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Preliminary communication

Analysis of Operational Readiness and Reliability of the Paper Machine System after Implementation of Model of Influence

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Abstract: Specific results of effects of investment activities are expressed through effectiveness and reliability of a production process, or business system operations. Investment activities are implemented and verified through a certain decision-making matrix - the model of influence. Corrective effect of implementation of investment activities on effectiveness of real industrial system is shown by the research of operational readiness and reliability of the paper machine real system. Positive movements resulting from the raising of overall efficiency of industrial plant which are expressed by the change of operational readiness and reliability, and thus by higher performance per hour, are the confirmation and justification of investments in new technical solutions. Operational readiness and reliability of a real industrial system are analysed for two equal monitoring periods immediately before and after implementation of corrective measures i.e. investment activities, i.e. from the term of general overhaul of the paper machine.

Keywords: efficiency; investment activity; maintenance; model of influence; operative readiness; reliability

1 INTRODUCTION

Production, as a basic element of profit making, is an activity that has to be acted on positively. The conditions for the smooth functioning of production have to be created as well as the conditions for its growth. The growth of production provides the creation of positive economic developments enabling the development of business systems as well as of the society as a whole. Maintenance, unscheduled downtime, and energy costs are three of the highest budget items for any facility [1].

One of the ways of active work on production is the investment activity. Specific results of investment activities are represented through effectiveness and reliability of the production process, i.e. business operations of the business system. Correct evaluation of reliability for the system or components is very important for high quality and security [2].

The research within this paper includes the influence of production investment on its effectiveness through the effects of maintenance.

Theoretical and scientific implications are connected with very good and simple research of effectiveness of industrial system as well as the reliability of operative readiness. The system is analysed in the condition before and after the realization of key investment activities, which provides its full verification by measurable parameters.

There are many papers published in the field of analysis of the maintenance, effectiveness and reliability of production systems as well as the selection of strategy of investing in production processes.

The efficacy of application of the combination of Markov chains and systematic-dynamic modelling during research on technical systems reliability problem is elaborated in [3]. By the application of systematic-dynamic simulation model it is possible to quantify the system structure maintenance efficacy parameters and enable better reliability and availability of a specific technical system.

The analysis of the importance of investment in the working process in relation to the performance of maintaining was given in [4]. An example of adequate maintenance strategy is presented through the organization of technical system of thermal power plant.

Maintenance of the power generating facilities in due time is essential for reliable and secure operation of the electric power system. The paper [5] addresses the problem of obtaining the optimal maintenance schedule of hydro generating units. For this purpose, the paper discusses the mathematical programming method – Benders decomposition.

The analysis of parameters of efficiency of production systems is presented in a systematic and transparent manner in [6]. Relevant data describing the performance of a system can be obtained by calculating operational readiness and reliability. The efficiency is presented as a characteristic of the production system, but it is also to the same extent the aim and measure of the success of production system maintenance.

The cost analysis of reliability for all stages of life cycle with an emphasis on the design and development stage, the production stage and the exploitation stage is shown in [7]. The paper appropriately explains a very important issue for all industrial plants and technical systems in general, and the costs in their life cycle.

The reliability tests on the example of thermal plant Nikola Tesla B are presented in [8]. The reliability is analysed as a function of the probability that the observed system will perform certain function of the objective. Special emphasis is given to the analysis of cross section of curves reliability and unreliability. The parameters of analytical verification of the proposed model for the assessment of optimal reliability were tested by applying the graphical method of assessment of distribution parameters – paper of probability [9].

2 IMPLEMENTATION OF INVESTMENT ACTIVITIES

2.1 Application of the model of influence

Critical spots leading to a significant number of system downtimes were identified by creating a database of the history of downtimes of paper machine. The specific problems were solved by applying the Model of influence of implementation of investment activities. The Structure of Model of influence is shown in Fig. 1.

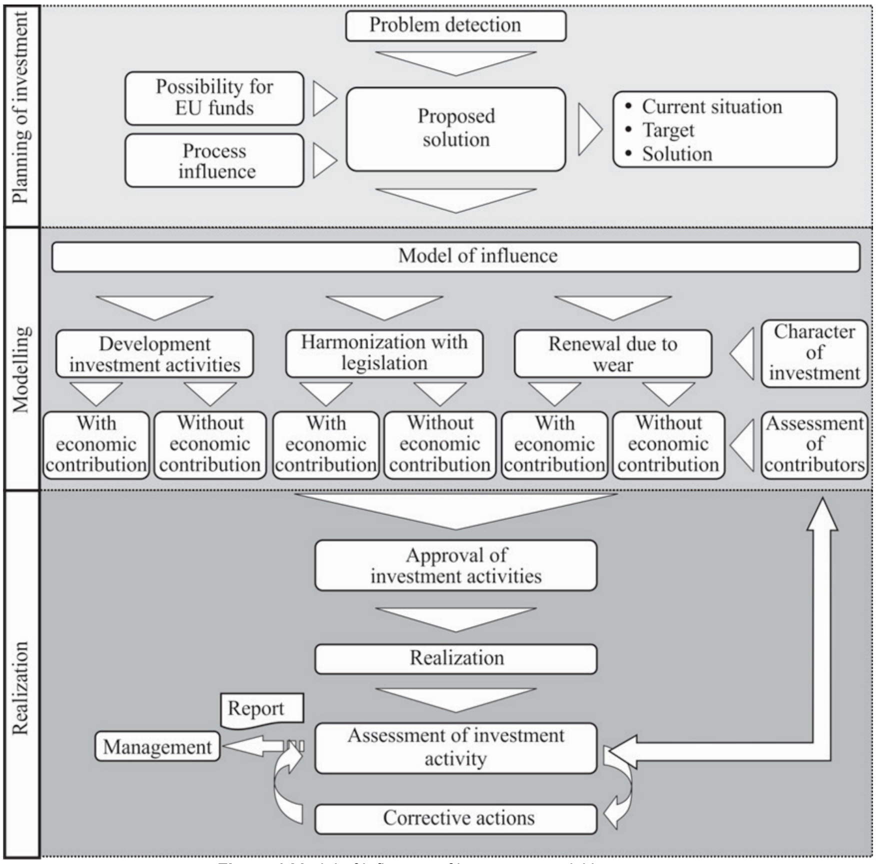

Figure 1 Model of influence of investment activities

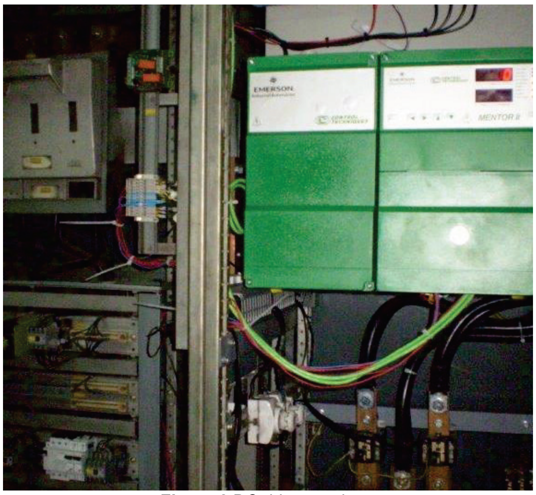

Figure 2 DC drive regulator

Figure 3 Condensing unit

Figure 4 High voltage cells of engine

2.2 Verification of the Model of Influence

The observed real system, i.e. the international company SHP Celex, a.d. Banja Luka has been analysed since 2003. Keeping of records of downtime and defining of nature of the failures were included in the analysis. Certain critical spots that cause downtime of paper machine can be identified on the basis of the records of downtime.

The results of technical solutions for recorded problems:

- Replacement of old analogue controller with the new digital controller produced by "Control Techniques", United Kingdom on DC motors of paper machine, as shown in Fig. 2.
- System for increase of the cooling capacity of low-voltage room and control room of paper machines, as shown in Fig. 3.

- Design, delivery and assembly of high-voltage cells, as shown in Fig. 4.

3 ANALYSIS OF OPERATIONAL READINESS AND RELIABILITY OF THE REAL SYSTEM

3.1 Analysis of Operational Readiness

Readiness (G) of the production system is defined as a probability that the real system successfully operates at any given point in time under real environmental conditions. The readiness of the real system is calculated by the following mathematical relation:

$$G(t) = \frac{\overline{t_i}}{\overline{t_i} - \overline{t_o}}, \tag{1}$$

where is: $\overline{t_i}$ - mean time of the system in good working order; $\overline{t_o}$ - mean time of the system in failure.

Readiness is exponential function of the time of operation and time of failure, and it may be expressed as follows:

$$G(t) = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} \cdot \mathrm{e}^{-(\lambda + \mu) \cdot t} \tag{2}$$

where is: $\mu = \frac{1}{\overline{t_o}}$ - intensity of operation; $\lambda = \frac{1}{\overline{t_i}}$ - intensity of failure.

If we calculate limit of a function $G(t)$ the result is the coefficient of readiness k_G, i.e.:

$$k_G \lim G(t) = \frac{\mu}{\lambda + \mu} = \frac{\overline{t_i}}{\overline{t_i} + \overline{t_o}} = k_{OG} \tag{3}$$

When we get the operational readiness (OG) as a function of time when the system is in operation and in failure:

$$OG(t) = \lim G(t) = \frac{\overline{t_r}}{\overline{t_r} + \overline{t_o}} = k_{OG} \tag{4}$$

where is: $\overline{t_r}$ - time of the system in operation; $\overline{t_o}$ - time of the system in failure.

The condition of the real system was analysed for the period before the time of implementation of investment activities and k_{OG} at that moment as well as k_{OG} in the period after the implementation of the aforementioned activities.

3.1.1 Operative Readiness to the Moment of General Overhaul

Analysis of k_{OG} before the implementation of activities is shown in Tab. 1 and graphically presented in Fig. 5. If we analyse the given Graph we can notice the tendency of fall of the curve of operational readiness coefficient, which indicates certain trend of the decrease in efficiently of the plant in real system.

Table 1 Operational readiness coefficient to the moment of implementation of investment activities

Month		Total availability (hours)	t_{ri} – time of the system in operation (hours)	t_{oi} – time of the system in failure (hours)	$t_{ri} + t_{oi}$	$k_{OG}(t)$ operational readiness coefficient	Number of failures
2011	January	744	664	14,5	678,5	0,978629329	12
	February	672	620	22,5	642,5	0,964980545	7
	March	744	672	32	704	0,954545455	11
	April	720	666	9,25	675,25	0,98630137	5
	May	744	667	8,3	675,3	0,987709166	7
	June	720	622	32,2	654,2	0,950779578	12
	July	744	680	36,2	716,2	0,949455459	13
	August	744	668	36	704	0,948863636	14
	September	720	685	9,5	694,5	0,986321094	9
	October	744	661	41,5	702,5	0,940925267	6
	November	720	673	7	680	0,989705882	3
	December	744	674	25	699	0,964234621	15
2012	January	744	622	45,5	667,5	0,931835206	9
	February	672	598	46,2	644,2	0,928283142	13
	March	744	686	19,5	705,5	0,972360028	14
	April	720	512	18,7	530,7	0,96476352	6
Total:		11640	10370	403,85	10773,85	0,962480831	156

3.1.2 Operational Readiness after the Term of General Overhaul

Analysis of k_{OG} after the implementation of investment activities is shown in Tab. 2 and graphically presented in Fig. 6. The growth and accordingly the increase of the efficiency of the real system plant can be seen by analysing the obtained Graph.

3.2 Analysis of the Real System Reliability

Analysis and research of reliability defines the behaviour of the system and maintenance of operating characteristics under the influence of various factors causing changes of the system. The observed factors are directly related to the work of the maintenance service.

Reliability is the probability of retaining the required performance of the system in real-time exploitation with all limiting factors appearing in the given interval. Reliability can be clearly and unambiguously quantified only after recording the conditions of system failures. The goal is to predict the moment of failure based on previously collected data.

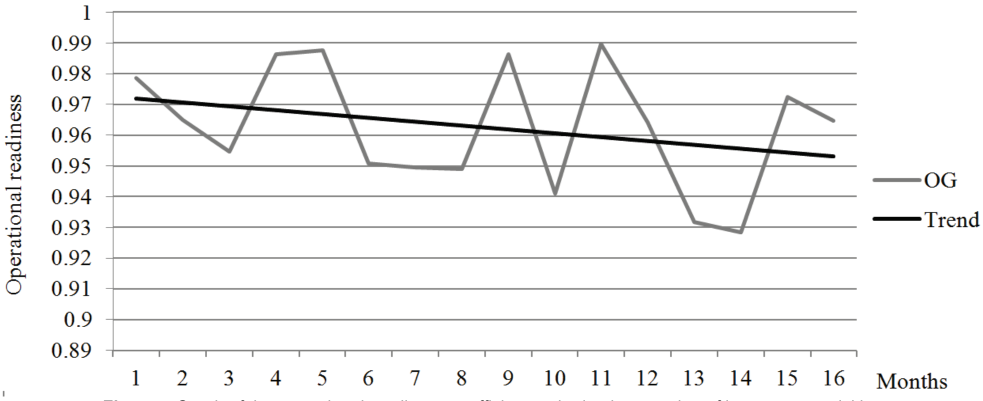

Figure 5 Graph of the operational readiness coefficient to the implementation of investment activities

Table 2 Operational readiness coefficient after the implementation of investment activities

Month		Total availability (hours)	t_{ri} time of the system in operation (hours)	t_{oi} time of the system in failure (hours)	$t_{ri} + t_{oi}$	$k_{OG}(t)$ operational readiness coefficient	Number of failures
2012	May	744	659	22,5	681,5	0,966984593	21
	June	720	654	16,2	670,2	0,975828111	19
	July	744	668	27,5	695,5	0,960460101	11
	August	744	660	35,75	695,75	0,948616601	14
	September	720	663	13,7	676,7	0,979754692	10
	October	744	666	14,5	680,5	0,978692138	10
	November	720	669	7,7	676,7	0,98862125	11
	December	744	709	5	714	0,992997199	8
2013	January	744	685	8,7	693,7	0,987458556	8
	February	696	635	7,5	642,5	0,988326848	5
	March	744	688	11,25	699,25	0,983911334	12
	April	720	675	6	681	0,991189427	7
	May	744	680	23	703	0,967283073	9
	June	720	663	15,5	678,5	0,97715549	11
	July	744	707	3,5	710,5	0,995073892	5
	August	744	707	1,5	708,5	0,997882851	3
Total:		11736	10788	219,8	11007,8	0,98001476	164

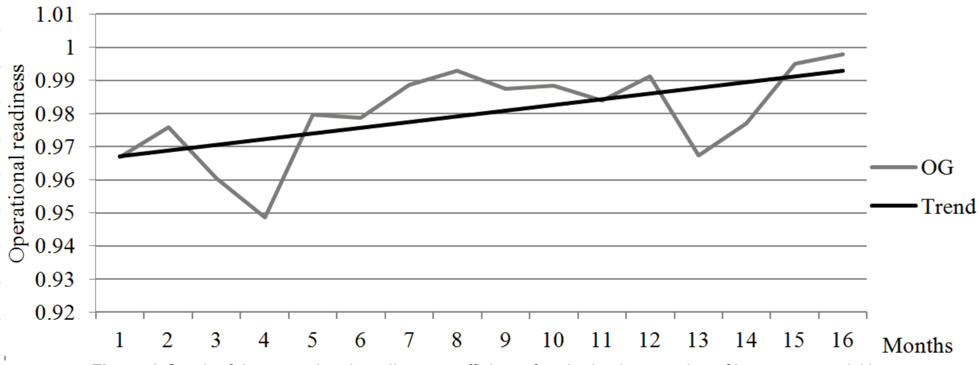

Figure 6 Graph of the operational readiness coefficient after the implementation of investment activities

3.2.1 Analysis of the General Overhaul Reliability

Calculation of elements of reliability is based on the analysis of time of operation of paper machine taking into account the following information:

- time of operation of the real system,
- number of hours of downtime caused by maintenance,
- number of hours of operation to the occurrence of failure.

The results of the analysis are collectively presented in Tab. 3.

The analysis of reliability consists of:

- setting of hypothesis of the law of distribution
- checking of suitability of the set analysis
- setting of parameters of the law of distribution
- presentation of diagram - density function of the time of operation to the failure.

Table 3 Reliability to the moment of implementation of investment activities

Production on the paper machine January 2011 – April 2012 (Period to the general overhaul aimed at increasing the effectiveness of the paper machine)							
Month		Total availability (hours)	Planned maintenance downtimes (hours)	Degree of use – total working hours (hours)	Downtimes caused by maintenance (hours)	Production output (tons)	Waste (tons)
2011	January	744	4	664	14,5	2947,8	260
	February	672	4	620	22,5	2748,7	232
	March	744	4	672	32	2783,9	185
	April	720	4	666	9,25	2702,1	152
	May	744	4	667	8,3	2769,6	249
	June	720	4	622	32,2	2759,9	143
	July	744	4	680	36,2	3239,6	211
	August	744	124	668	36	3197	271
	September	720	4	685	9,5	3435,5	267
	October	744	4	661	41,5	3167,2	339
	November	720	4	673	7	3352,7	286
	December	744	4	674	25	3206,2	270
2012	January	744	18	622	45,5	2507,4	188
	February	672	18	598	46,2	2679,5	193
	March	744	18	686	19,5	3313,1	196
	April	720	128	512	18,7	2455,5	175
	Total:	11 640	350	10 370	403,85	47 265,7	3617

Table 4 Concept of graphical determination of parameters of Weibull distribution for the interval before the general overhaul

Months n_i	Interval hours (h)	Mean of the interval hours (h)	t_i number of hours of operation	Cumulative number of hours of operation	Cumulative probability $F(t)$
1	0÷744	372	45,79	45,79	0,076
2	744÷1416	1080	27,56	73,35	0,122
3	1416÷2160	1788	21,00	94,35	0,157
4	2160÷2880	2520	72,00	166,35	0,276
5	2880÷3624	3252	80.36	246,71	0,409
6	3624÷4344	3984	19,32	266,03	0,44
7	4344÷5088	4716	18,78	284,81	0,472
8	5088÷5832	5460	18,56	303,37	0,503
9	5832÷6552	6192	72,11	375,48	0,622
10	6552÷7272	6912	15,93	391,41	0,648
11	7272÷7992	7632	96,14	487,55	0,807
12	7992÷8732	8362	26,96	514,51	0,852
13	8732÷9476	9104	13,67	528,18	0,875
14	9476÷10 148	9812	12,94	541,12	0,896
15	10 148÷10 892	10 520	35,18	576,3	0,955
16	10 892÷11 612	11 252	27,38	603,68	1

Analyses/testing of hypotheses about the laws of distribution have shown that the time of operation of the equipment to the occurrence of failure does not correspond to the normal or exponential distribution. For this reason, the assumption that the time of operation of equipment to the occurrence of failure corresponds to the Weibull distribution has been introduced.

Weibull distribution density function of:

$$f(t)=\frac{\beta}{\eta}\cdot\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}\cdot \mathrm{e}^{-\left(\frac{t-\gamma}{\eta}\right)} \tag{5}$$

Where: $f(t)\geq 0$, $t\geq\gamma$ – distribution density, $\beta > 0$ – shape parameter, $\eta > 0$ – scale parameter, $-\infty < \gamma < +\infty$ – location parameter for three-parameter distributions.

Where: $f(t)=\lambda(t)\cdot R(t)$ (6)

the following values can be seen:

$$\lambda(t)=\frac{\beta}{\eta}\cdot\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \text{ – failure intensity} \tag{7}$$

$$R(t)=\mathrm{e}^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \text{ – reliability} \tag{8}$$

In case of two-parameter distribution cumulative function of Weibull distribution is:

$$F(t)=1-R(t)=1-\mathrm{e}^{-\left(\frac{t}{\eta}\right)^{\beta}} \tag{9}$$

Where $F(t)$ – unreliability function.

Parameters of Weibull distribution are analytically determined according to Tabs. 4 and 5.

Parameters of the Weibull model are:

$$\beta=\frac{\sum X_i\cdot Y_i-\frac{1}{n}\sum Y_i\cdot\sum X_i}{\sum X_i^2-\frac{1}{n}\sum X_i\cdot\sum X_i}=1,27 \tag{10}$$

$$\eta=\exp\left[-\frac{\frac{1}{n}\left(\sum Y_i-\beta\cdot\sum X_i\right)}{\beta}\right]=1311,172 \tag{11}$$

According to Tab. 6 maximum difference $D_{\max}$ = 0,115 while DCR = 0,328 according to table values [9] for K-S test for 16 measurements and significance factor 0,05.

Where: $D_{\max} > D_{CR}$ (12)

are parameters of real system corresponding to Weibull distribution.

Diagram of probability of Weibull distribution for the period to the general overhaul is shown in Fig. 7. Fig. 8 presents graphical interpretation of reliability/unreliability functions.

Table 5 Tabular concept of analytical determination of parameters for interval to the general overhaul

Months n_i	X_i= ln(t)	Y_i= lnln $1/(1-F(t))$	X_i^2	X_i-Y_i
1	5,918	-2,537	35,022724	-15,013966
2	6,984	-2,039	48,776256	-14,240376
3	7,488	-1,767	56,070144	-13,231296
4	7,832	-1,130	61,340224	-8,85016
5	8,087	-0,642	65,399569	-5,191854
6	8,290	-0,545	68,7241	-4,51805
7	8,458	-0,448	71,537764	-3,789184
8	8,605	-0,357	74,046025	-3,071985
9	8,731	-0,027	76,230361	-0,235737
10	8,841	0,043	78,163281	0,380163
11	8,940	0,497	79,9236	4,44318
12	9,031	0,647	81,558961	5,843057
13	9,116	0,732	83,101456	6,672912
14	9,191	0,816	84,474481	7,499856
15	9,261	1,131	85,766121	10,474191
16	9,328	1		

Table 6 Kolmogorov–Smirnov test for the period to the general overhaul

Months n_i	$F_e(t)$	$F_e(t)$ = $1-e^{-(t/5694,213)^{1,14}}$	$\lvert F_e(t)-F_t(t)\rvert$
1	0,076	0,0436	0,0324
2	0,122	0,1395	0,0175
3	0,157	0,2343	0,0773
4	0,276	0,3262	0.0502
5	0,409	0,4102	0,0012
6	0,44	0,4860	0,046
7	0,472	0,5536	0,0816
8	0,503	0,6145	0,1115
9	0,622	0,6672	0,0452
10	0,648	0,7127	0,0647
11	0,807	0,7525	0,0545
12	0,852	0,7876	0,0644
13	0,875	0,8186	0,0564
14	0,896	0,8442	0,0518
15	0,955	0,8664	0,0886

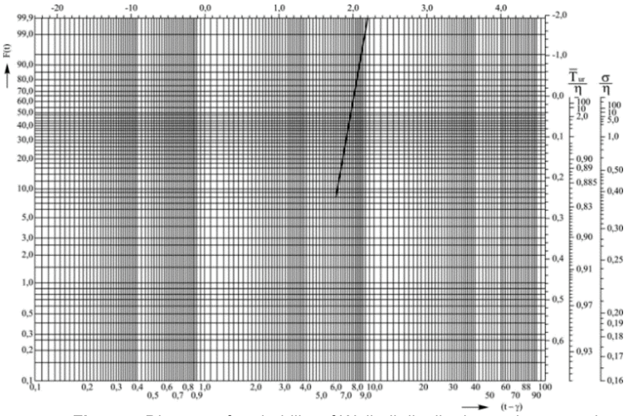

Figure 7 Diagram of probability of Weibull distribution to the general overhaul

Table 7 Statistical values of reliability for the period to the investment activities implementation

	Distribution	Distribution parameters	Komogorov-Smirnovljev test - $D_{\max}$	Note
Before the general overhaul	Normal	SV = 25,68; SD = 28,85	1,71	It is not accepted
	Exponential	SV = 25,68; λ = 0,03893	-0,02	It is not accepted
	Weibull	B = 1,14; η = 569,213	0,1115	It can be accepted

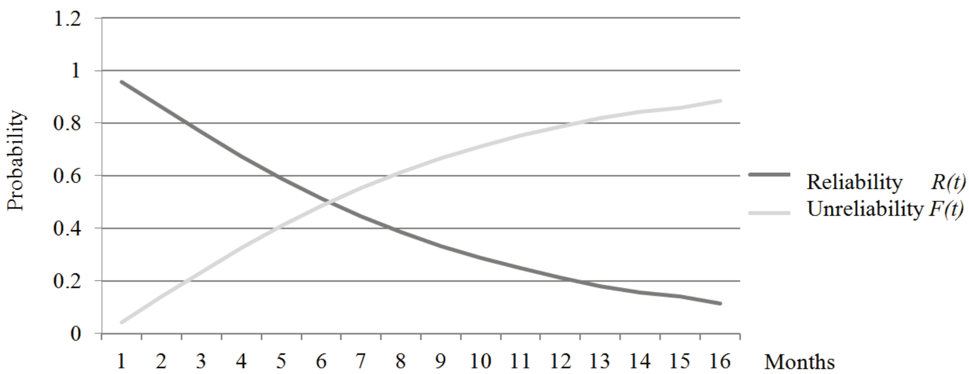

Figure 8 Graph of the reliability/unreliability function to the implementation of the investment activities

3.2.2 Analysis of Reliability after the Term of General Overhaul

Results of the analysis of work of real system and the hours of downtime caused by maintenance are presented collectively in Tab. 8.

As in the previous case, the task comes down to the setting of assumption about the law of distribution, the checking of suitability of the set hypotheses and the determination of parameters of the law of distribution.

Analysis/testing of hypotheses about the laws of distribution has shown that operation of equipment to the occurrence of failure does not correspond to the normal or exponential distribution. For this reason, the assumption that the operation of the equipment to the occurrence of failure corresponds to Weibull distribution has been introduced. On the basis of (1), for the period after the term of the general overhaul, the Weibull distribution parameters are set according to Tabs. 9 and 10.

Table 8 Reliability after the implementation of investment activities

Month		Total availability (hours)	Planned hours of maintenance downtimes	Achieved hours of operation of equipment	Downtimes (sati)	Hours of operation to the occurrence of failure
2013	May	744	18	659	22,5	29,29
	June	720	18	654	16,2	40,37
	July	744	18	668	27,5	24,29
	August	744	18	660	35,75	18,46
	September	720	18	663	13,7	48,39
	October	744	18	666	14,5	45,93
	November	720	8	669	7,7	86,88
	December	744	18	709	5	141,80
2014	January	744	23	685	8,7	78,74
	February	696	23	635	7,5	84,67
	March	744	23	688	11,25	61,16
	April	720	23	675	6	112,50
	May	744	23	680	23	29,57
	June	720	23	663	15,5	42,77
	July	744	23	707	3,5	202,00
	August	744	37	707	1,5	471,33
Total:		11736	332	10788	219,8	49,08

Table 9 Numerical values of indicators of reliability of exponential distribution after realization of investment activities

Months n_i	t_i – downtime	$F_E(t_i) = n_i/n$	$F_E(t_i) = \lambda \cdot e^{-(\lambda)t_i}$	$D_i = \lvert F_o – F_E \rvert$
1	29,29	0,0625	0,01996	0,04254
2	40,37	0,125	0,01956	0,10544
3	24,29	0,1875	0,01916	0,16834
4	18,46	0,25	0,01878	0,23122
5	48,39	0,3125	0,0184	0,2941
6	45,93	0,375	0,01803	0,35697
7	86,88	0,4375	0,01766	0,41984
8	141,8	0,5	0,01731	0,48269
9	78,74	0,5625	0,01696	0,54554
10	84,67	0,625	0,01661	0,60839
11	61,16	0,6875	0,01628	0,67122
12	112,5	0,75	0,01595	0,73405
13	29,57	0,8125	0,01563	0,79687
14	42,77	0,875	0,01531	0,85969
15	202	0,9375	0,015	0,9225
16	471,33	1	0,0147	0,9853

Parameters of Weibull model are:

$$\beta = \frac{\sum X_i \cdot Y_i - \frac{1}{n}\sum Y_i \cdot \sum X_i}{\sum X_i^2 - \frac{1}{n}\sum X_i \cdot \sum X_i} = 1,27 \tag{13}$$

$$\eta = \exp\left[-\frac{\frac{1}{n}\left(\sum Y_i - \beta \cdot \sum X_i\right)}{\beta} \right] = 1311,172 \tag{14}$$

According to the following Tab. 11, maximum difference $D_{\max}$ = 0,1543 while DCR = 0,328 according to table values [9] for K-S test for 16 measurements and significance factor 0,05.

Initial hypothesis should be accepted, i.e. the analysed parameters of the real system correspond to Weibull distribution.

Diagram of probability of Weibull distribution for the period after the general overhaul is shown in Fig. 9. The analysis of the mentioned data is presented in Tab. 12 and Fig 10.

Table 10 Tabular concept of analytical determination of parameters for the interval after the general overhaul

Months n_i	$X_i = \ln(t)$	$Y_i = \ln\ln 1/\left(1-F(t)\right)$	X_i^2	$X_i - Y_i$
1	5,918	-3,953	35,022724	-23,393834
2	7,006	-3,078	49,084036	-21,564468
3	7,515	-2,765	56,475225	-20,778975
4	7,855	-2,565	61,701025	-20,148075
5	8,105	-2,198	65,691025	-17,81479
6	8,304	-1,922	68,956416	-15,960288
7	8,471	-1,539	71,757841	-13,036869
8	8,613	-1,088	74,183769	-9,370944
9	8,740	-0,885	76,3876	-7,7349
10	8,849	-0,691	78,304801	-6,114659
11	8,947	-0,563	80,048809	-5,037161
12	9,038	-0,343	81,685444	-3,100034
13	9,122	-0,286	83,210884	-2,608892
14	9,199	-0,208	84,621601	-1,913392
15	9,270	0,155	85,9329	1,43685
16	9,338	1		

Table 11 Kolmogorov– Smirnov test for the period after general repair

Months n_i	$F_e(t)$	$F_e(t) = 1-e^{-(t/13111,72)^{1,27}}$	$\lvert F_e(t) - F_t(t)\rvert$
1	0,019	0,0107	0,0083
2	0,045	0,0422	0,0028
3	0,061	0,0790	0,018
4	0,074	0,1191	0,0451
5	0,105	0,1598	0,0548
6	0,136	0,2010	0,065
7	0,193	0,2421	0,0491
8	0,286	0,2827	0,0033
9	0,338	0,3232	0,0148
10	0,394	0,3613	0,0327
11	0,434	0,3982	0,0358
12	0,508	0,4345	0,0735
13	0,528	0,5305	0,0025
14	0,556	0,5028	0,0532
15	0,689	0,5347	0,1543

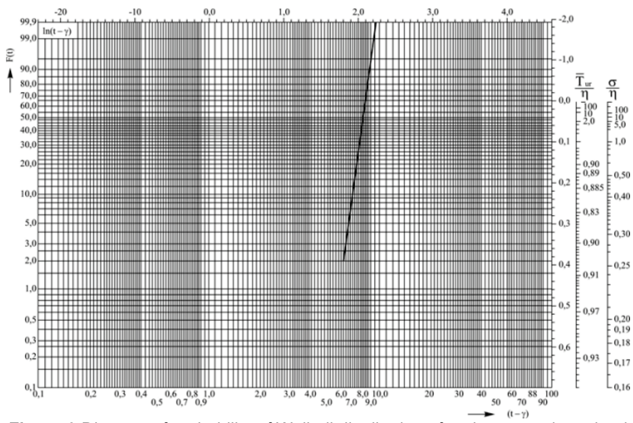

Figure 9 Diagram of probability of Weibull distribution after the general overhaul

Table 12 Statistical values of reliability for the period after implementation of investment activities

	Distribution	Distribution parameters	Komogorov-Smirnovljev test D_{max}	Note
After the general overhaul	Normal	$SV = 49,08$ $SD = 117,38$	2,597	It is not accepted
	Exponential	$SV = 49,08$ $\lambda = 0,02038$	-0,02	It is not accepted
	Weibull	$B = 1,27$ $\eta = 13111,72$	0,1543	It can be accepted

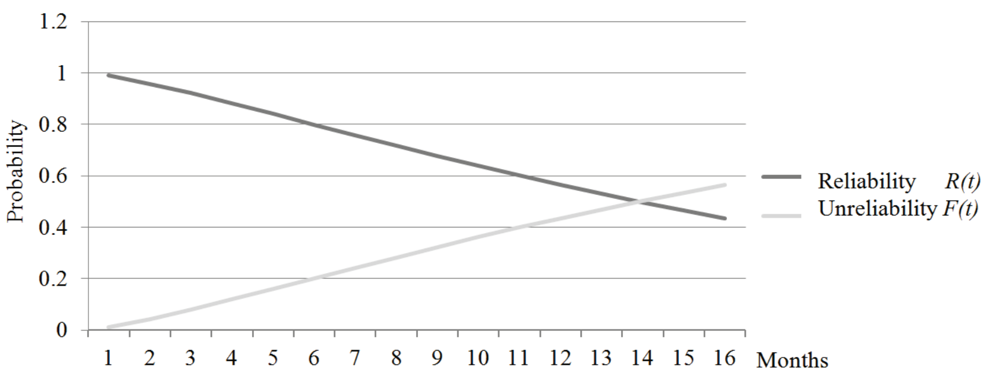

Figure 10 Graphical representation of the reliability/unreliability function after implementation of investment activities

4 CONCLUSION

The results of operational readiness and reliability research give a clear picture of the extent to which implemented investment activities have increased the overall effectiveness of the real industrial system.

The reduction in the total number of hours of failure of the production system (from 403.85 hours to 219.8 hours for the same observed period), which can be directly linked to the failure of system components which were the subject of investment, can be emphasized as the main result of implementation of the model of influence and realization of investment activities. The analysis of obtained results confirms a positive trend of significant increase in operational readiness. The trend of the increase of operational readiness shows the increase of probability that the real system is in good working order under normal working conditions. The result of the increase of operational readiness had also a great impact on increasing the reliability of the production system. The increase of the reliability from 6 to 14 months means that the real system retains the necessary operating characteristics for a longer period of time by applying the corrective measures.

The positive trend of increasing the effectiveness of key parameters of the real industrial system is a confirmation that the investments in the production process and maintenance system have met planned expectations.

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