WP4: The Economic Appraisal

Dondur N., Spasojević Brkić V., Brkić A.

This workpackage analyses the economic feasibility of Smart Process INdustry CranEs application in various scenarios in aim to connect human, technology and organization isuses through cost-benefit framework. There are 3 proposed scenarios:

A)Production and sale of Smart Process INdustry CranEs with Visual guidance system

B) Usage (purchase) of with Smart Process INdustry CranEs characteristics – with Visual guidance system and

C) Instalation (purchase) of crane cabin with Visual guidance system.

It includes development of economic appraisal criteria and analysis of obtained results.

The analysis proved that the total economic benefit in all scenarios in the overall exploitation period is several times higher than the purchase price, as well as that the internal rate of return is several times higher than the relevant average weighted interest rate and the payback period is less than 5 years. The analysed project is in the category of projects with very low risk.

This approach requires developing complete tables of financial and economic flows, necessary for the calculation of the selection criteria (FNPV, FIRR, ENPV, EIRR, pay-back period, BCR). The second approach refers to an assessment of economic feasibility of investing and/or comparison of such investments (initial investment costs) and discounted additional effects (savings) in the exploitation over the lifetime. Thus developed net flow serves as a basis for developing the quantitative parameters for the justification of investment and/or purchase of the new generation crane cabins from the aspect of the crane owner or user and from the aspect of the entire economy (NPV, IRR, BCR, pay-back period). For creating an economic net flow, it is necessary to identify and quantify relevant costs and effects (Rosenfeld, Shapira, 1998, Neitzel et al., 2001, Beavers et al., 2006).

Scenario A

The investment in construction works amounts 800.000 EUR while investment in mechanical equipment amounts 480.150 EUR, that amounts in total 1.280.150 EUR.

Crane cabin production costs are as follows:

Crane cabin production costs	EUR
Air conditioning device	1.445
Steel	600
Glass	575
Painting material	150
Electrical/Control equipment	2.600
VGS	1.100

Total material and parts costs amount 6.470 EUR. If there is a labour force of 20 employees and production volume of 200 cabins per year, cost of labour per cabin amount 750 EUR. Maintenance costs are calculated as percent of total value of investment, while amortization is calculated by proportions method in the exploitation period (20 years). In the planned exploitation period equipment is fully depreciated, while production site has value of 160.000 EUR. The planned maximum production capacity of 200 cabins would be reached in the third year. In the first two years of exploitation, the capacity would be used with 75% and 83% of the maximum capacity. The stock of ready-made cabins are planned on a monthly basis (17 at full capacity), while the receivables as part of the working capital are planned on a monthly basis. The projected selling price is the main price on the international market for similar products and amounts to 10 000 euros per sold cabin. The average annual sales revenue at constant prices is 1.833.333 euros. Table 3 provides an overview of the aggregate values of the basic positions of the projected profit and loss.

Aggregate income statement items are as follows:

Aggregate income statement items	EUR
Total income	36.063.333
Total expenditures	31.076.998
Profit before tax	4.986.335
Net profit	4.487.701

The average annual net profit of the factory is 224.385 euros.

Project profitability indicators are as follows:

Profitability indicators	Value	Unit
Net present value	1.312.721	EUR
Internal rate of return	24,43%	%
Investment return period (undiscounted)	4,1	year

The net present value of the project is positive and exceeds the initial investment costs in several ways. The net present value at a rate of 10% amounts to 13,127,211 euros, which is more than the initial investment costs. By reducing the discount rate, the net present value increases dramatically. The net present value can be calculated at a lower discount rate, taking into account the relevant interest rate on the domestic financial market. With a discount rate of 5% of the NPV of the project is twice higher of the initial investment . Following the criteria for assessing the justification our project is acceptable. In addition to the positive net present value, the project also achieves a positive internal rate of return of 24.4%. Since the average profit rate of the project (IRR) is several times higher than the relevant interest rate (capital price) in the capital market, the project for the construction of a factory for the production of cabin boats with previously defined technology and the volume of production is economically justified by this criterion. The investment return period is 4.1 years, which is acceptable for projects in the metal industry.

Sensitivity analysis gives the following results:

Input		**Parameters of economic justification**		
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
Production volume	0%	1.312.721	24,43%	4,1
	-10%	903.951	20,19%	5
	10%	1.721.491	28,56%	3,5
Critical production volume (pcs)	136	0	10%	/
	Change	NPV	IRR	Payback

	(in %)	(EUR)	(%)	(year)
Price of the cabin	0%	1.312.721	24,43%	4,1
	-10%	-47.164	9,40%	9,1
	10%	2.672.605	37,49%	2,6
Critical cab price (Eur / Cab)	9.035	0	10%	/
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
Volume of investment	0%	1.312.721	24,43%	4,1
	-10%	1.430.007	27,28%	3,8
	10%	1.196.343	22,10%	4,5
Critical volume of investment investments (€)	2.720.0 00	0	10%	/

On the basis of these results, it can be concluded that this is a project with acceptable risk ranges.

Scenario B

The exploitation of the new generation of crane cabins has direct and indirect positive effects from the aspect of the owner or user of the crane, but also positive effects on the overall economy. Direct positive effects from the point of view of the crane owner are primarily manifested through increase in productivity of the crane use. The cabin with integrated visual systems for the detection and interpretation of environment allows the crane operator to perform work operations faster. Savings of time at one duty allows the crane owner to engage the crane at another job without any additional exploitation costs. Reduction of the annual crane exploitation costs due to the assembly of the new crane cabin, which allows saving of time in performing work operations (Δt) represents benefit from the aspect of the crane owner. As the exploitation costs depend on the time of the crane operation (t), for the calculation purposes the positive effect for the crane owner represents a product of the sum of all exploitation costs and weight of the average time saving in performing operations ($\sum CE_t \cdot \rho_t$).
The annual crane exploitation costs can be decomposed to the costs of depreciation (capital recovery), costs of maintenance and repairs, as well as insurance and registration costs. Formally, these costs can be presented as follows:

$$\sum CE_t = PC * PMT_n^i + MC_t + RC_t + IC_t \quad (1)$$

where PC represents a purchase value of the crane, PMT_n^i stands for capital recovery factor for the specific exploitation lifespan of the crane (n) and interest rate (i). Depreciation of the crane is observed as depreciation of debt and/or future value of equal annual repayments of the amount invested in the purchase of the crane.
Weight of the average time saving is determined as a relative ratio of the sum of differences in time of the operations performed by the crane without the new generation cabin and the time of operations with the new cabin and the total time of operations without the cabin with the integrated visual crane management system:

$$\rho_t = \frac{\sum_j^N (T_j^1 - T_j^2)}{\sum_j^N T_j^1} \tag{2}$$

where ρ_t represents weight of the average reduction in time of operation of the crane with the new cabin, T_j^1 time of operation (j) without the cabin with the integrated visual system for detection and T_j^2 stands for time of operation (j) with the new generation crane cabin.
The following direct benefit of installing the new generation crane cabins is reduction in labour costs. If we assume that the number of workers and labour cost per hour remain the same, operation time reduction allows the worker to perform in such time reduction an additional work that is beneficial for the crane owner. Accordingly, time reduction of the operations (ρ_t) which the crane achieves thanks to the use of the new generation cabins represents a weight for calculation of the annual savings in labour costs (LSC_t) as a product of the number of workers, cost of labour per hour and number of working hours of the crane:

$$LSC_t = n * h_t * w_h * \rho_t \tag{3}$$

where LSC_t represents savings of labour costs in a year (t), n stands for a number of crane operators, h_t number of effective working hours of the crane in a year (t), w_h average value of the working hour and ρ_t is a weight of average savings of time of the crane operation in a year (t).
By installing the new generation crane cabin, incidence of professional diseases and injuries of crane operators is reduced. This positive effect can be quantified through reduction of number of working hours which the crane operator spends on a sick leave, during which period a new worker must be hired. This saving can be quantified as a product of the number of workers, number of hours lost due to the crane operator's absence, labour cost per hour and average weight of time reduction of the crane operations:

$$LSDC_t = n * Dh_t * w_h * \rho_t \tag{4}$$

where $LSDC_t$ represents annual savings in labour costs while the crane operator is on a sick leave, *n* a number of crane operators, Dh_t number of working hours lost due to sick leaves, w_t represents a cost of the working hour and ρ_t weight of average time saving of the crane operation in a year (t).
Thanks to a better visibility, the use of the new crane cabin reduces a number of breakdowns and slows down wear and tear of the crane mobile parts and/or reduces the costs of crane maintenance and repairs. This positive effect is determined as a product of the crane value and difference in the relative annual maintenance and repair costs:

$$MRSC_t = PC * \left[\frac{MRC_t^1}{PC} - \frac{MRC_t^2}{PC} \right] \tag{5}$$

where $MRSC_t$ represents savings on the annual costs for maintenance and repairs of the crane, PC is a purchase value of the crane, MRC_t^1 is the value of the annual costs for maintenance and repairs of the crane without crane cabin with visual system and MRC_t^2 is a value of the annual costs for maintenance and repairs of the crane with the new generation crane cabin.

Through a more efficient use of the crane, the new generation crane cabin is supposed to exend the assumed crane exploitation lifespan. Extension of the crane exploitation lifespan brings additional benefits through reduction of annual depreciation (recapitalisation) costs of the crane which is quantitatively determined as the difference between recapitalised annual write-offs and the lifetime of the crane (n) without the new generation crane cabin and recapitalised annual write-offs with the extended crane exploitation lifespan (n+m):

$$ELSC_t = PC * PMT_n^i - PC * PMT_{n+m}^i \tag{7}$$

where $ELSC_t$ represents annual savings on depreciation write-offs, PC purchase value of the crane, PMT_n^i capital recovery factor with the assumed exploitation lifespan without the new crane cabin *(n)* with appropriate interest rate *(i), whereas* PMT_{n+m}^i represents a capital recovery factor with the extended exploitation lifespan *(n+m)* due to the use of the new crane cabin with appropriate interest rate *(i)* .

For the assessment of economic feasibility of the crane cabin with integrated visual systems for the detection and interpretation of environment, the following standard cost benefit criteria are defined: net present value, internal rate of return, cost - benefit ratio and return on investment. Net present value (NPV) of an investment in the new generation crane cabin represents the difference between the sum of initial investment costs and the sum of discounted savings over the entire lifetime of the crane, whereby such savings are resulting from the use of the new crane cabin:

$$NPV = -(I_0 + I_1) + \sum_t^{n+m} \frac{(CE_t + LSC_t + LSDC_t + MRSC_t + ELSC_t)}{(1+i)^t} \tag{8}$$

where NPV represents net present value of savings on costs of the crane exploitation achieved by the crane cabin with the integrated visual system over the crane lifetime $(n+m)$ and *(i)* represents relevant discount rate. Based on this criterion, use of the new crane cabin is justified if the net present value is positive.
Internal rate of return (average rate of profit) IRR of the investment in acquisition of the new crane cabin is the value of discounted rate which equates the difference of the initial costs for the acquisition of the new crane cabin and the present value of the total savings on the costs with zero.For a project to be economically justified, this rate should be above the average weighted interest rate.
Cost benefit ratio of the justification of using the new crane cabin represents a relative ratio of the total net value of the crane exploitation and the costs of acquisition, assembly and training of the crane operator for the work in that cabin. According to this criterion, purchase of the crane cabin will be economically justified if this relative ratio is greater than one.

For the assessment of the economic feasibility of the new generation crane cabin acquisition, we used the data referring to the bridge crane cabin. Table 1 provides the estimated data and, by using figures from (1) to (7), calculated values referring to the costs of acquisition and savings during the exploitation of the new crane cabin.

Table 1. Economic cost- benefit appraisal inputs

Variables	**Values (Euros, %, hours, years, number)**
Costs	
• Cabin manufacturing costs (costs of materials, labour, energy - I_0)	10.645 Eur
• Costs of assembly, testing, crane operator training and disassembly of the existing cabin if it is already fitted on the crane (I_1)	670 Eur
Benefits (Savings)	
• Savings in time of operations /cycle reduction / (ρ_t)	10 % (8-12%)
• Purchase price of the crane	268,000 Eur (20,000-500,000)
• Annual savings on labour costs (LSC_t) .	1,440 Eur
• Annual savings due to reduced incidence of professional diseases and injuries of crane operators (LSC_t)	400 Eur
• Reduction of the crane maintenance and repair costs ($LSDC_t$)	1,655 Eur
• Savings due to the extended exploitation lifespan (from 15 to 18 years) ($ELSC_t$)	751 Eur

By using the expression (8), we defined empirically net present value of the net effect of the acquisition and use of the new generation crane cabin. Net present value as a synthetic measure of absolute economic viability is in the first step calculated on the basis of the best estimates of the values of variable models. Those values are given in Table 1. Net present value is, at the discount rate of 10%, Eur 34.934,95. The total economic benefit of the exploitation of the cabin in the overall exploitation period is several times higher than the purchase price of the cabin and according to this criterion, the project of installing the new generation cabin is economically justified. Internal rate of return as a relative measure of economic feasibility of the purchase and exploitation of the new crane cabin is several times higher than the relevant average weighted interest rate and is equal to 37.39%, which implies high economic profitability of the investment. Annual savings which are made in the operation of the crane managed from the new generation cabin are Eur 6.746, which shows that the payback period is slightly less than three years. As these are estimated input values applied in the calculation of the relevant criteria for the assessment of feasibility, we used sensitivity and risk assessment to test the robustness of the obtained results.

Sensitivity analysis gives the following results:

Input		**Parameters of economic justification**		
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
The cost of the crane	0%	34.860	37,33	2,75
	-10%	31.205	34,63	3,21
	10%	38.664	40,14	2,01

Critical cost of crane	69.960	0	10%	/
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
Price of the cabin	0%	34.860	37,33	2,75
	-10%	36.571	41,58	2,50
	10%	33.298	33,94	3,10
The critical value of the cab	56.346	0	10%	/
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
Savings in working hours	0%	34.860	37,33	2,75
The cost of the crane	-10%	34.631	37,16	2,81
	10%	35.239	37,61	2,51

The sensitivity analysis shows the relative stability of the results on changes in the selected variables in the range (± 10%). The obtained results do not significantly affect the value of the criteria for assessing the economic justification of the procurement project and the use of a new generation of crane cabins. The critical cost of the crane (the value of the crane according to which the net profit of the savings equals zero) is 69,960 euros. The price of the cabin can be increased to as much as 56,346, and the project for procuring the cabin cab for the detection of the environment is still economically justified. The period of return of funds invested in the purchase and installation of the new cranes cabin is not too sensitive to the variation of the value of the input economic parameters. The payback period varies from 2 to 3 years.

Scenario C

In the third scenario (C), the feasibility of purchasing and installing visual systems (VGS) and monitoring of the work of the crane in a real time is assessed economically. The methodological approach is identical to that used in scenario (B).

In the scenario of the assessment of the system for the detection of the environment, the initial investment costs include hardware purchase costs (2 Wi-Fi cameras OpenNI type, 1 Remote control, 2 Portable power pack 10400 mAh, 2 MicroSDXC Memory Card 64 GB, 1 Computer, 2 Raspberry pi 3) Software costs, equipment and program installation costs, adjustment costs for the existing cab and initial training costs. In the model of assessment of the economic feasibility of installing the system for the detection of the environment in the existing cabin and the existing crane of smart cranes in the process industry, the initial investment costs range from 5,800 to 8,900 euros, depending on the characteristics of the equipment. In our conservative estimate, the initial investment cost is 7,400 euros. Starting from the assumed lifespan of the crane (17 years old), in the eighth year, a complete replacement of hardware is planned, which evaluates the treatment of a new investment cost. Additional operating costs that entail the installation of VGS system in the cabin of smart cranes for the process industry include hardware and software maintenance costs, increased labour costs, additional electricity costs that implicate the exploitation of a VGS system and other dependent operating costs.

Investment Costs	EUR
• Hardware costs • 2 Open-type Wi-Fi cameras • 1 Remote control • 2 Portable power pack 10400 mAh • 2 MicroSDXC Memory Card 64 GB • 1 Computer • 2 Raspberry pi 3	5.900
• Software costs	1.000
• Costs of installation, testing and training	500
Additional operating costs	
Additional labor costs	1.800
Costs for software maintenance and additional costs of electricity	100

Benefits / year	**EUR**
Savings in more efficient use of crane	2.494
Savings in labor costs	
$LSC_t = n * h_t * w_h * \rho_t$	1.440
Annual savings due to reduced incidence of professional diseases and injuries of crane operators	
$LSDC_t = n * Dh_t * w_h * \rho_t$	441
Reduction of the crane maintenance and repair costs	
$MRSC_t = PC * \left[\frac{MRC_t^1}{PC} - \frac{MRC_t^2}{PC} \right]$	1.652
Reduction of annual depreciation costs	750
$ELSC_t = PC * PMT_n^i - PC * PMT_{n+m}^i$	
Total	**6.776**

The total additional net effects (savings) resulting from the exploitation of the VGS are € 6,776 per year. The net present value of the installation of visual and audio detection systems for the environment is 26,828 euros for a 17-year exploitation period and at a discount rate of 10%. According to this criterion and with very conservative estimates of the discount rate, the project is economically justified.
The internal rate of return of the project for the installation of a visual detection system on the existing crane is 65%, and this rate is several times higher than the discount rate. The system is also economically justified by this criterion.

Sensitivity analysis gives the following results:

Input		Parameters of economic justification		
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
VGS price	0%	26.328	64,9	1,5
	-10%	27.115	70,8	1,4
	10%	25.54	59,9	1,7
Critical value for VGS price	334%	0	10%	-
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
Increase in labour costs	0%	26.328	64,9	1,5
	-10%	27,64	67,4	1,3
	10%	25,15	62,4	1,8
Critical value of increasing labour costs	150%	0	10%	-
	Change (in %)	NPV (EUR)	IRR (%)	Payback (year)
Savings in working hours	0%	26.328	64,9	1,5
	-10%	25.972	64,3	1,6
	10%	26.614	65,5	1,5
Critical value of savings in working hours	-701%	0	10%	-

The sensitivity analysis shows the relative stability of the parameters of economic justification for changes in uncertain input quantities. The investment cost could be increased by more than three times and the design of a detection system would be on the margin of economic justification. Increasing the crankshaft will not significantly affect the overall economic performance of the installation of visual and audio detection systems on an existing crane for the process industry. The sensitivity analysis shows that the project for the installation of a visual surveillance system on an existing crane is a very low prospect for unfavourable economic performance and from this aspect it is assessed as very acceptable.

Conclusion

The techno-economic analysis and assessment of the use of smart cranes for the process industry was carried out in this study in three different scenarios. In the first scenario (A), the justification for the development, production and sale of "smart cranes for the process industry" was economically assessed. For the projected capacity of 200 cabins per year, the period of exploitation of the 19-year-old factory and the selling price of 10,000 euros per cabin, the results show that the production of this type of cabins is economically justified with a net present value of 1,312,721 euros, an internal rate of return of 24.5% and the pay-back period of invested of four years. The results of the risk analysis in this scenario show a relatively significant reactivity of the values of the parameters of economic justification to reduce or increase the volume of cabin production. To reduce production by 10%, the net present value is reduced by 31% and the IRR by 18%. In this case, the pay-back period will be extended for one year. The critical production volume is 136 cabins per year, which means that the scope of production can be reduced by 64 cabins, and that the whole project of building and exploitation of the factory is at the margin of economic justification. Changing the price of the cab has more dramatic effects on the performance of the project. Reducing the price of the cab by 10% leads the whole project of building and exploitation of the factory in loss, and the period of return on investment is extended to over 9 years. On the other hand, the increase in the cabin price by 10% increases the net present value by 103% and the internal rate of return by 54%. At the same time, with this increase in the selling price, the repayment period of the invested is reduced to 2 years and 7 months. The cabin price limit, on which the effects cover costs, is 9,035 euros per cabin. If a production volume of 200 cabins is maintained annually, this is the price below which a potential investor should not go down.

Scenario (B) examines the economic justification for the use (purchase) of the aforementioned type of cabin "smart cranes for the process industry". Purchase of the previously described cabin crane is considered in this scenario as an investment of a potential user. Costs and effects in this scenario are calculated on the basis of the best estimate, and the second time based on the measured technical parameters.

The scenario analysis (B) shows that the economic benefits of exploiting "smart cranes for the process industry" in the entire exploitation period are several times higher than the purchase price of the cabin. Following this criterion, procuring and installing "smart cranes for the process industry" is economically justified. The internal rate of return is several times higher than the average weighted interest rate and implies high economic profitability of the investment. The annual savings achieved through the use of such a cab realize the pay-back period of the investment in less than three years. In addition, the project of installing and exploiting the new generation cabin with an integrated visual recognition and interpretation system is one of the projects with a very low degree of risk.

In the third scenario (C), the economic feasibility of installing the systems for real-time detection of the existing crane and cabin was assessed. In this scenario, the cost of purchasing video and audio detection systems is treated as an investment. The effects of the project, similar to the scenario (B), are manifested through savings in reducing the costs of crane exploitation (shortening the load transport cycle), and reducing lost work hours due to the more comfortable working environment of the cranberries. The indicators of economic justification show a high economic justification for the installation of this system. The net present value for the 17-year exploitation period is € 26,328, and the internal rate of return (average annual return on investment) is 65%, which is several times the average weighted productivity in the metal industry sector. The pay-back period of invested funds spent on the acquisition and installation of visual environments visualization systems is 1.5 years and shows that the procurement of this system from the aspect of time dimension is profitable and justified. As in Scenarios (B), installing and using a visual detection system for smart cranes for the processing industry is an investment with a very low degree of risk.

References

1. Beavers J. E., Moore J. R., Rinehart R., Schriver W. R., (2006), Crane-Related Fatalities in the Construction Industry, Journal of Construction Engineering and Management, Vol. 132, No. 9, , pp. 901-910.

2. Curry, S. And Weiss, J. (2000). Project Analysis in Developing Countries, MacMillan Press. London.

3. Dondur, N., (2002). Economic analysis of projects, Faculty of Mechanical Engineering, Belgrade.

4. Neitzel, R. L., Seixas, N. S., and Ren, K. K., (2001), A review of crane safety in the construction industry, Appl. Occup. Environ. Hyg., Vol. 16 No.12, pp. 1106–1117.

5. Potts, D. (2002). Project Planning and Analysis for Development, Lynne Rienner Publishers, Inc. London.

6. Rosenfeld, Y. and Shapira, A. (1998). Automation of existing tower cranes: economic and technological feasibility, Automation in Construction, vol. 7. pp. 285-298.