Risk Analysis To Determine Schedules And Reduce Maintenance Costs In Elevators With Fmea, Qfd, And Markov Chain Methods

by Dimas Indra Laksmana Dimas Indra Laksmana

Submission date: 11-Apr-2022 09:01AM (UTC+0700)
Submission ID: 1807201451
File name: ce-Costs-In-Elevators-With-Fmea-Qfd-And-Markov-Chain-Methods.pdf (471.66K)
Word count: 2886
Character count: 15070

Risk Analysis To Determine Schedules And Reduce Maintenance Costs In Elevators With Fmea, Qfd, And Markov Chain Methods

Bambang Priambodo, Ellysa Nursanti, Dimas Indra Laksmana

Abstract : PT. Balistha Gapala Nandya is a service company engaged in the procurement and maintenance of elevators (travelators), escalators, elevators. The company is the only authorized distributor in Indonesia that has been certified by The Fuji HD Elevator Sino Japan Joint Venture. PT. Balistha Gapala Nandya is a service company engaged in elevators (elevators) both procurement and maintenance and has a maximum cost (maintenance) limit of IDR 50,000,000 for 1 elevator unit. Based on actual conditions in the field of PT. Balistha Gapala Nandya implements corrective maintenance. The maintenance issued by the company is IDR 64,990,000, which means it has passed the maximum limit of the company's maintenance costs. The purpose of this research is to reduce the risk value in the elevator, get a maintenance schedule that can reduce the risk of damage and reduce / save maintenance costs. Data collection is done by obtaining primary data, namely the number of machines categorized according to the condition of the damage and secondary data, namely written data on elevator maintenance in 2019. The methods used in this study are the FMEA, QFD and Markov Chain methods. The results of the research get the proposed P3 maintenance scheduling (preventive on minor and moderate damage, corrective for heavy damage) as routine maintenance every month with a cost savings of 41%.

Index Terms : FMEA, Markov, Maintenance, Maintenance Scheduling, QFD, Risk

---

1 Introduction

Technological advances that are increasingly fast and sophisticated have resulted in the need for human labor to begin to be shifted to be replaced by machines or other production equipment. Machines and equipment that are in good condition will be able to smooth the production process. In the industrial discussion, to keep machines in the best possible use, continuous maintenance of components or machines is needed [1][2][3][4][5][6]. PT. Balistha Gapala Nandya is a service company engaged in the procurement and maintenance of elevators (travelators), escalators, elevators. The company is the only authorized distributor in Indonesia that has been certified by the Fuji HD Elevator Sino Japan Joint Venture factory. Based on actual conditions in the field of PT. Balistha Gapala Nandya implements corrective maintenance. In maintenance activities the company has a standard maintenance fee of IDR 50,000,000 for 3 units of elevators. Based on maintenance data for 2019, the company issued a maintenance fee of IDR 64,990,000 (4 units of elevator), which means that the maintenance cost limit set by the company has passed. By paying attention to the risk of damage to each component of the elevator, [7] it is necessary to take preventive maintenance measures properly and correctly. The FMEA (Failure Mode and Effect Analyze) method is used to analyze the potential risk of damage and determine the value of the RPN (Risk Priority Number) [8], [9]. This method identifies the source and root causes of problems such as failure, damage, risk and quality [10], [11]

- *Bambang Priambodo is currently pursuing masters degree program in Industrial Engineering in National Institute of Technology (ITN) Malang, Indonesia. E-Mail : bambangoffc@gmail.com*
- *Ellysa Nursanti and Dimas Indra Laksmana is senior lecturer in Industrial Engineering Department postgraduate program National Institute of Technology (ITN) Malang, Indonesia. E-Mail : ellysa.nursanti@lecturer.itn.ac.id, indra@lecturer.itn.ac.id by calculating the level (ranking) of risk that can be mitigated [8], [12], [13].*

Risk mitigation is carried out using the QFD method, [11] this method is used to improve machine performance and maintenance capabilities. The QFD method is a mathematical optimization to improve the quality of both services and products [14], [15]. The components in QFD are customer needs, technical requirements, correlation matrix, ranking of customer's language, relationship matrix and ranking of technical language are used to identify weak (problematic) attributes [16]. After identifying the attributes, the measurement and improvement of performance, work improvement, development, innovation, and service were carried out [16]. Analysis with the Markov method is used to obtain a low cost maintenance schedule. This method is a suitable forecasting tool for maintenance of equipment [17], [18]. The use of this method is carried out to obtain accurate predictions and decision makers on various aspects of management in the future [18], [19].

2 Methods

This research uses quantitative research using quantitative data or variables [20]. The data analysis technique used are as follows :

1. FMEA

Failure Mode and Effect Analyze (FMEA) method is used to analyze potential damage and know the value of Risk Priority Number (RPN). The largest RPN value should be repaired to reduce the risk of damage to the elevator.

2. QFD

QFD is a method used to determine what is cooled into proper technical design, manufacturing, and production planning. QFD method is used to reduce the risk of elevator damage by mitigating the risk.

3. Markov

Markov method used to get low cost maintenance scheduling. Research looking at the condition of elevator damage is sought probability value based on elevator maintenance data. The probability is used to determine the proposed maintenance action of the elevator and the cost of the appropriate proposal. The smallest maintenance costs will be used to determine the schedule and maintenance actions of the elevator.

3 RESULT AND DISCUSSION

Figure 1 shows the amount of damage to elevator components in 2019.

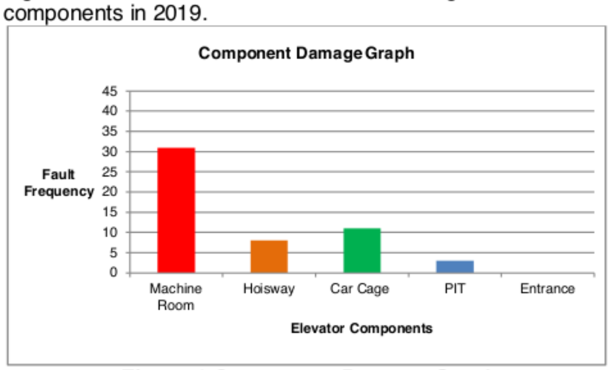


Figure 1 Component Damage Graph

It can be seen that the parts / components that were damaged were 31 machine rooms, 8 hoistways, 11 car cages, 9 PITs, and 1 entrance.

1. FMEA

Risk identification is carried out for each component of the elevator to obtain the RPN value before repair. The assessment is done by calculating severity, occurrence, and detection [15], [16]. The RPN values are as follows:

Table 1 RPN Value Before Repair

Sub System	Component	RPN
	Main Supply Switch	480
	Traction Machine	56
	Magnetic Brake	60
	Deflector Sheave	9
Machine Room	Control System	192
	Rotary Encoder	36
	Governoor	35
	Light	12
	Air Conditioner	20
	Door Interlock	84
	Door Open & Closer	35
	Travelling Cable	32
	Limit Switch Up - Down	30
Hoist Way	Counterweight & Guide Shoes	27
	Joint Rails & Brackets	70
	Oil Box	16
	Sparator Beam	60
	Compesation Ropes	20
	Car Operating Panel	32
	Level Indicator	16
	Car Light & Celling	8
Car Cage	Safety Edge/Multibeam	40
	Leveling	21
	Interphone/Emergency Bell	21
	Safety Block	40
PIT	Safety Overload	32
	Acess & Lighting	9
Entrance	Level Indicator	21
	Hall Button	24

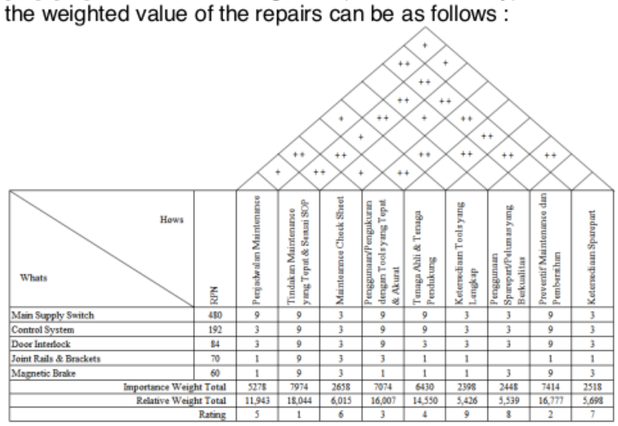
It can be seen that the largest RPN values are found in the machine room, hoist way, and car cage because the RPN value has exceeded 200 and needs to be repaired [17]. Table 2 shows the priority category of risk improvement.

Table 2 Risk Category

RPN Value	Risk Category	Risk Control
< 100	Low	Acceptable
100 - 200	High	Undesirable
> 200	Very High	Urgent Corrective Actions

2. QFD

Mitigating the risk of damage to the elevator with the QFD method is to reduce the risk value (RPN) of damage elevator [21]–[23]. Calculations using HoQ (House of Quality) to obtain the weighted value of the repairs can be as follows :



Whats \ Hows	RPN	Penjadwalan Maintenanse	Tindakan Maintenanse yang Tepat & Sesuai SOP	Maintenance Check Sheet	Penggunaan/Pengukuran dengan Tools yang Tepat & Akurat	Tenaga Ahli & Tenaga Pendukung	Ketersediaan Tools yang Lengkap	Penggunaan Sparepart/Pelumas yang Berkualitas	Preventif Maintenance dan Pembersihan	Ketersediaan Sparepart
Main Supply Switch	480	9	9	3	9	9	3	3	9	3
Control System	192	3	9	3	9	9	3	3	9	3
Door Interlock	84	3	9	3	9	3	3	3	9	3
Joint Rails & Brackets	70	1	9	3	3	1	1		1	1
Magnetic Brake	60	1	9	3	1	1	1	3	9	3
Importance Weight Total		5278	7974	2658	7074	6430	2398	2448	7414	2518
Relative Weight Total		11,943	18,044	6,015	16,007	14,550	5,426	5,539	16,777	5,698
Rating		5	1	6	3	4	9	8	2	7

Figure 2 HoQ Calculation

The results of the RPN calculation before and after the repairs are made are seen as follows :

Table 3 RPN Value After Repair

Sub System	Component	RPN
	Main Supply Switch	18
	Traction Machine	6
	Magnetic Brake	9
	Deflector Sheave	3
Machine Room	Control System	18
	Rotary Encoder	8
	Governoor	9
	Light	12
	Air Conditioner	6
	Door Interlock	12
	Door Open & Closer	6
	Travelling Cable	16
	Limit Switch Up - Down	12
Hoist Way	Counterweight & Guide Shoes	9
	Joint Rails & Brackets	6
	Oil Box	8
	Sparator Beam	10
	Compesation Ropes	8
	Car Operating Panel	6
	Level Indicator	8
	Car Light & Celling	8
Car Cage	Safety Edge/Multibeam	12
	Leveling	18
	Interphone/Emergency Bell	15
	Safety Block	4
PIT	Safety Overload	32
	Acess & Lighting	9
Entrance	Level Indicator	21
	Hall Button	24

For all components the RPN value has decreased below 100. RPN values below 100 do not need to be repaired but still need to be monitored regularly.

3. Markov

Maintenance scheduling is carried out using the Markov method to obtain low cost maintenance proposals. This analysis uses a probability matrix to determine the proposed maintenance plan and the expected average cost savings. Table 4 shows the probability of elevators.

Table 4 Elevator Probability

i \ j	P1	P2	P3	P4
P1	0.563	0.264	0.146	0.028
P2	0	0.45	0.15	0.4
P3	0	0	0.417	0.583
P4	1	0	0	0

The probability of the elevator is calculated to get a steady state in the long run. So the elevator machine steady state probability is as follows:

$\pi_1 = 0.437$ $\pi_2 = 0.209$ $\pi_3 = 0.373$ $\pi_4 = 0.191$

Then calculate the proposed maintenance to get low cost maintenance [20]. There are 4 types of maintenance proposals that are calculated, these calculations are as follows:

1. Maintenance corrective in heavily damaged conditions and preventive in moderate damage conditions
   $\pi_1 = 0.334$ $\pi_2 = 0.334$ $\pi_3 = 0.186$ $\pi_4 = 0.146$
2. Maintenance corrective in moderate and severe conditions and preventive in minor damage conditions
   $\pi_1 = 0.696$ $\pi_2 = 0.184$ $\pi_3 = 0.101$ $\pi_4 = 0.019$
3. Maintenance corrective in severely damaged conditions and preventive in minor and moderate damaged conditions
   $\pi_1 = 0.632$ $\pi_2 = 0.259$ $\pi_3 = 0.092$ $\pi_4 = 0.018$
4. Maintenance corrective in moderate and severe damaged conditions
   $\pi_1 = 0.522$ $\pi_2 = 0.25$ $\pi_3 = 0.114$ $\pi_4 = 0.115$

The result of this calculation is a steady state / condition of the proposed maintenance probability in the long term. Figure 3 shows the calculation of the average cost of maintenance expectations of the elevator to find out the cost of each proposed expectation.

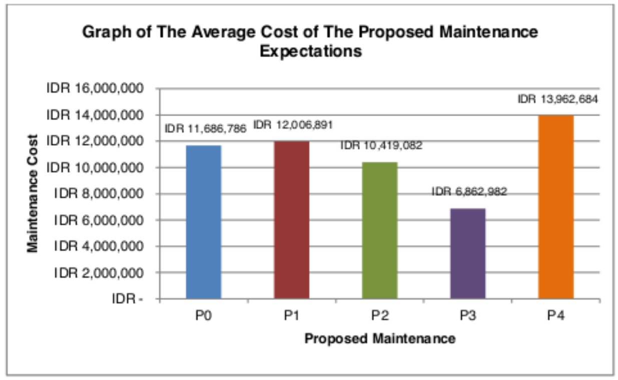


Figure 3 Graph of The Average Cost of The Proposed Maintenance Expectations

The graph is the expected average cost obtained from the proposed maintenance. Table 5 shows the maintenance costs of elevator before and after repairs.

Table 5 Maintenance Cost of Elevator Before and After Repairs

Proposed Maintenance	Before	After	Percentage Savings
P1	IDR 11,686,768	IDR 12,006,891	-3%
P2		IDR 10,419,082	11%
P3		IDR 6,862,982	41%
P4		IDR 13,962,684	19%

Comparison results indicate that the biggest cost savings are found in the P3 maintenance proposal. These maintenance actions are corrective maintenance in severely damaged status, prevention of minor and moderate damage status. Maintenance cost savings of 41% or IDR 6,862,982, - with a difference of IDR 4,823,804 from the company's expected cost of IDR 11,686,786. P3 proposed maintenance actions chosen as a routine maintenance action every month. Maintenance measures are to take precautions (prevention) on the elevator in a light and moderately damaged state, then corrective (repair after damage) to the elevator in a state of severe damage.

4 CONCLUSION

Based on the results of the risk analysis, after the repair, the RPN score for the machine room was 92, the hoistway was 87, the car cage was 71, the PIT was 41, and the entrance was 45. The RPN score decreased after repairs were made with QFD mitigation. Maintenance measures proposed by P3 are selected as routine maintenance actions every month. Maintenance scheduling was chosen based on the biggest maintenance cost savings with a cost savings percentage of 41%. This maintenance action is chosen as a routine maintenance action every month by doing preventive (prevention) on the lift when it is lightly and moderately damaged, then making corrections (repairs after damage) to the elevator when it is heavily damaged. Based on the results of Markov's analysis, the P3 proposed maintenance action is much more efficient than the other maintenance proposals. From the average cost of expected maintenance, the savings are 41% or IDR 6,862,982 in 1 year, with a difference in costs of IDR 4,823,804 from the company's expected cost of IDR 11,686,786.

REFERENCES

[1] E. Nursanti, R. M. S. Avief, Sibut, and M. Kertaningtyas, Maintenance Capacity Planning Efisiensi & produktivitas. Malang: CV. Dream Litera Buana, 2019.

[2] S. Hadi, D. Gustopo, and D. Indra, "Predictive Maintenance Analysis Overhead Crane Machine in PT Bromo Steel Indonesia," in Journal of Physics: Conference Series, 2020, vol. 1569, no. 2, pp. 0–7, doi: 10.1088/1742-6596/1569/2/022093.

[3] E. Nursanti, "Hybrid Minimal Repair for Maximizing Availability of a Serial Continuous Production System," in International Conference on Mechanical Engneering, Automation and Control Systems, 2014, pp. 6–9.

[4] E. Nursanti, A. Ma, T. Simatupang, and B. Iskandar, "Cost and Availability Functions Using Imperfect Maintenance Policy for A Serial System," pp. 386–391, 2012.

[5] E. Nursanti, R. M. S. Avief, Sibut, and M. Kertaningtyas, "Parallel Series Scheduling for Aircraft Overhaul Maintenance," in International Conference of Organizational Innovation (ICOI 2019), 2019, vol. 100, pp. 640–644.

[6] E. Nursanti, S. Avief, and F. Handoko, "Overhaul Maintenance Scheduling Optimization of Indonesian Air Force Hawk MK-209 Aircraft Using CPM/PERT," Int. J. Ind. Syst. Eng., vol. X, 2017.

[7] D. T. Septiani, E. Nursanti, and H. Galuh, "Analisa Peningkatan Produktifitas Dengan Menggunakan Metode TPM Berdasarkan Nilai OEE Dan Losses Mesin Di Advertising Ozy Bisa," vol. 3, no. 2, pp. 41–45, 2020.

[8] A. Sutrisno, I. Gunawan, and S. Tangkuman, "Modified Failure Mode and Effect Analysis (FMEA) Model for Accessing the Risk of Maintenance Waste," Procedia Manuf., vol. 4, pp. 23–29, 2015, doi: 10.1016/j.promfg.2015.11.010.

[9] T. M. El-dogdog, A. M. El-assal, I. H. Abdel-aziz, and A. A. El-betar, "Implementation of FMECA and Fishbone Techniques in Reliability Centred Maintenance Planning," vol. 5, no. 11, pp. 18801–18811, 2016, doi: 10.15680/IJIRSET.2016.0511001.

[10] C. S. Carlson, Understanding and Applying the Fundamentals of FMEAs. 2014.

[11] J. Doshi and D. Desai, "Application of failure mode & effect analysis (FMEA) for continuous quality improvement - multiple case studies in automobile SMEs," Int. J. Qual. Res., vol. 11, no. 2, pp. 345–360, 2017, doi: 10.18421/IJQR11.02-07.

[12] A. Pandey, M. Singh, A. U. Sonawane, and P. S. Rawat, "FMEA Based Risk Assessment of Component Failure Modes in Industrial Radiography," Int. J. Eng. Trends Technol., vol. 39, no. 4, pp. 216–225, 2016, doi: 10.14445/22315381/ijett-v39p237.

[13] R. Kumar and R. K. Mondloi, "Failure Mode and Effect Analysis of Petrol Engine of Car," Int. J. Sci. Res., vol. 7, no. 6, pp. 180–183, 2018, doi: 10.21275/ART20182731.

[14] W. Rizlan, H. H. Purba, and S. Sudiyono, "Performance Maintenance Analysis Using QFD Method: A Case Study in Fabrication Company in Indonesia," ComTech Comput. Math. Eng. Appl., vol. 9, no. 1, pp. 25–35, 2018, doi: 10.21512/comtech.v9i1.4456.

[15] M. Moradi and S. Raissi, "A Quality Function Deployment Based Approach in Service Quality Analysis to Improve Customer Satisfaction," Int. J. Appl. Oper. Res., vol. 5, no. 1, pp. 41–49, 2015.

[16] K. S. Arvindakarthik, M. K. K. K, and G. S. E, "QFD for the Motorcycle Service Quality Analysis and Improving Customer Satisfaction," Int. J. Sci. Res., vol. 4, no. 11, pp. 689–692, 2015, doi: 10.21275/v4i11.nov151210.

[17] Marsetio, Supartono, A. Octavian, Ahmadi, R. Ritonga, and Rudiyanto, "Optimization of Time Delay based Preventive Maintenance using Markov Decision Process," Int. J. Signal Process. Image Process. Pattern Recognit., vol. 10, no. 8, pp. 125–134, 2017, doi: 10.14257/ijsip.2017.10.8.11.

[18] E. A. Elsayed, S. D. A. K, A. Rahaman, and R. Karthikeyan, "Intelligent Maintenance System by Using MARKOV Chain with Monte Carlo Intelligent Maintenance System by Using MARKOV Chain with Monte Carlo Simulation Approaches," IOSR J. Mech. Civ. Eng., vol. 15, no. 1, pp. 18–24, 2018, doi: 10.9790/1684-1501031824.

[19] S. Assauri, Manajemen Produksi dan Operasi, Edisi 4. Jakarta: Fakultas Ekonomi Universitas Indonesia, 2004.

[20] Sugyono, Penelitian Kuantitatif Kualitatif dan R&D. Bandung: Alfabeta, 2016.

[21] R. D. Azka and R. Nurcahyo, "Quality management strategy for Indonesian aircraft MRO companies based on Kano Model, QFD matrix, and AHP," in Proceedings of the International Conference on Industrial Engineering and Operations Management, 2018, pp. 1544–1555.

[22] H. Dubey, A. K. Paharia, and C. Joshi, "Application of Quality Function Deployment (QFD) and Lean To Minimise Industrial Wastes," Int. J. Res. Manag., vol. 1, no. 7, pp. 15–35, 2017.

[23] E. J. Pulikkottil, "Application of Quality Function Deployment (QFD) In Aluminium Pot Manufacturing Industry with TPM Pillars," Int. Res. J. Eng. Technol., vol. 6, no. 4, pp. 1349–1354, 2019.

Risk Analysis To Determine Schedules And Reduce Maintenance Costs In Elevators With Fmea, Qfd, And Markov Chain Methods

ORIGINALITY REPORT

3%	2%	2%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Rajiv Gandhi Proudyogiki Vishwavidyalaya Student Paper	3%

Exclude quotes	On	Exclude matches	< 2%
Exclude bibliography	On		