RISK CONTROL STRATEGY ON GAS TRANSPORTATION PROJECTS WITH THE AGGREGATE RISK PRIORITY METHOD TO IMPROVE PROJECT SUSTAINABILITY PERFORMANCE (CASE STUDY: PT. TRANSPORTASI GAS INDONESIA)

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Abstrak

Proyek transportasi gas memiliki peranan penting dalam mendukung ketahanan energi nasional dan transisi menuju energi yang lebih ramah lingkungan. Namun demikian, proyek semacam ini sangat rentan terhadap berbagai risiko yang dapat berdampak pada efisiensi, keselamatan, dan keberlangsungan proyek. Penelitian ini bertujuan untuk mengidentifikasi risiko terbanyak yang dapat memengaruhi proyek transportasi gas secara sistematis, menjaga kinerja proyek agar sesuai dengan standar keselamatan dan efisiensi yang berlaku, mengkaji faktor-faktor penyebab kegagalan kualitas pada setiap tahapan proyek, serta menerapkan metode Aggregate Risk Priority (ARP) dengan pendekatan heat map, diagram pareto, histogram, dan fishbone diagram untuk pengendalian dan peningkatan kinerja proyek. Penelitian dilakukan di PT Transportasi Gas Indonesia melalui studi lapangan, wawancara, dan analisis dokumentasi teknis, kemudian dilanjutkan dengan pengolahan dan analisis data risiko sebelum dan sesudah mitigasi. Hasil penelitian menunjukkan bahwa metode ARP efektif dalam menetapkan prioritas risiko berdasarkan nilai RPN (Risk Priority Number), yang dihitung dari kombinasi antara likelihood, consequence, dan severity. Visualisasi dengan heat map dan diagram pareto membantu dalam fokus mitigasi risiko paling kritis, sedangkan fishbone diagram mempermudah identifikasi akar penyebab dari masalah kualitas. Setelah mitigasi, terjadi penurunan signifikan pada nilai RPN untuk sebagian besar proyek, yang menunjukkan keberhasilan pendekatan yang digunakan. Dengan demikian, penerapan ARP dan alat analisis pendukungnya terbukti menjadi strategi efektif dalam pengendalian risiko dan peningkatan kualitas proyek transportasi gas di lingkungan industri energi.

Kata kunci: *manajemen risiko, transportasi gas, aggregate risk priority (ARP), heat map, diagram pareto, fishbone diagram*

Abstract

Gas transport projects play an important role in supporting national energy security and the transition to greener energy. However, such projects are susceptible to a variety of risks that can impact project efficiency, safety, and sustainability. This study aims to systematically identify the most risks that can affect gas transportation projects, maintain project quality in accordance with applicable safety and efficiency standards, examine the factors that cause quality failures at each stage of the project, and apply the Aggregate Risk Priority (ARP) method with a heat map, pareto diagram, histogram, and fishbone diagram approach to control and improve project quality. The research was conducted at PT Transportasi Gas Indonesia through field studies, interviews, and analysis of technical documentation, then continued with the processing and analysis of risk data before and after mitigation. The results showed that the ARP method is effective in setting risk priorities based on the RPN (Risk Priority Number) value, which is calculated from a combination of likelihood, consequence, and severity. Visualisation with heat maps and pareto diagrams helps to focus on mitigating the most critical risks, while fishbone diagrams make it easier to identify the root causes of quality problems. After mitigation, there was a significant decrease in the RPN values for most projects, indicating the success of the approach used. Thus, the application of ARP and its supporting analytical tools proved to be an effective strategy in risk control and quality improvement of gas transportation projects in the energy industry environment.

Keywords: *risk management, gas transportation, aggregate risk priority (ARP), heat map, pareto diagram, fishbone diagram,*

INTRODUCTION

Gas transport is becoming very important both at international and national level in the supply chain of energy demand currently felt all over the world. Gas transport by pipeline is still the main business, not only between interconnected countries such as Europe and Russia but also in national markets. Pipeline gas transport will continue to be important at both regional and national levels. Nationally such as in Indonesia, transport gas plays a role in contributing to national energy security, supporting economic development, and providing environmentally friendly fuel for power generation, industry, and households. Technological innovation, synergy between the government and private companies, and strengthened infrastructure are expected to change the fortunes of this industry towards a strategic role in the green energy transition and future aspirations.

Before the occurrence of a gas transportation, it is certain that a company will definitely conduct a project to build the gas transportation. A project can be defined as a temporary activity that takes place within a limited period of time, with the allocation of certain resources, including costs, which are planned and intended to carry out tasks with clearly outlined objectives and completed within a predetermined time (Budihartono, 2010). Therefore, a project must have risks in its existence, so quality control must be carried out on the risks in the project. Quality control is a control activity that is useful for measuring quality characteristics, comparing them with specifications or requirements, and taking appropriate corrective actions with differences from the standard (Rampersad, 2015). This quality control is useful in order to carry out risk management, where risk management is a process of proactively managing risks by mitigating threats that can hinder the achievement of organisational goals, which includes identifying risks in a planned and measurable manner, and preparing various approaches to control risks so that goals can be achieved (Guruh Prasetyo Putro, 2022).

PT Transportasi Gas Indonesia (TGI) is a company engaged in the transportation of natural gas through a strategic and reliable pipeline network. TGI operates more than 1000 km, 28 inch open access pipeline which consists of two pipelines, Grissik - Duri for ± 536 KM and Grissik - Singapore for ± 468 KM. PT Transportasi Gas Indonesia is committed to becoming a 'Transporter of Choice' by continuing to implement the principles of 'Prudent Operator' and has a vision of 'Becoming an integrated and reliable energy provider', and has a mission of 'Achieving sustainable financial growth is one of the main objectives, accompanied by the provision of integrated energy products and services, including natural gas transportation'. In this context, the role of the Engineer Directorate can be very important to maintain or develop infrastructure sustainability as the company grows. At Perusahaan Transportasi Gas Indonesia there are several divisions, one of which is the Engineer Division, which operates with Pipelines, Facilities and Project Management (PMO).

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One method that can be used in processing risk data is aggregate risk priority (ARP). This method allows organisations to group and prioritise risks based on their severity, probability of occurrence, and impact on the system as a whole. By combining various risk analysis tools such as heat maps, pareto diagrams, and fishbone diagrams, the ARP method can provide a more comprehensive picture in the decision-making process.

The heat map approach is used to visualise the severity of risks based on certain parameters, which helps in making quick decisions regarding the most urgent risk mitigation. Meanwhile, pareto diagrams enable the identification of the main factors contributing to risks based on the 80/20 principle, where most problems often stem from a small number of causes that end up creating pareto diagrams, to be able to visualise the biggest risks. Furthermore, fishbone diagrams help in identifying the root causes of risks by grouping the contributing factors into several main categories, such as people, methods, machines, materials, environment, and management.

With this structured approach, companies can optimise risk mitigation strategies, increase operational efficiency, and improve product and service quality. Therefore, this research will focus on the application of the aggregate risk priority method with heat map, pareto, histogram and fishbone diagram approaches to improve the effectiveness in managing risks in an industrial environment.

The purpose of this research is to systematically identify the most risks that can affect gas transport projects, as well as efforts to prevent greater impacts on safety and efficiency. This research also aims to maintain the project quality in accordance with the applicable safety and efficiency standards, as well as identify the factors that cause quality failure at each stage of the project and design appropriate mitigation measures. In addition, this research explores the application of the aggregate risk priority method and various approaches such as heat maps, pareto diagrams, histograms, and fishbone diagrams in an effort to control and improve the quality of gas transportation projects at PT Transportasi Gas Indonesia.

RESEARCH METHODS

The research steps in developing risk control strategies in gas transportation projects using the Aggregate Risk Priority (ARP) method to improve the quality of project sustainability at PT Transportasi Gas Indonesia. The research began with field studies and literature studies to identify and understand the various risks that may occur in gas transportation projects. Field studies were conducted by direct observation at the project site to obtain empirical data on risk factors, potential hazards, and impacts that could occur on the project. Meanwhile, the literature study was conducted by researching various references, scientific journals, and industry standards related to risk management and the application of the ARP method in infrastructure projects. The results of these two approaches are then used to formulate the main issues that are the focus of the research, such as how the ARP method can assist in risk prioritisation and how appropriate mitigation strategies can be applied to maintain project continuity.

After the problem formulation was established, the research continued with the formulation of research objectives which included: (1) identification and prioritisation of risks based on their severity and impact, (2) application of the ARP method in risk mitigation strategies, and (3) analysis of the effectiveness of risk control strategies on project sustainability. To achieve these objectives, data collection, both quantitative and qualitative data, was carried out from historical records related to disruptions or accidents in gas transportation projects, interviews with industry experts, and technical documentation related to pipeline systems and project management.

The next stage is method design, where the research begins to develop a suitable approach based on the ARP method. If the designed method does not meet the criteria or produces invalid results, then revisions are made until a suitable approach is obtained. Once the method is established, the research enters the data processing stage, where the data that has been collected will be analysed using one main application, namely Microsoft Excel.

In Microsoft Excel, the data was processed with various visual analysis techniques, including Pareto diagrams, histograms, and heatmaps. Pareto diagrams are used to determine which risks are the most dominant based on the 80/20 principle, where a small percentage of risks have the greatest impact on project sustainability. Histograms are used to understand the frequency distribution of risk occurrence, helping in determining trends and patterns of risk occurrence in the project. Meanwhile, heatmaps are used to provide a visual representation of the level of risk based on the impact (IC), likelihood (IL), and interaction strength (IS) values, making it easier to prioritise mitigation.

The next stage is analysis using a Fishbone Diagram, which helps identify the root causes of the various risks faced in the gas transport project. This diagram is used to map the factors that cause risks from various aspects, such as humans, methods, materials, environment, and machines, so that the most effective mitigation solutions can be found.

After the analysis process is complete, the research ends with conclusions and suggestions, which contain recommendations for risk control strategies to improve the quality of gas transportation project sustainability at PT Transportasi Gas Indonesia. This conclusion includes a prioritised list of risks that need to be addressed immediately, effective mitigation strategies, and an evaluation of the effectiveness of the ARP method in reducing risks that can hinder project sustainability.

RESULTS AND DISCUSSION

Calculation of RPN Value on Risk Data

Calculation of Risk Priority Number (RPN) value is very important in project risk data analysis. This RPN value comes from a combination of the Initial Likelihood (IL), Initial Consequence (IC), and Initial Score (IS) values. IL is a value that shows the initial likelihood of a risk occurring before mitigation actions are taken, while IC shows how much impact is caused if the risk occurs. IS is a combined value of IL and IC that reflects the initial risk level before mitigation is carried out. Calculating the initial RPN value aims to find out how much risk there is in a project, as well as helping to identify critical risks that must be addressed immediately, determine mitigation priorities, and evaluate the potential impact of risks on project cost, time, and quality.

After mitigation, the RPN calculation is also calculated again to assess how effective the mitigation efforts have been. At this stage, the Residual Likelihood (RL), Residual Consequence (RC), and Residual Score (RS) values are used, which describe the likelihood, impact, and risk score after mitigation. Through the comparison between the initial RPN and the RPN after mitigation, we can quantitatively evaluate the reduction in risk level and measure the effectiveness of the mitigation measures implemented. To determine whether the difference between the two values is significant, statistical analyses such as paired t-test can be used.

In addition, risk heat maps are also used to provide a visualisation of the level of risk in the form of a matrix that shows the relationship between likelihood and consequence. The colours on the heat map represent the severity of the risk, ranging from green (low), yellow (medium), to red (high). By using a heat map, the most critical risks can be more easily identified and prioritised to be addressed. This heat map can be applied to both pre- and post-mitigation conditions, making it easier to visually compare changes in overall risk levels. The following is the Excel calculation:

$$IS = IL \times IC$$

$$RPNawal = IL \times IC \times IS$$

$$RS = RL \times RC$$

$$RPNawal = RL \times RC \times RS$$

$$RPN_{total} = \text{Adding all risks to each project}$$

$$\text{Resolved Percentage} = \frac{RPN\ Total\ After}{RPN\ Total\ Before} \times 100\%$$

Calculating the initial RPN value and also the final RPN up to the next 19 projects, so as to get the overall result. The following are the results of all calculations.

Table 1 RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-17/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-17/2024/R2	Biaya	2	2	4	18		2	2	4	16		
	33/P-17/2024/R3	Waktu	1	1	1	9		1	1	1	1		
	33/P-17/2024/R4	Waktu	2	2	4	64		2	2	4	16		
1.	33/P-17/2024/R5	Waktu	2	2	4	36		2	2	4	16		
	33/P-17/2024/R6	Waktu	1	1	1	36	307	1	1	1	1	99	32%
	33/P-17/2024/R7	Waktu	1	1	1	36		1	1	1	1		
	33/P-17/2024/R8	Waktu	2	2	4	36		2	2	4	16		
	33/P-17/2024/R9	Waktu	2	2	4	36		2	2	4	16		

Table 2 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-04/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-04/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-04/2024/R3	Waktu	2	2	4	36		2	2	4	16		
2	33/P-04/2024/R4	Waktu	3	2	6	64	204	3	2	6	36	85	42%
	33/P-04/2024/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-04/2024/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-10/2023/R1	Kualitas	2	2	4	36		2	2	4	16		
3	33/P-10/2023/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-10/2023/R3	Waktu	2	2	4	36	204	2	2	4	16	85	42%
	33/P-10/2023/R4	Waktu	3	2	6	64		3	2	6	36		

Table 3 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-10/2023/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-10/2023/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-01.1/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-01.1/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-01.1/2024/R3	Waktu	2	2	4	36		2	2	4	16		
4	33/P-01.1/2024/R4	Waktu	3	2	6	64	204	3	2	6	36	85	42%
	33/P-01.1/2024/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-01.1/2024/R6	Kualitas	1	2	2	16		1	2	2	4		
5	33/P-01/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-01/2024/R2	Waktu	3	1	3	16	204	3	1	3	9	85	42%

Table 4 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-01/2024/R3	Waktu	2	2	4	36		2	2	4	16		
	33/P-01/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-01/2024/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-01/2024/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-02/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-02/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-02/2024/R3	Waktu	2	2	4	36		2	2	4	16		
6	33/P-02/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-02/2024/R5	Kualitas	1	2	2	36	204	1	2	2	4	85	42%
	33/P-02/2024/R6	Kualitas	1	2	2	16		1	2	2	4		

Table 5 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-06/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-06/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-06/2024/R3	Waktu	2	2	4	36		2	2	4	16		
7	33/P-06/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-06/2024/R5	Kualitas	2	2	4	36		2	2	4	16		
	33/P-06/2024/R6	Kualitas	1	2	2	36	240	1	2	2	4	101	42%
	33/P-06/2024/R7	Kualitas	1	2	2	16		1	2	2	4		
	33/P-07/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
8	33/P-07/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-07/2024/R3	Waktu	2	2	4	36	240	2	2	4	16	89	37%

Table 6 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-07/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-07/2024/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-07/2024/R6	Kualitas	1	2	2	36		1	2	2	4		
	33/P-07/2024/R7	Kualitas	1	2	2	16		1	2	2	4		
	33/P-08/2024/R1	Waktu	2	1	2	9		2	1	2	4		
	33/P-08/2024/R2	Waktu	1	2	2	36		1	2	2	4		
9	33/P-08/2024/R3	Kualitas	2	2	4	36		2	2	4	16		
	33/P-08/2024/R4	Waktu	2	1	4	36	121	2	1	4	8	33	27%
	33/P-08/2024/R5	Kualitas	1	1	1	4		1	1	1	1		
10.	33/P-12/2024/R1	Kualitas	2	2	4	36		2	2	4	16		

Table 7 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-12/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-12/2024/R3	Waktu	2	2	4	36		2	2	4	16		
	33/P-12/2024/R4	Waktu	2	2	4	64	204	2	2	4	16	65	32%
	33/P-12/2024/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-12/2024/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-13/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-13/2024/R2	Waktu	3	1	3	16		3	1	3	9		
11.	33/P-13/2024/R3	Waktu	3	1	3	16		3	1	3	9		
	33/P-13/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-13/2024/R5	Waktu	3	2	6	64	228	3	2	6	36	124	54%

Table 8 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-13/2024/R6	Waktu	3	1	3	16		3	1	3	9		
	33/P-13/2024/R7	Kualitas	3	1	3	16		3	1	3	9		
	33/P-15/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
	33/P-15/2024/R2	Waktu	3	1	3	16		3	1	3	9		
	33/P-15/2024/R3	Waktu	2	2	4	36		2	2	4	16		
12.	33/P-15/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-15/2024/R5	Kualitas	1	2	2	36	204	1	2	2	4	85	42%
	33/P-15/2024/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-15/2024/R1	Kualitas	2	2	4	36		2	2	4	16		
13.	33/P-15/2024/R2	Waktu	3	1	3	16	204	3	1	3	9	85	42%

Table 9 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-15/2024/R3	Waktu	2	2	4	36		2	2	4	16		
	33/P-15/2024/R4	Waktu	3	2	6	64		3	2	6	36		
	33/P-15/2024/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-15/2024/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-05/2021/R1	Biaya	3	4	12	256		3	4	12	144		
	33/P-05/2021/R2	Biaya	2	4	8	100		2	4	8	64		
	33/P-05/2021/R3	Hukum	2	4	8	100		2	4	8	64		
14.	33/P-05/2021/R4	Biaya	2	4	8	144		2	4	8	64		
	33/P-05/2021/R5	Waktu	3	2	6	144		3	2	6	36		
	33/P-05/2021/R6	Kualitas	2	3	6	144	2239	2	3	6	36	948	42%

Table 10 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-05/2021/R7	Waktu	2	3	6	144		2	3	6	36		
	33/P-05/2021/R8	Waktu	2	1	2	9		2	1	2	4		
	33/P-05/2021/R9	Waktu	2	2	4	64		2	2	4	16		
	33/P-05/2021/R10	Kualitas	3	2	6	81		3	2	6	36		
	33/P-05/2021/R11	Waktu	3	2	6	81		3	2	6	36		
	33/P-05/2021/R12	Waktu	3	2	6	81		3	2	6	36		
	33/P-05/2021/R13	Waktu	3	2	6	81		3	2	6	36		
	33/P-05/2021/R14	Waktu	2	2	4	81		2	2	4	16		
	33/P-05/2021/R15	Waktu	3	2	6	81		3	2	6	36		
	33/P-05/2021/R16	Waktu	3	2	6	81		3	2	6	36		

Table 11 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-05/2021/R17	Kualitas	3	2	6	81		3	2	6	36		
	33/P-05/2021/R18	Kualitas	3	2	6	81		3	2	6	36		
	33/P-05/2021/R19	Kualitas	3	2	6	81		3	2	6	36		
	33/P-05/2021/R20	Biaya	2	3	6	81		2	3	6	36		
	33/P-05/2021/R21	Biaya	3	2	6	81		3	2	6	36		
	33/P-05/2021/R22	Hukum	3	2	6	81		3	2	6	36		
	33/P-05/2021/R23	Biaya	3	2	6	81		3	2	6	36		
	34/P-04 /2023/R1	Waktu	3	1	3	16		3	1	3	9		
15.	34/P-04 /2023/R2	Waktu	3	1	3	16		3	1	3	9		
	34/P-04 /2023/R3	Waktu	3	1	3	16		3	1	3	9		

Table 12 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	34/P-04 /2023/R4	Kualitas	3	2	6	81		3	2	6	36		
	34/P-04 /2023/R5	Kualitas	1	1	1	9		1	1	1	1		
	34/P-04 /2023/R6	Kualitas	1	3	3	36	214	1	3	3	9	90	42%
	34/P-04 /2023/R7	Waktu& Kualitas	2	2	4	36		2	2	4	16		
	34/P-04 /2023/R8	Kualitas	1	1	1	4		1	1	1	1		
	34/P-01/2023/R1	Waktu	2	2	4	36		2	2	4	16		
	34/P-01/2023/R2	Waktu	3	1	3	16		3	1	3	9		
16.	34/P-01/2023/R3	Biaya	2	2	4	36		2	2	4	16		
	34/P-01/2023/R4	Waktu	3	2	6	64	228	3	2	6	36	109	48%
	34/P-01/2023/R5	Waktu& Kualitas	2	2	4	36		2	2	4	16		

Table 13 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	34/P-01/2023/R6	Biaya	2	2	4	36		2	2	4	16		
	34/P-04 /2024/R1	Waktu	3	1	3	16		3	1	3	9		
	34/P-04 /2024/R2	Waktu	3	1	3	16		3	1	3	9		
	34/P-04 /2024/R3	Waktu	3	1	3	16		3	1	3	9		
17.	34/P-04 /2024/R4	Kualitas	3	2	6	81		3	2	6	36		
	34/P-04 /2024/R5	Kualitas	1	1	1	9		1	1	1	1		
	34/P-04 /2024/R6	Waktu& Kualitas	2	2	4	36	178	2	2	4	16	81	46%
	34/P-04 /2024/R7	Kualitas	1	1	1	4		1	1	1	1		
	33/P-09/2023/R1	Kualitas	2	2	4	36		2	2	4	16		
18.	33/P-09/2023/R2	Waktu	3	1	3	16		3	1	3	9		

Table 14 (Cont) RPN Calculation

Project	Kode Risiko	Jenis Risiko	IL	IC	IS	RPN Sebelum	Total RPN Sebelum	RL	RC	RS	RPN Sesudah	Total RPN Sesudah	Presentase Teratasi
	33/P-09/2023/R3	Waktu	2	2	4	36		2	2	4	16		
	33/P-09/2023/R4	Waktu	3	2	6	64	208	3	2	6	36	85	41%
	33/P-09/2023/R5	Kualitas	1	2	2	36		1	2	2	4		
	33/P-09/2023/R6	Kualitas	1	2	2	16		1	2	2	4		
	33/P-01/2023/R1	Biaya	2	2	4	64		2	2	4	16		
	33/P-01/2023/R2	Kualitas	2	2	4	36		2	2	4	16		
19.	33/P-01/2023/R3	Waktu	1	1	1	9		1	1	1	1		
	33/P-01/2023/R4	Waktu	1	1	1	64	254	1	1	1	1	70	28%
	33/P-01/2023/R5	Waktu	2	3	6	81		2	3	6	36		

After calculating for all 19 projects, a recapitulation of the RPN value calculation can be made. The following is a recapitulation of the RPN value calculation data.

Table 15 Recapitulation of RPN Value

Recapitulation of RPN Value			
Project No.	RPN Total Before	RPN Total After	Resolved Percentage
1	307	99	32%
2	204	85	42%
3	204	85	42%
4	204	85	42%
5	204	85	42%
6	204	85	42%
7	240	101	42%
8	240	89	37%
9	121	33	27%
10	204	65	32%
11	228	124	54%
12	204	85	42%
13	204	85	42%
14	2239	948	42%
15	214	90	42%
16	228	109	48%
17	178	81	46%
18	208	85	41%
19	254	70	28%

Based on the results of the risk analysis of the 19 projects shown in the table, it can be concluded that each project has several main types of risks including quality, time, cost, and legal. The risks were then analysed based on three main parameters, namely likelihood, impact, and level which were then multiplied to produce a Risk Priority Number (RPN) value before mitigation. After mitigation actions are taken, the risk value is calculated again based on the RL, RC, and RS parameters, to obtain the RPN after mitigation. From the overall data, it is known that the average project experienced a significant reduction in risk, ranging from 27% to 48%, which indicates that mitigation measures have been carried out effectively in most projects.

The projects with the most significant risk reduction include the 16th and 17th projects, with a reduction of 48% and 46% respectively. However, the 14th project is a major concern because it has a total RPN value before mitigation that is very high compared to other projects, which is 2,239 and was successfully reduced to 948 after mitigation, with a percentage reduction of 42%. This high RPN value is dominated by risks originating from the cost and legal categories, indicating that these two aspects are critical risk sources that require further attention and more intensive mitigation actions. In addition, the 9th project is the only project that has the smallest risk reduction compared to other projects, which is only 27%. This shows that the mitigation strategy implemented in the project is not very effective and needs to be re-evaluated so that the mitigation results can be more optimal.

In general, the most frequently occurring risks in these 19 projects were of the time and quality risk types, with time risks being more dominant in quantity but tending to have lower RPN values than cost and legal risks. Thus, despite the frequent occurrence of time risks, cost and legal risks proved to make a large contribution to the total RPN value of the project as a whole. The fairly consistent decrease in RPN across projects also indicates that the mitigation methods used have relatively uniform patterns and effectiveness, although their effectiveness still varies depending on the context and risk characteristics of each project. Therefore, to improve the effectiveness of risk management in the future, it is necessary to focus on improving mitigation against cost and legal risks, as well as optimising mitigation strategies on projects with low risk reduction. In addition, improvements in planning and monitoring on aspects that repeatedly become sources of risk such as time and quality also need to be carried out on an ongoing basis.

After calculating the total RPN before mitigation and after mitigation, it can identify the type of risk that is the greatest according to the RPN value. The following is a pareto table of existing risk types.

Table 16 Pareto Risk

No.	Risk Type	RPN Total	Percentage	Cumulative Percentage
1.	Time	3071	51%	51%
2.	Quality	1982	33%	83%
3.	Cost	928	15%	98%
4.	Legal	100	2%	100%
RPN Total		6801		

After the pareto table is created, the next step is to create a histogram, here is a histogram of the existing risk types, according to the pareto table that has been made.

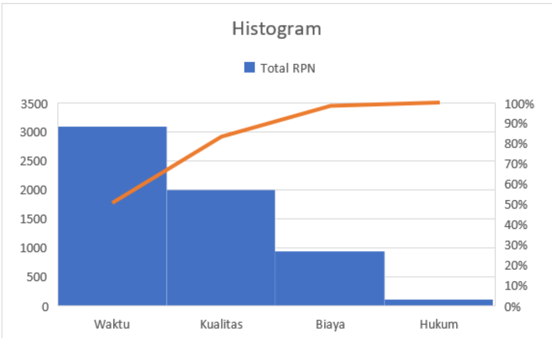

Figure 1 Risk Histogram

Based on the histogram shown, analysis of the Risk Priority Number (RPN) values indicates that the most significant risks are in the time category, followed by quality, cost, and finally legal. Risks in the time aspect have the highest RPN value, which indicates that there are many potential failures or time mismatches in the implementation of activities, such as delays in completion, schedule inaccuracies, or lack of realistic time planning. These risks can directly impact the overall project timeline and cause costly delays, both operationally and financially.

The second category that has a high RPN is quality, which indicates a potential failure to meet product or service quality standards. These risks can include product defects, unstable production processes, lack of quality control, or non-conformance to technical specifications. If not handled properly, quality risks can impact customer satisfaction, company reputation, and increased repair or rework costs.

Meanwhile, the cost category has a relatively low RPN value compared to the previous two categories, but still indicates the presence of risks related to budget overruns, inefficient use of resources, or inaccuracy in the initial cost estimate. Although its contribution to the total risk is not as great as time and quality, it is still important to monitor and control this aspect so as not to impact the profitability of the project. The last category is legal, with the lowest RPN value. This indicates that risks related to legal or regulatory aspects, such as compliance with government regulations, licensing, or contractual issues, are currently considered the most minimal. However, even though the risk is low, legal aspects should not be ignored because violations of regulations can lead to serious legal sanctions.

Overall, this analysis shows that primary attention should be paid to risks related to time and quality, as these two aspects account for about 90% of the total identified risks. The focus of risk mitigation needs to be on developing realistic schedules, improving coordination between teams, strengthening quality control, and technical training for the personnel involved. By lowering the RPN values in these two categories, the overall efficiency and effectiveness of the project can be significantly improved

Fishbone Analysis

After data processing, an analysis of the risks that have the most influence on 19 gas transportation projects at PT Transportation Gas Indonesia can be carried out. In accordance with the pareto diagram, it can be seen that there are 2 types of risks that are most influential, namely in terms of time risk and quality risk. Therefore, a fishbone diagram was created, to be able to analyse these 2 types of risks.

The following is a fishbone diagram for time risk, using 5 factors, namely in the form of humans (Man), machines (Machine), methods (Method), materials (Material), measurement (Measurement).

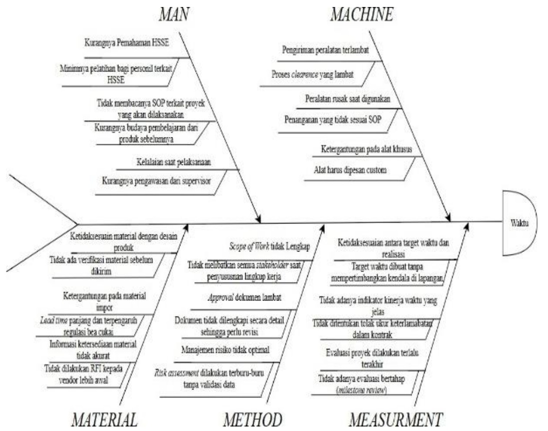

Figure 2 Fishbone Diagram of Time Risk

The fishbone diagram presented shows that time risk in project implementation is caused by various interrelated factors, namely: Man, Machine, Material, Method, and Measurement. The human factor plays an important role due to the lack of understanding of HSSE (Health, Safety, Security, and Environment) aspects, the lack of training for project personnel, and the lack of discipline in reading and applying the established SOPs. In addition, the culture of learning from previous projects has not been built, supervision from supervisors is weak, and there is negligence in the implementation in the field. To overcome this, it is necessary to conduct regular training on HSSE and SOPs, establish a learning culture through project evaluation and team discussions, and strengthen the role of supervisors in the field through regular reporting and monitoring systems.

Machine factors are also a significant contributor to delays, mainly due to late delivery of equipment, slow clearance processes, and the use of damaged and inappropriate equipment. Reliance on specialised tools that must be ordered in advance also adds to lead times. Possible solutions include improving logistics efficiency by ordering tools early, providing backup equipment, and training operators to use and maintain tools in accordance with SOPs. For specialised tools, it is necessary to establish long-term cooperation with vendors so that the ordering time can be shorter.

Meanwhile, in terms of materials, delays are caused by material mismatches with product designs, the absence of a verification process before delivery, and high dependence on imported materials. Long lead times and customs regulations are a challenge, especially if the information on material availability is not accurate. The problem was compounded by delays in conducting RFIs (Request for Information) to vendors. Appropriate solutions include improving the material verification and validation process from the start, prioritising the use of local materials, and an accurate and up-to-date logistics information management system. Procurement planning should also be done earlier to anticipate external obstacles.

Method factors involve incomplete work planning, such as a scope of work that is not developed by involving all stakeholders, a slow document approval process, and incomplete technical documents that cause frequent revisions. In addition, risk assessments are often done in a rush without adequate data validation. For this reason, all relevant parties must be involved from the start in compiling a comprehensive scope of work. Document approval procedures should be simplified, and all technical documents should be prepared in detail from the start. Risk assessment must be done carefully using valid data to provide a basis for accurate decision-making.

Finally, the measurement aspect shows that delays occur due to the absence of clear time performance indicators and unrealistic time targets that do not consider conditions in the field. Delay benchmarks are not specified in the contract, and project evaluations are often conducted too late, without a phased evaluation. To fix this, it is necessary to set realistic time performance indicators (KPIs) that are based on field data. Setting time targets should consider potential risks, and project contracts should include tolerances and consequences for delays. Project evaluation should be conducted in stages through milestone reviews so that problems can be identified and resolved early. Overall, a comprehensive approach to these five factors will strengthen project time management and significantly reduce the risk of delays.

The following is a fishbone diagram for quality risk, using 5 factors, namely in the form of humans (Man), machines (Machine), methods (Method), materials (Material), measurement (Measurement).

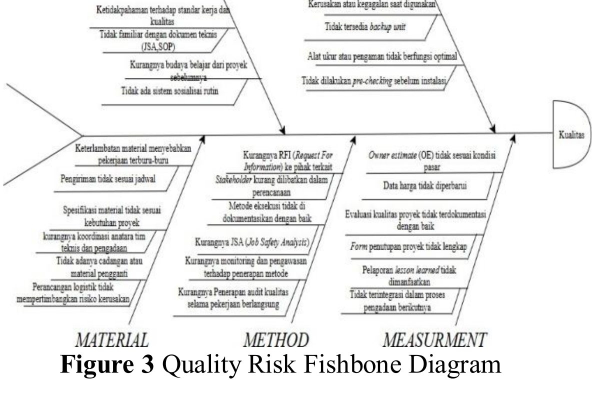

Figure 3 Quality Risk Fishbone Diagram

The fishbone diagram shown identifies the root causes of the quality risks in the project, which are grouped into five main categories namely: Man, Machine, Material, Method, and Measurement. Each category indicates a factor that significantly affects the quality of the deliverables, and therefore requires appropriate analysis and strategic solutions.

In the Human aspect, quality risks arise due to personnel's negligence of HSSE aspects, lack of daily briefings, unfamiliarity with work and quality standards, and lack of familiarity with technical documents such as JSA (Job Safety Analysis) and SOP. In addition, the absence of a regular socialisation system and a weak culture of learning from previous projects meant that personnel were ill-prepared and unmotivated to work to quality standards. To overcome this, the company needs to set mandatory training standards for all project personnel, especially related to HSSE and technical work. Daily briefings should be made part of the work culture so that personnel are always updated with information. In addition, there should be periodic socialisation of quality standards and evaluation of previous work results as a form of collective learning.

The Machinery factor also has a major impact on the quality of work, mainly because the equipment used does not meet safety standards, no regular inspections are carried out, and no backup units are available in the event of damage or failure. In addition, sub-optimal measuring instruments and no pre-checking prior to installation add risk to the end result. The solution to this is to implement a regular inspection schedule for all equipment, ensure that all tools meet safety standards before use, and provide backup equipment in case of failure. Pre-checking procedures must be implemented before equipment is operated, especially those that play a role in the installation or measurement process.

In terms of materials, late deliveries and materials that did not meet specifications disrupted the rhythm of the work resulting in rushed work, which ultimately reduced the quality of results. The lack of coordination between the technical and procurement teams, the absence of replacement materials, and logistics planning that did not consider the risk of damage also worsened the situation. To address this, material procurement planning should be more thorough and integrated with technical requirements. Specifications should be specified in detail and re-verified before ordering. Communication between the technical and procurement teams needs to be strengthened, and the logistics system should be able to anticipate delays by providing time buffers and spare materials.

On the Methods side, the main cause of the decline in quality was the lack of coordination and supervision during execution, as well as the non-application of consistent and well-documented execution methods. This was exacerbated by the lack of JSA implementation, the non-involvement of stakeholders in planning, and the lack of audits on the application of methods in the field. The solution to this problem is to strengthen the collaborative planning system that involves all stakeholders from the beginning, and to ensure that every execution method is systematically documented. Internal audits of method implementation should also be carried out regularly, and JSAs should be prepared and socialised before work begins.

Finally, in terms of Measurement, many quality risks arise because the owner estimate (OE) does not match market conditions, price data is not updated, and quality evaluation results are not well documented. In addition, project lessons learned reports were not utilised and not integrated in subsequent procurements. This leads to repetition of the same mistakes and low accuracy of quality estimation in subsequent projects. To address this, a system of regular price data updates and an OE validation mechanism that considers current market conditions are needed. Quality evaluation should be formally documented and used as a reference in subsequent projects. Lessons learnt from each project should be processed into a corporate learning database, which is then used as part of planning and procurement.

Overall, project quality improvement can only be achieved through a systemic approach to all five factors. Improvements in people, machines, materials, methods, and measurements must be made in an integrated manner to support each other and prevent repetition of mistakes in the future. Integration between planning, execution, and evaluation systems is essential to ensure that quality standards are maintained throughout the project cycle.

CONCLUSION

The conclusion of this research shows that risk identification and control efforts on gas transportation projects at PT Transportasi Gas Indonesia are carried out through a systematic and data-driven approach, by applying the Aggregate Risk Priority (ARP) method that combines risk likelihood, impact and severity analyses. Key risks were identified through field studies, interviews and technical documentation, and mapped using heat maps and pareto diagrams to determine the level of urgency and priority of response. To maintain project quality in accordance with safety and efficiency standards, the company implements a quality control system that is based on the results of risk evaluation and is carried out on an ongoing basis from the planning stage to project completion. Visualisation of risk data in the form of histograms and heat maps helps detect quality deviations early so that corrective action can be taken immediately. The research also revealed that quality failures in the project were mostly sourced from human, method, material, machine, and management aspects, which were successfully identified through fishbone diagrams. Appropriate mitigation measures, such as workforce training, standardisation of procedures, material verification, and improved documentation and communication systems, were shown to reduce the risk level after being implemented. The combined use of the ARP method with various visual analysis tools results in a comprehensive approach to quality control, strengthens the decision-making process, and promotes continuous improvement of the quality of gas transport projects.

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