Num.	Type of activity	Symbol of operations							Time [min]
		operation	transport	control	X un/loading	storage	packing	waiting	
1.	Sawing of plastic profiles								15
2.	Cutting of reinforcement								15
3.	Completion								25
4.	Milling								10
5.	Drilling								7
6.	Welding								22
7.	Machining of corners								15
8.	Bonding of gaskets								30
9.	Montage of fitting								45
10.	Cutting of glazing beads								15
11.	Glazing								30
12.	Final testing								12
13.	storage and transportation								-

Simulation time: 8:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
vystup	hlinikove_okno	28:16.8821	22	3	99.59%	0.41%	0.00%	99.01%	
vystup	plastove_okno	31:05.8623	19	2	99.62%	0.38%	0.00%	90.04%	

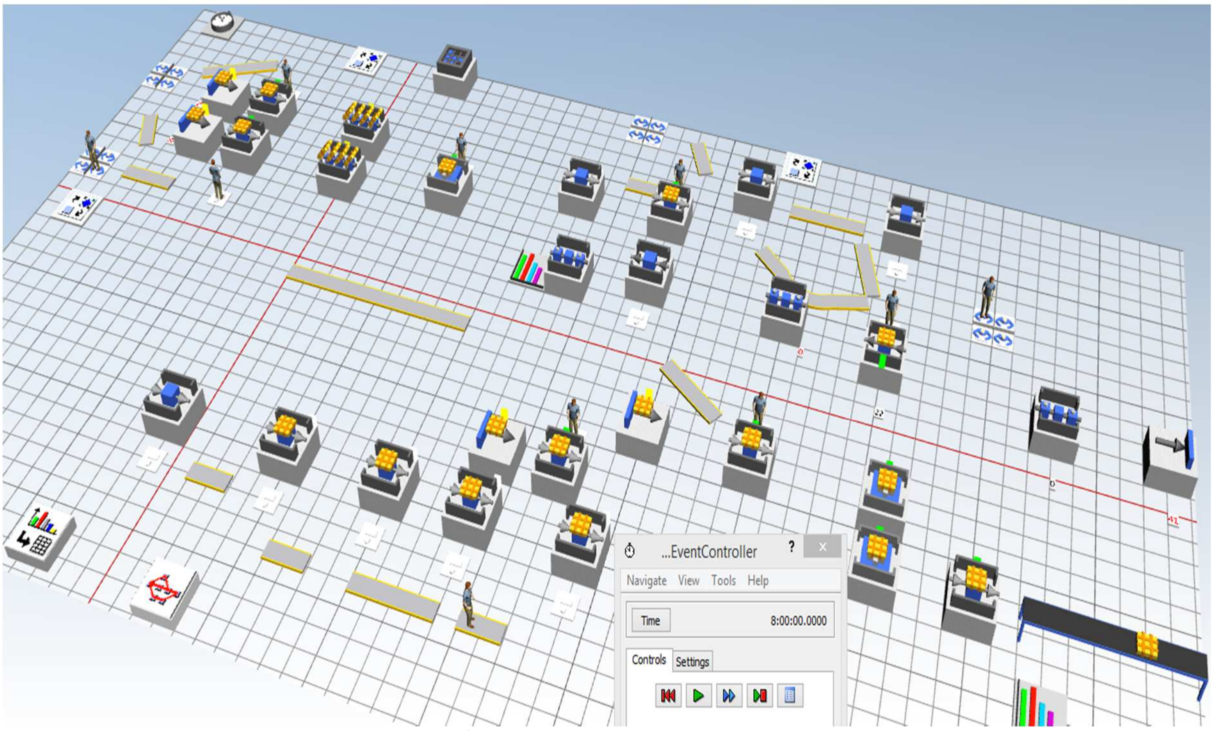

Figure 3 Production hall of the company modelled in Tx Plant Simulation in 3D

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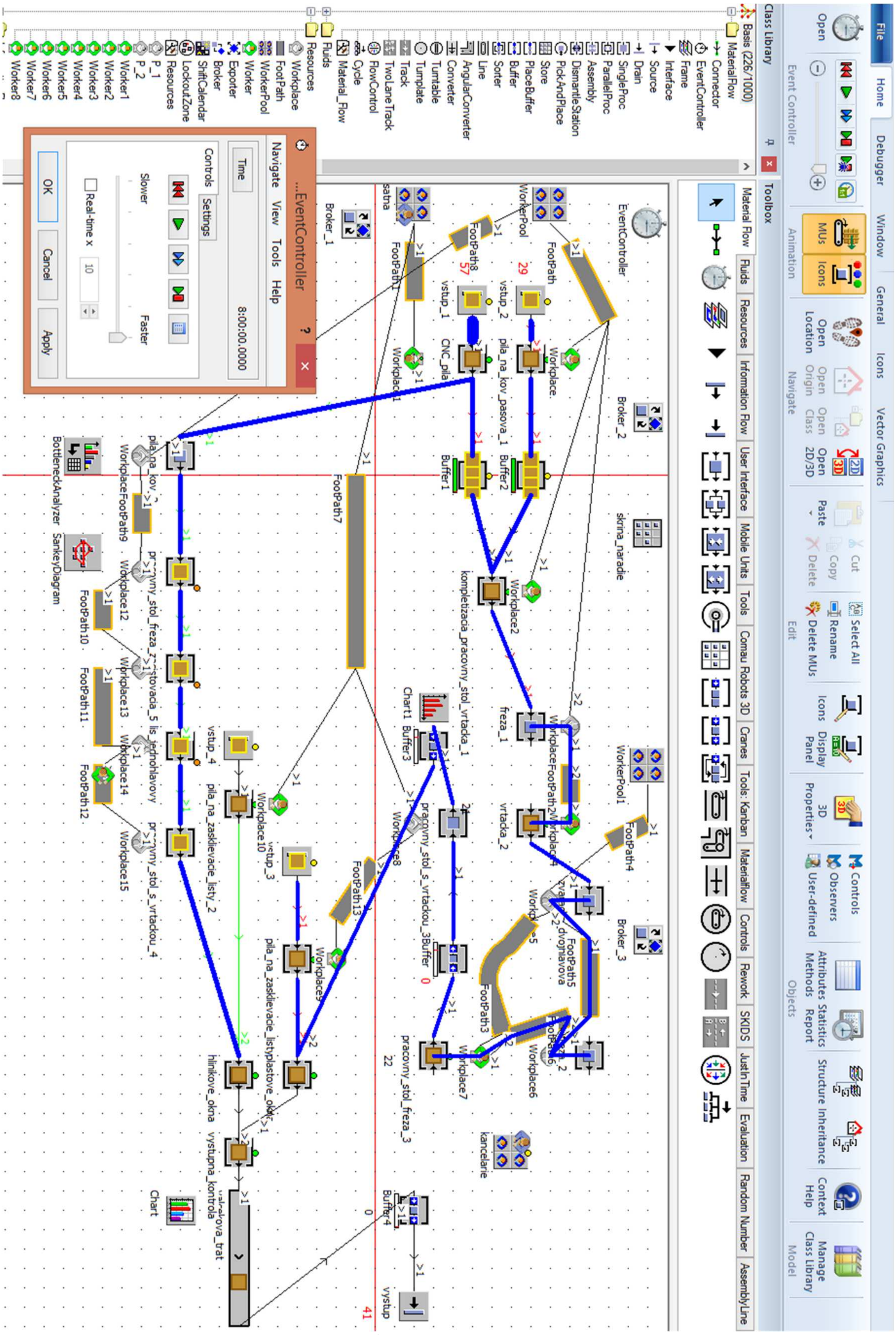


Figure 4 Production hall of the company modelled in Tx Plant Simulation

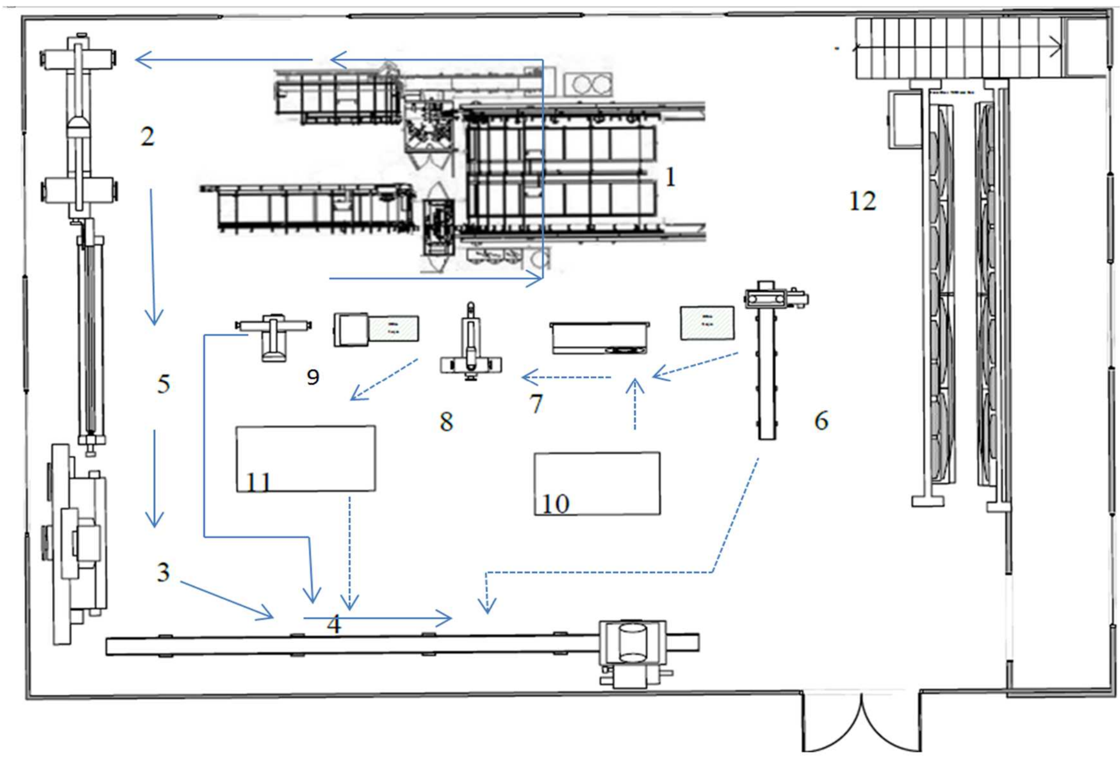
Table 2 Time portions of the workers in Tx Plant Simulation

	Working	Setting-up	Repairing	Transporting	En-route to job	Waiting for Importers	Waiting for MUs	Failed
Worker8	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Worker	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Worker1	59.57%	0.00%	0.00%	0.00%	0.01%	40.42%	0.00%	0.00%
Worker2	82.90%	0.00%	0.00%	0.00%	0.01%	17.09%	0.00%	0.00%
Worker4	97.07%	0.00%	0.00%	0.00%	0.01%	2.92%	0.00%	0.00%
Worker3	47.06%	0.00%	0.00%	0.10%	0.10%	52.74%	0.00%	0.00%
Worker6	90.18%	0.00%	0.00%	0.33%	0.30%	9.20%	0.00%	0.00%
Worker8	5.02%	0.00%	0.00%	0.00%	0.02%	94.96%	0.00%	0.00%
Worker5	50.42%	0.00%	0.00%	0.00%	1.09%	48.50%	0.00%	0.00%
Worker7	89.15%	0.00%	0.00%	0.00%	0.33%	10.52%	0.00%	0.00%

The result of the analysis of material flow of plastic windows in the company is concerned to the fact, that if a company wants to increase its productivity from about 30 windows per day to at least 80 windows per day, it will be necessary to optimize production disposition and propose a new production line, Fig.3 and Fig. 4 and Tab. 2. To increase productivity, factory needed to rationalize the material flow through the simulation program Tx Plant Simulation.

Aim was to:

- eliminate unnecessary handling,
- increase production productivity,
- ensure proper working conditions and safety at work,
- optimize in-process handling and storage.



Legend: 1. STBAZ PVC 300 X-Slicers and machining center, 2. SE-VSM-CS-Vertical quadriceps welder, 3. FBS-2M-H - Semi screwdriver to screw the fitting components to the wing 4. Fixus D-Control and glazing unit, 5. ELAN OS- retaining wall, 6. Hacksaw, 7. cutter, 8. the single-press, 9. Saw on glazing bars, 10. Workbench with unique debarring cutter, 11. Work desk with a drill, 12. Tool cabinets

Figure 5 Production hall with the proposed production line

The proposed production line needs four employees to operate the machinery. It´s lead to a reduction in the number of employees from the eight staff allocated to the production of plastic windows to 4. Fig. 5 shows the flow of materials between workplaces. Material flow of plastic windows is marked in red, material flow of aluminum products is marked in dashed line.

Optimization of the production process was elaborated with help of software support TX Plant Simulation, Fig. 6 and Fig. 7. It is a view of placement some particular workplaces, needs of workers' and views of material flow in the form of Sankey diagram, which reflects the intensity of flow between the different workplaces.

With the investment in this range company will shorten the production process, reduce scrap, improve the quality of their products, and increase productivity. It will be able to expand into foreign markets, such as Poland, Czech Republic. Also reduce the number of production workers from 8 to 4, which will have the effect of reducing labour costs. The result is an increase of income.

Simulation time: 8:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
vystup	hlinikove_okna	12:24.7130	47	6	98.97%	0.81%	0.22%	88.62%	
vystup	plastove_okna	13:57.8330	37	5	97.32%	0.72%	1.97%	78.77%	

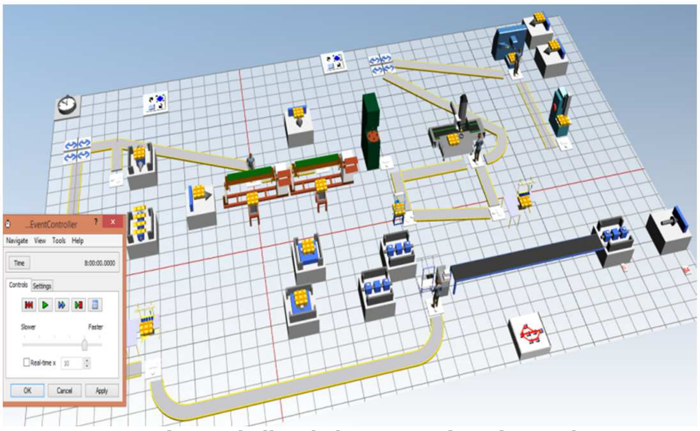


Figure 6 Production hall with the proposed production line in 3D

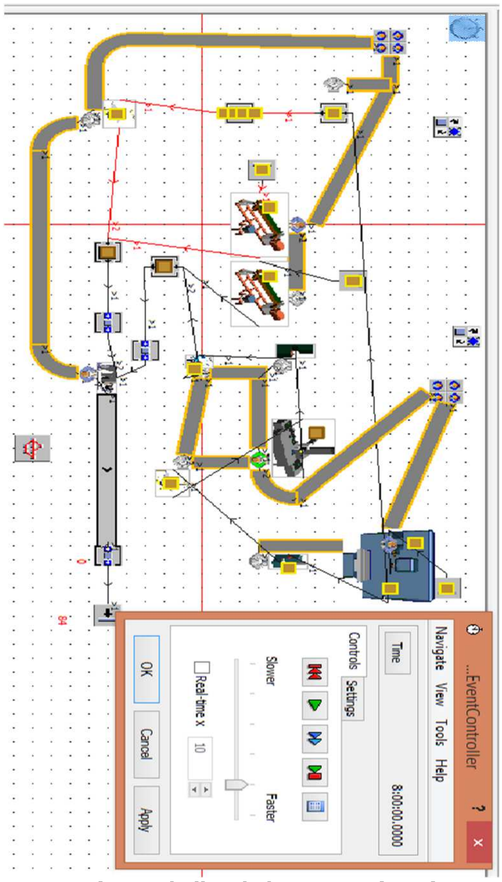


Figure 7 Production hall with the proposed production line

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Resource statistics as listed in Tab. 3, Tab.4 gives an overview of capacity utilization as well as downtimes of individual machines and equipment for the production of plastic and aluminum windows. It is a statistical summary of production during the course of an eight-hour work shift. Summary statistics indicate the number of pieces that have been produced and the time of production, transportation and storage expressed as a percentage.

Table 3 Time portions of the workers in Tx Plant Simulation after optimization

	Working	Setting-up	Repairing	Transporting	En-route to job	Waiting for Importers	Waiting for MUs	Failed
Worker4	12.36%	0.00%	0.00%	0.00%	1.40%	86.24%	0.00%	0.00%
Worker1	29.58%	0.00%	0.00%	0.00%	1.23%	69.19%	0.00%	0.00%
Worker6	98.50%	0.00%	0.00%	0.00%	1.20%	0.30%	0.00%	0.00%
Worker2	27.71%	0.00%	0.00%	0.00%	2.14%	70.15%	0.00%	0.00%

Table 4 Resource statistic in Tx Plant Simulation after optimization

Cumulated Statistics of the Parts which the Drain Deleted

Object	Working	Set-up	Waiting	Stopped	Failed	Paused	Mean Life Time	Mean Exit Time	Total Throughput	Throughput per Hour	Throughput per Day
vystup	84.76%	0.00%	15.24%	0.00%	0.00%	0.00%	13:05.7301	5:32.6095	84	10.5	252

Part Types which the Drains Deleted

Object	All Types	hlinikove_okna	plastove_okna
vystup	84	47	37

Detailed Statistics of the Part Types Which the Drain Deleted

vystup	Production							Transport							Storage						
	Working	Set-up	Waiting	Stopped	Failed	Paused	Sum	Working	Set-up	Waiting	Stopped	Failed	Paused	Sum	Working	Set-up	Waiting	Stopped	Failed	Paused	Sum
hlinikove_okna	88.62%	0.00%	10.35%	0.00%	0.00%	0.00%	98.97%	0.81%	0.00%	0.00%	0.00%	0.00%	0.00%	0.81%	0.00%	0.00%	0.22%	0.00%	0.00%	0.00%	0.22%
plastove_okna	78.77%	0.00%	18.54%	0.00%	0.00%	0.00%	97.32%	0.72%	0.00%	0.00%	0.00%	0.00%	0.00%	0.72%	0.00%	0.00%	1.97%	0.00%	0.00%	0.00%	1.97%

vystup	Life Time				Exit Time				Throughput		
	Mean Value	Standard Deviation	Minimum	Maximum	Mean Value	Standard Deviation	Minimum	Maximum	Total	Per Hour	Per Day
hlinikove_okna	12:24.7130	27.2623	12:19.1737	15:22.5978	10:00.1432	9.4462	9:31.7228	10:28.2772	47	5.875	141
plastove_okna	13:57.8330	2:45.1775	13:14.3832	29:52.7912	12:08.3832	56.1849	10:02.7682	14:13.9983	37	4.625	111

Portions of the States

Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
vstup_2	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
narezove_obrabacie_centrum	3.40%	0.00%	10.36%	86.24%	0.00%	0.00%	0.00%	0.00%	0.00%	
stvorhlava_zvaracka	11.25%	0.00%	2.74%	86.01%	0.00%	0.00%	0.00%	0.00%	0.00%	
vstup_1	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
poloautomaticky_skrutovac	10.21%	0.00%	2.42%	87.37%	0.00%	0.00%	0.00%	0.00%	0.00%	
vystupna_kontrolna	17.50%	0.00%	82.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
pila_na_kov	8.96%	0.00%	0.90%	90.14%	0.00%	0.00%	0.00%	0.00%	0.00%	
freza	41.67%	0.00%	58.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
jednohlavovy_lis	8.13%	0.00%	91.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
pila_na_zasklievacie_listy	10.21%	0.00%	10.64%	79.15%	0.00%	0.00%	0.00%	0.00%	0.00%	
pracovny_stol_zacistovacia_freza	8.54%	0.00%	91.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
pracovny_stol_vrtacka	40.17%	0.00%	59.83%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
oporna_stena	0.00%	0.00%	2.30%	97.70%	0.00%	0.00%	0.00%	0.00%	0.00%	
valcekova_trat	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
vystup	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
vstup_3	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
hlinikove_okna	99.12%	0.00%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer1	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Buffer2	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Source	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
pila_na_zasklievacie_listy_1	8.13%	0.00%	2.74%	89.13%	0.00%	0.00%	0.00%	0.00%	0.00%	
plastove_okna	79.16%	0.00%	20.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	

Simulation time: 8:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
vystup	hlinikove_okna	12:24.7130	47	6	98.97%	0.81%	0.22%	88.62%	
vystup	plastove_okna	13:57.8330	37	5	97.32%	0.72%	1.97%	78.77%	

2 Economic efficiency evaluation of the proposed production disposition,

The price of production line is 320 000 €, costs associated with installation, shipping is 2000 €. The company can invest 40% from the price, it represents 128 800 €. The remaining 60%, which amounts to 193 200 €, would have asked for a loan from the bank for six years, the other inputs data are in Tab. 5.

Table 5 Inputs data

price of the production line	320 000 €
costs related to installation, transportation	2 000 €
own resources	128 800 €
external resources	193 200 €
time of the loan	6 years
interest rate	6 %
installment	the same height
depreciation group	2
required rate of return	11%
increase in net working capital	o 1 000 €/for 6 years
number of pieces per year	18 000 pieces
price	220 €/ pieces
WACC	11%

The calculation of labour costs:

- for 1 worker:
  - o number of hours of one worker 1687,5 hours.
  - o hourly wage is 3,20 €
  - o annual costs for hourly wage is 5 400 €.
- for 8 workers:
  - o -8 hours for workers is 13 500 hours.
  - o hourly wage is 3,20 €.
  - o annual costs for hourly wage is 43 200 €.

Labour costs would be 21 600 €. In Tab. 6 there is composed of repayments for a period of six years.

Table 6 Repayment Schedule

Year	State of the loan	Installment of the loan	Payment of interest	Annuity
1.	193200,00	27697,66	11592,00	39289,66
2.	165502,34	29359,52	9930,14	39289,66
3.	136142,82	31121,09	8168,57	39289,66
4.	105021,73	32988,36	6301,30	39289,66
5.	72033,37	34967,66	4322,00	39289,66
6.	37065,72	37065,72	2223,94	39289,66
∑		193200,00	42537,96	235737,96

After the completion of the repayment plan (with the same amount of total payments) payment will get the sum 39 289,66 €. The total loan amount is 235 737,96 €. Quantifying the expected costs and benefits:
Revenues: 3,960,000 € (unit price x volume)
Cost:
+ direct materials: 2 340 000 € (130 €*18 000 pieces)
+ direct salary: 21 600 € (6750 hrs.*3.20 €)
+ indirect materials: 18 000 € (10 €*18 000 pieces)
+ energy: 25 500 € (0.3 €/kWh*85 000 kWh)
Σ 2 405 100 €, the cost is 133.6 €/window.

Tab.7 contains calculations that are needed to determine the annual cash receipts, net present value, index, and present value discounted payback period.

Table 7 Calculations for net present value, index present value, discounted payback period

Indicator	**1**	**2**	**3**	**4**	**5**	**6**
Revenue	3 960 000	3 960 000	3 960 000	3 960 000	3 960 000	3 960 000
-Costs	2 405 100	2 405 100	2 405 100	2 405 100	2 405 100	2 405 100
-Depreciation	53666,67	53666,67	53666,67	53666,67	53666,67	53666,67
Gross profit	1501233,33	1501233,33	1501233,33	1501233,33	1501233,33	1501233,33
-Income tax (19%)	285234,33	285234,33	285234,33	285234,33	285234,33	285234,33
Net profit	1215999	1215999	1215999	1215999	1215999,	1215999
+Depreciation	53666,67	53666,67	53666,67	53666,67	53666,67	53666,67
- Net working capital	1000,00	1000,00	1000,00	1000,00	1000,00	1000,00
Annual cash income	1268665,67	1268665,67	1268665,67	1268665,67	1268665,67	1268665,67
i=0,11	0,9009	0,8116	0,7319	0,6587	0,5935	0,5346
Discounted	1142940,90	1029649,06	928536,40	835670,08	752953,07	678228,67

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payback period						
Cumulated DPP	1142940,90	2172589,96	3101126,36	3936796,43	4689749,51	5367978,17

Annual cash income of 1 268 665,67 €.

The net present value (1):

$$\check{C}SH = \sum PPn * \frac{1}{(1+i)^n} - KV \qquad (1)$$

NPV = 5367978,17- 322 000
NPV = **5045978,17 € -** Investment is acceptable.

Index present value (2):

$$ISH = \frac{\sum PPn * \frac{1}{(1+i)^n}}{KV} \qquad (2)$$

$$ISH = \frac{5367978,17}{322000} = 16,67$$

IPV = **16,67 € -** 1 € the investment will bring € 16.67.

Discounted payback period (3):

$$DDN = \sum PPn * \frac{1}{(1+i)^n} = KV \qquad (3)$$

$$DDN = 0 + \frac{322000}{1142940,90} = 0,28$$

DPP = **0,28** year.

Annual cash income reaches 1 268 665,67€. Net present value is a positive value of 5 045 978,17€, the investment is acceptable. Index of present value is 16.67€, bringing one euro invested. Payback period is 0.28 years. By help of indicator DEVA/discounting the economic value added is determined whether the market value of the company will grow. The procedure of the calculation for DEVA is in Tab.8.

Table 8 Calculations for DEVA

Indicator	1	2	3	4	5	6
Revenue	3 960 000	3 960 000	3 960 000	3 960 000	3 960 000	3 960 000
-Costs	2 405 100	2 405 100	2 405 100	2 405 100	2 405 100	2 405 100
-Depreciation	53666,67	53666,67	53666,67	53666,67	53666,67	53666,67
Gross profit EBIT	1501233,33	1501233,33	1501233,33	1501233,33	1501233,33	1501233,33
-Income tax (19%)	285234,33	285234,33	285234,33	285234,33	285234,33	285234,33
Net profit NOPAT	1215999	1215999	1215999	1215999	1215999,	1215999
C	322000	268333,33	214666,66	160999,99	107333,32	53666,65
C*WACC	35420	29516,6663	23613,3326	17709,9989	11806,6652	5903,3315
EVA	1180579	1186482,33	1192385,66	1198289,00	1204192,33	1210095,67
i=0,11	0,9009	0,8116	0,7319	0,6587	0,5935	0,5346
DEVA	1063583,62	962949,06	872707,07	789312,96	714688,15	646917,14
						∑ 5050158

DEVA is 5 050 158,00 €, which means that DEVA> 0 - the investment is acceptable, the market value of the company will grow.

From the optimization of production line of company, benefits are following:

- increasing the production of 30 windows of at least 80 windows per day, representing an impact of 166,6%;
- reducing the number of employees from 8 to 4, saving staff costs is 21 600 €,
- return on investment in the production of 80 windows per day is 0,28 years,
- one euro invested would give 16,67 €,
- the company's market value will increase,
- speedier customer orders,
- possibility of involvement in demanding projects,
- penetration into foreign markets,
- increasing quality of product.

Conclusions

To increase the productivity in the context of increasing the efficiency of the production process of plastic and aluminum windows and doors, as a whole, there was processed draft of the measures to optimize material flow in software program TX Plant Simulation.

The optimal solution is related to the introduction of a new production line. This software was helpful in the process of design and appreciation by comparison with the default state. Chosen production facilities were allocated to the production hall of the company in area of Tx Plant Simulation. The principal value of the simulation is that the proposed solutions allow you to check prior to their implementation and to identify possible errors. Direct intervention into the production process would initiate significant expenses.

Evaluation of investment measures is an important part of a comprehensive process of optimization. This is a quantification of economic indicators which help to assess the proposed solutions and prepare a basis for decision-making in relation to planned changes in the company. The case study focused specifically to quantify labor costs, net present value, index, present value, discounted payback period, and determining whether the investment would increase the market value of the company. Based on the above facts it can be concluded that the proposed measures would certainly contribute to the optimization of material flow and increase the productivity of the enterprise.

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