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Analyzing operational risks of a recyclable waste-based payment public transit system in Surabaya, Indonesia

Maria Anityasari[*], Naning Aranti Wessiani, Atikah Aghdhi Pratiwi, Fathaliati Zikri Musev Putri, Hilmi Cahya Rinardi, Matheus Bimo Aryo Prakoso, Nofinda Ghaisani

Department of Industrial and Systems Engineering, Institut Teknologi Sepuluh Nopember, Jl. Teknik Kimia, Surabaya 60111, Indonesia

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ABSTRACT

Suroboyo Bus, a municipal public transportation initiative managed by the Surabaya Department of Transportation (SubDOT) in Indonesia, was launched to promote the use of public transit by accepting recyclable plastic waste as transit fare payments. However, this transportation system presented challenges, as prior to 2019, Suroboyo Bus performed its operational activities without adequately incorporating operational risk, specifically considering Health, Safety, and Environment (HSE) factors. The analysis of risk profiles and a mitigation plan concerning the well-being of both their staff and passengers was uncomprehensive. To address these issues, this paper evaluates the operational risk based on ISO 31000:2018, the Failure Mode and Effect Analysis (FMEA), and the Benefit Cost-Analysis (BCA). The analysis identified 114 risks and 189 combinations of risks and impacts across 70 business processes associated with Suroboyo Bus operations, with varying degrees of risk severity. Risk prioritization analysis was performed using the Pareto 80:20 principle. Proposed risk response strategies include avoidance, mitigation, transfer, and tolerance. Evaluation of the feasibility of these strategies through benefits and cost analysis, supplemented by a sensitivity analysis, revealed Benefit-Cost Ratio (BCR) values ranging from 1.041 to 1.471, indicating that the proposed mitigation plan is feasible for all evaluated scenarios. These findings underscore the importance of implementing risk mitigation measures to improve the sustainability and effectiveness of the Suroboyo Bus service. Future research should explore the digital application developed for Suroboyo Bus passengers as part of the business process named "Golek Bis" (GOBIS) and other methods that can be used to enhance the quality and comprehensiveness of risk management.

*Corresponding Author

Maria Anityasari
E-mail: maria@its.ac.id

1. INTRODUCTION

Public transportation is commonly portrayed as a crucial element in constructing sustainable cities. Conversely, transportation's societal, economic, and environmental consequences are depicted as pivotal concerns that could undermine the sustainability of cities and regions [1]. Offering a top-notch public transportation network fosters loyalty among existing users and can entice commuters away from alternative modes of transportation. Essential aspects include minimizing wait times, walking distances, and time spent in transit and prioritizing safety, reliability, and passenger comfort. Consequently, managing and delivering effective, high-quality service presents significant challenges for public transportation operators and authorities [2].

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Risk management, which encompasses health, safety, and environmental concerns, is crucial for public transportation. However, ensuring that all these aspects are fully addressed can sometimes be challenging [3]. In recent times, there has been a notable increase in the occurrence of public traffic accidents, resulting in significant loss of life and property and adversely affecting social progress [4]. These accidents have emerged as a substantial societal issue. Globally, road traffic accidents lead to 1.25 million fatalities and 50 million disabilities annually [4], [5]. The problem of regional public transportation safety risk assessment is very complicated, so it needs to be considered from different angles [6].

Many organizations have used several methods, techniques, and tools as risk management frameworks. The International Standardization Organization (ISO) has established Risk Management principles and guidelines that have been used worldwide and were created to be widely applicable across contexts and projects [7], [8], [9]. A study by Zhang *et al.* [7] found that empirical evidence from the study suggests that ISO 31000 [10] is a promising guideline for establishing risk management in the engineering management community. This finding provides legitimacy to the standard and suggests that risk management motivated by the ISO 31000 guideline can lead to an organization's goal and project success. However, ISO 31000 does not provide a clear example of risk identification and assessment techniques [11].

In recent years, there has been a proliferation of effective tools for identifying and analyzing risks, including the failure mode and effect analysis (FMEA) method, which offers a systematic approach to risk analysis. It evaluates failure modes based on three key risk factors, severity (S), occurrence (O), and detection (D), and prioritizes them using the risk priority number (RPN = S × O × D). FMEA finds widespread application across various sectors, including aerospace, mechanical engineering, healthcare management, and oil companies [12], [13]. Consequently, it exhibits considerable promise in effectively managing transportation risks [14]. Integration of ISO 31000 and the FMEA approach is a highly efficient method for operational risk assessment and control [15].

According to Rahimi *et al.* [16], risk can be divided into 4 categories which are 1) compliance risk, 2) hazard risk, 3) control risk, and 4) opportunity risk. Operational risk is usually a hazard risk. The significance of overseeing operational risk has long been recognized. This form of risk is characterized by its potential to interrupt routine business operations. This study focuses on identifying, assessing, and finding a suitable risk response for operational risk, which poses a threat to the business operations of Suroboyo Bus. In the scope of risk management, risk response plays a significant role in mitigating the negative impact of risks in the business process and project [17]. However, the organization must focus on risks that significantly impact the business process. The Pareto Principle states that 80% of the output or effects are generated by just 20% of the input or causes for numerous phenomena. This principle is frequently employed in management, economics, and business to enhance productivity and guide better decision-making. It underscores the insight that the majority of outcomes often come from a minority of inputs [18], [19].

Once risks have been identified and analyzed, selecting suitable risk response strategies becomes crucial for minimizing overall risk exposure during project implementation [20]. Consequently, risk response analysis emerges as a significant consideration within Risk Management [21], [22]. Benefit-cost analysis (BCA) has been a popular method in the last decade as it can support decision-making by integrating both the advantages and disadvantages of a suite of risk treatment options [23]. Using BCA will improve the quality of risk treatment decision-making [24], [25]. Therefore, this study proposes a framework integrating ISO 31000, FMEA, and BCA for the risk management system.

The proposed framework was implemented within the operational risk analysis of the transportation system in Surabaya, Indonesia. Surabaya is the second largest city in Indonesia, with a population of 2,896,185 people and an average population growth rate of 0.37% annually [26]. Surabaya faces concerns about accommodating its growing population. As the city becomes more densely populated, the city government must address residents' needs, particularly regarding accessible public transportation for sustainable urban development [27], [28]. To address this challenge, the city government, through the Surabaya Department of Transportation (SubDOT), has introduced innovative efforts by deploying various integrated public transportation modes under the Surabaya Integrated Transportation System (SIUTS). The first of those introduced efforts is the Suroboyo Bus transit system. Not only is Suroboyo Bus a flexible solution for mass public transit in Surabaya City [29], but it also aims to promote environmental sustainability awareness among its users by allowing transit fares to be paid using recyclable waste, such as plastic bottles. Suroboyo Bus officially operated in Surabaya since April 2018.

From April 2018 to 2019, Suroboyo Bus carried out its operational activities without adequately incorporating Health, Safety, and Environment (HSE) factors. There was a lack of comprehensive analysis of risk profiles and mitigation plans concerning the well-being of both their staff and passengers. This oversight could potentially lead to complex cascading failure events within or across various functions [30]. HSE factors are critical for ensuring the sustainability of a business and fostering trust among stakeholders and the community [31], [32]. This research aims to enhance Suroboyo Bus's preparedness by addressing its business model implementation and risk management policies, thereby taking a step closer to business independence and sustainability.

The article has three main contributions. First, it presents a study for integrating ISO 31000, FMEA, and Benefit Cost-Analysis, which contributes to overcoming the gaps found in extant literature. Emphasizing systematic risk identification and mitigation, ISO 31000 offers a strong framework for risk management that can simultaneously increase the efficacy of FMEA, a methodology mainly focused on spotting possible failure modes and their effects [33], [34]. Furthermore, the research provides empirical evidence concerning validating the proposed model and its contribution to improving an existing service. Finally, the article highlights specific contributions, including new ways of risk assessment and risk response prioritization, and findings regarding operational risk identification, risk analysis, and risk response strategies to provide a comprehensive framework adaptable to similar transportation systems in other cities.

After this introductory section, Section 2 provides an overview of the development of related literature reviews. Section 3 provides a succinct overview of fundamental concepts, theories, methodological approaches, and the obtained data that serve as the foundation of this study. Subsequentially, Section 4 outlines the primary process undertaken in this study, specifically focusing on the risk management procedures related to operational risks faced by Suroboyo Bus and presents the findings and additional analysis derived from the study results. Finally, Section 5 delivers the research conclusion and how it aligns with the study objectives.

2. RELATED WORK

Several important factors characterize the orientation of this research and emphasize its special contributions to the subject of operational risk management in public transportation, therefore separating it from earlier studies (Table 1). First, this study combines all three frameworks, ISO 31000, FMEA, or BCA, in isolation, creating a whole approach to risk management while most studies use one. This all-encompassing approach provides a more significant and comprehensive framework for operational risk analysis. In this research, the ISO 31000 framework is adopted. It consists of risk identification, analysis and evaluation, and risk response stage. FMEA is used in the second stage, which is analysis and evaluation to enhance the comprehensiveness of the risk assessment. BCA, as one of the feasibility analysis indicators, is used in the last stage, risk response identification, to complement the suggested risk response method for each risk event. Second, this study combines explicitly recyclable waste-based payment systems with operational risk management, bringing a different aspect of sustainability even if previous studies address sustainability [1]. The study is especially unique since current literature rarely addresses this twin focus on environmental sustainability and risk management. Third, whereas most studies center on industrialized nations or broad settings, the research concentrates on Surabaya, Indonesia, a growing city. This offers context-specific insights for such metropolitan environments in underdeveloped countries where public transportation systems encounter particular difficulties. Fourth, unlike other research that lacks clear prioritizing strategies or employs less effective techniques, the Pareto 80:20 principle for risk prioritizing is fresh. By means of this data-driven approach, resources are distributed to minimize the most important hazards, improving risk management's effectiveness. Fifth, as most studies do not complete feasibility analyses, including BCA and sensitivity analysis for assessing risk-reducing options is a major contribution. This guarantees that suggested plans are both efficient and financially feasible, offering public transportation authorities a useful tool for making decisions. At last, the study especially combines HSE (Health, Safety, and Environment) elements into operational risk control, tackling cascading hazards and guaranteeing sustainability and safety in public transportation. This integration is absolutely important since it emphasizes the need for comprehensive planning for environmentally friendly public transportation networks. These components, taken together, highlight the originality and importance of this study in developing operational risk management in public transportation.

3. RESEARCH METHODS

3.1. Risk definition and categories

For several decades, the common conception has been that every business process and activity carries internal and external uncertainties, which can lead to potential failures. These uncertainties are referred to as risks. A risk is an event characterized by uncertainty because it may or may not occur [25]. Risks can lead to positive or negative impacts or simply may just result in uncertainty. Consequently, risks can also be associated with opportunities for gain, potential losses, or uncertainty within an organization. Each risk has distinct features that necessitate specific management strategies or analytical approaches. Risk is divided into four categories, which are 1) compliance (or mandatory) risks, 2) hazard (or pure) risks, 3) control (or uncertainty) risks, and 4) opportunity (or speculative) risks [17]. Hazard risks are linked to sources of possible harm or circumstances that could compromise objectives, and risk management involves reducing its potential impact. While the other three

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Table 1. Literature review for study comparation

Author	Year	Focus area	Methodology	Sustainability focus	Risk prioritization	Benefit-cost analysis	Operational risk focus	Risk mitigation strategies	Feasibility analysis
Liu *et al.* [35]	2024	Maritime transportation risk management using FMEA.	Improved FMEA method based on expert trust networks.	Limited focus on sustainability.	Uses expert trust networks for risk prioritization.	No BCA used.	Focuses on maritime operational risks.	Mitigation strategies based on FMEA results.	No feasibility analysis.
Hoyos & Silva [25]	2022	Earthquake risk mitigation using BCA.	Benefit-Cost Analysis (BCA) for risk mitigation.	Focus on disaster risk reduction, not explicitly on sustainability.	No explicit risk prioritization method.	Strong focus on BCA for risk mitigation.	Focuses on earthquake-related risks, not operational risks.	Mitigation strategies based on BCA results.	Strong focus on feasibility using BCA.
Zhang *et al.* [7]	2022	Public transportation safety risk assessment in China.	Risk grading assessment using time dimension analysis.	Limited focus on sustainability.	Risk grading based on time dimension.	No BCA used.	Focuses on public transportation safety risks.	Mitigation strategies based on risk grading.	No feasibility analysis.
Alizadeh *et al.* [36]	2022	Risk assessment in wastewater treatment using FMEA.	Fuzzy FMEA for risk assessment.	Focus on environmental risk in wastewater treatment.	Fuzzy FMEA for risk prioritization.	No BCA used.	Focuses on wastewater treatment operational risks.	Mitigation strategies based on fuzzy FMEA results.	No feasibility analysis.
Rahimi *et al.* [16]	2018	Construction project risk management using FMEA and ISO 31000.	The hybrid approach combines FMEA, ISO 31000, and evolutionary algorithms.	Limited focus on sustainability.	Evolutionary algorithms for risk prioritization.	No BCA used.	Focuses on construction project risks.	Mitigation strategies based on hybrid approach.	No feasibility analysis.
Miller *et al.* [1]	2016	General review of public transportation and sustainability.	Literature review on sustainability in public transportation.	Strong focus on sustainability in public transportation.	No explicit risk prioritization method.	No BCA used.	No specific focus on operational risks.	No specific mitigation strategies.	No feasibility analysis.
Olechowski *et al.* [8]	2016	Professionalization of risk management using ISO 31000.	ISO 31000 principles for risk management.	Limited focus on sustainability.	No explicit risk prioritization method.	No BCA used.	General focus on risk management principles.	General risk management strategies.	No feasibility analysis.
Candelieri *et al.* [30]	2019	Vulnerability of public transportation networks to cascading failures.	Network analysis for cascading failures in public transportation.	Limited focus on sustainability.	Network analysis for cascading risk prioritization.	No BCA used.	Focuses on network vulnerabilities, not operational risks.	Mitigation strategies for network vulnerabilities.	No feasibility analysis.
Ojo [2]	2020	Sustainable infrastructure for Nigeria's economic development.	Literature review and case study on sustainable infrastructure.	Strong focus on sustainability in infrastructure development.	No explicit risk prioritization method.	No BCA used.	Focuses on infrastructure risks, not operational risks.	No specific mitigation strategies.	No feasibility analysis.
This Study		Operational risk analysis in a recyclable waste-based payment public transit system in Surabaya, Indonesia.	Integrated framework using ISO 31000, FMEA, and BCA.	Strong focus on sustainability through recyclable waste-based payment system.	Uses Pareto 80:20 principle for risk prioritization.	Strong focus on BCA for evaluating risk mitigation strategies.	Strong focus on operational risks in public transportation, including HSE factors.	Tailored mitigation strategies: avoidance, mitigation, transfer, and acceptance.	Strong focus on feasibility analysis using BCA and sensitivity analysis

types of risks are mostly inherent in strategic decision/strategic initiation, and hazard risks are among the most prevalent types of risks encountered in operational risk management, encompassing occupational health and safety. This study will mainly focus on operational risk. Operational risk is the risk that could only result in negative consequences. Typically, organizations have a certain threshold of tolerance for hazard risks, which are managed within the levels acceptable to the organization. Theft is A common hazard risk many organizations face [15].

3.2. ISO 31000 risk management principles and standard

Risk Management is increasingly essential for a business. Risk management exceeds compliance with the standard requirements [13]. According to ISO 31000, risk is defined as the effect of uncertainties on objectives, while risk management is defined as a series of coordinated activities to control an organization related to risk [10]. Furthermore, ISO 31000 defines risk management as a process that encompasses six main activities: 1) communicating and consulting; 2) establishing the context, scope, and criteria; 3) assessing risk (including identifying risk, analyzing risk, and evaluating risk); 4) treating risk; 5) monitoring and reporting; and 6) recording and reporting. It constitutes a crucial component of an organization's strategic planning, requiring continual enhancement [37].

The benefits of implementing proper risk management include a solid basis for the decision-making process, a long-term view in strategic making, better financial planning, minimizing potential loss, and sustainable development of the organization [25]. Risk management can be categorized into corporate, strategic business, operational, and project risk management according to its level of implementation [38]. Risk analysis is a key element in risk management, encompassing three essential processes. However, there is no uniform definition/description of risk analysis in the ISO 31000 Standard [39]. For this reason, incorporating ISO 31000 and other methods is essential.

3.3. Failure mode and effect analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a popular risk analysis method because of its ease of implementation [40]. FMEA is regarded as an efficient tool for identifying and eliminating system failures and an important tool in safety and reliability analysis [17]. FMEA, as discussed by Bhattacharjee *et al.* [39] and Hua *et al.* [40], stands as a valuable tool to quantitatively prioritize risks from high to low, which can direct upper management to take risk prevention and control measures effectively. It is employed to evaluate risk issues based on Severity (S), Occurrence (O), and Detection (D), with their product termed as the Risk Priority Number (RPN). Traditionally, RPN is utilized to prioritize various risks within the FMEA framework, allowing for a more efficient assessment of potential risks. Due to its ease of implementation, the FMEA method has been applied in various fields, such as the shipping industry [41], wastewater treatment [36], and the manufacturing industry [42]. On its own, FMEA is incapable of modeling the uncertainty of risk assessment information, enhancing the consensus among experts, aggregating experts' risk evaluation information, and deriving reliable risk analysis results [15]. This study addressed these limitations by using a combination approach that assesses the risk occurrence value through objective and subjective evaluation. The objective value is derived from historical data, quantifying the likelihood of a risk occurring in a process, whereas the subjective value is determined through expert consensus and the utilization of weighted questionnaires. The experts are stakeholders or management of Suroboyo Bus who are involved in the business process, including the supervisor, the driver, and the helper. The weight of each stakeholder depends on the involvement and the understanding of certain business process.

3.4. Benefit-cost analysis (BCA)

Benefit-cost analysis (BCA) compares potential benefits and costs implied from a decision [43]. It serves as a crucial tool in the planning stage for evaluating decisions [44]. The BCA approach is adopted in this research because it can analyze both financial and non-financial implications of benefits and costs. The analysis includes calculating the Benefit-Cost Ratio (BCR) [45]. A decision is deemed feasible only if the BCR value is greater than 1. If the BCR value is equal to or less than 1, it indicates that the implementation of the decision needs to be reconsidered and reevaluated.

3.5. Integration of ISO 31000:2018, FMEA, and BCA

Integrating ISO 31000, FMEA, and BCA provides a more comprehensive result compared to using each tool individually. This integration offers a clear risk analysis process and enables management to compare the benefits and costs of risk treatments. Consequently, management can determine the most suitable and effective treatment to reduce organizational risk. This research applies the ISO 31000:2018 standard, complemented by the FMEA framework, to enhance the risk assessment process. The Risk Priority Number (RPN) resulting from FMEA will be used as guidance to obtain prioritized risk. This combination identifies and mitigates potential failures and their consequences within the system [38], [46]. FMEA can be categorized into system, design, and process FMEA [47]. For this study, the process FMEA was selected due to its alignment with the case study on the operational risk

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management development of Suroboyo Bus. The application of BCA in this research aims to enhance the comprehensiveness of risk response decisions, particularly in a government-managed public transportation system. It is crucial to consider socio-environmental factors that may not be fully addressed without accounting for intangible benefits. This research used BCA to identify risk treatment or risk response stages. After the suggested risk response has been given, the authors identify and calculate the tangible and intangible benefits (primary and secondary benefits) and the cost of implementing the proposed risk treatment. BCA effectively incorporates these intangible benefits, ensuring a more holistic evaluation of risk responses [25].

3.6. Methodological approach

In previous studies, incorporating business process modeling and FMEA as integral components of the risk management process has been widely adopted. In the current context, the study applies similar methodologies to organize and streamline the operational activities of Suroboyo Bus, classifying them based on the respective work units' levels. This systematic approach enables a comprehensive identification of operational risks associated with the bus service. The operational risks will serve as input for proposing risk mitigation recommendations for the Surabaya Department of Transportation (SubDOT). Notably, this study enhances the well-adopted methodological approach by introducing a feasibility study utilizing the Benefit-Cost Analysis (BCA) principle. This addition aims to assess the practicality and viability of implementing the proposed risk mitigation plan, therefore providing a more thorough and informed basis for decision-making. The flow of this research methodology is depicted in Fig. 1 (Based on ISO 31000:2018 Risk Management Standard and Process) [10].

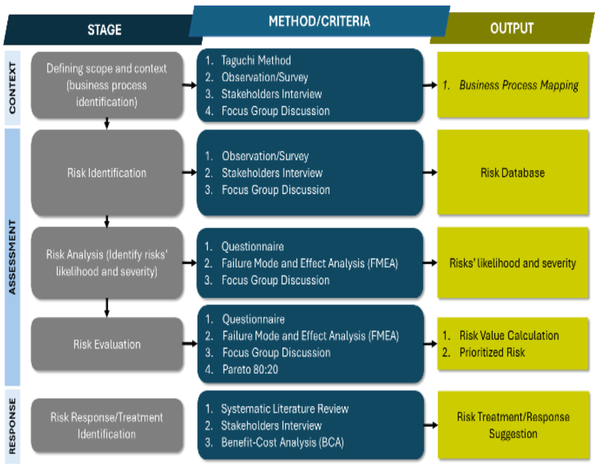

Fig. 1. Operational risk management process methodology

This study mainly consists of three activities: defining scope and context, risk assessment, and risk treatment, which consists of 5 stages. Defining scope and context commenced with business process identification combining several methods, such as observation/survey which encompasses Taguchi experiment to enhance the quality of the observation, interview, and focus group discussion with several stakeholders-the bus drivers, the supervisor, the helper, and SIUTS management in order to obtain a comprehensive depiction of the business process. The risk assessment activity consists of three stages, starting with risk identification. This stage uses the combination of observations and stakeholder interviews to obtain the risk event database from each of business processes and focus group discussion to validate the risk database. The following stage is risk analysis, which encompasses identifying risks' likelihood and severity value. It involves identifying causes and consequences for each combination through stakeholder interviews, surveys, direct observation, and historical data on Suroboyo Bus operations. Subsequently, the risk analysis utilizes the FMEA framework to categorize severity and likelihood attributes, determining values for each combination based on stakeholder input, observation, and historical data. Risk evaluation is the last step in a risk assessment activity, involving calculating risk value from the previous stage. The calculated risk values, obtained by multiplying likelihood and severity, form the basis for prioritizing risks in terms of urgency for mitigation. The prioritized risk is then chosen using the Pareto 80:20 principle. The process of recommending risk responses begins by determining treatment strategies for each risk-impact combination utilizing a systematic literature review and benchmark and evaluating their feasibility using the Benefit-Cost Analysis (BCA) approach. These recommended treatments consider compatibility and effectiveness in addressing the root causes of identified risks and their prioritization. A feasibility study using the BCA approach is conducted following the development of risk mitigation recommendations. This entails calculating the total costs and benefits associated with implementing the risk mitigation plan over a specified period. The analysis is further enhanced with sensitivity analysis, exploring various scenarios to provide a comprehensive understanding of the feasibility spectrum for the proposed risk mitigation recommendations. The criteria for sensitivity analysis is the risk treatment scenario change, which is then assessed with the implication to the benefit (reduction in severity or likelihood score). If the score changes, the Benefit-Cost Ratio has to be recalculated as a form of benefit-cost analysis.

3.7. Data collection process

The data collection process involved a

comprehensive approach, incorporating direct observation, focus group discussion, analysis of historical data, and conducting surveys and interviews with stakeholders. The authors conducted Direct observation across various facets of Suroboyo Bus operational activities, encompassing buses, bus stops, bus stations, pool points, and relevant sections within the Surabaya Department of Transportation (SubDOT). The sampling strategy involved selecting these locations based on their role in daily operations, potential risk factors, and relevance to Health, Safety, and Environment (HSE) considerations. Observations were carried out at different times of the day and across multiple routes to capture variations in operational conditions, passenger interactions, and safety practices, ensuring a comprehensive assessment of the system's overall functionality. This hands-on approach allowed the author to gather primary data on risk occurrences, travel times, and passenger movements. Simultaneously, secondary data on Suroboyo Bus operational activities were obtained through stakeholder responses to questionnaires and surveys (Table 2). Additionally, supporting and historical data were sourced from the records maintained by SubDOT.

According to Table 2, it was known that several questionnaires are utilized for collecting data method, as mentioned in Fig. 1. Questionnaire 1 is utilized in the risk identification stage, while Questionnaires 2-6 are utilized in the risk analysis stage to obtain the likelihood and severity scale, combining the objective and subjective assessment. Questionnaire 7 is used in the risk evaluation stage. The respondents who filled out the questionnaires are the Suroboyo Bus's stakeholders.

Table 2. Stakeholder survey questionnaire recapitulation

Questionnaire code	Stage	Questionnaire type	Question code	Question description	Option	Additional information
1	Risk identification	Risk validation	1-1	Is this risk valid?	Valid/not valid	If not valid,an interview must fill its reasoning
			1-2	If valid, is it ever occurred?	Ever/never occurred	
2	Risk Analysis	Likelihood scale validation	2	Is this scale valid?	Valid/not valid	If not valid,an interview must fill its reasoning
3	Risk Analysis	Severity scale validation	3	Is this scale valid?	Valid/not valid	If not valid,an interview must fill its reasoning
4	Risk Analysis	Likelihood assessment – objective	4	What central tendency best represents the actual condition?	Mean/median/ mode	
5	Risk Analysis	Likelihood assessment – subjective	5	How often did the riskoccurred?	Category 1–5 likelihood (Lowto high frequency)	
6	Risk Analysis	Severity assessment – subjective	6	How severe is the risk consequence?	Category 1–5 severity (Low to high severity)	
7	Risk Evaluation	Risk appetite validation	7	What risk level category is the likelihood–severity combination in?	Low/ Moderate/ High	

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Table 3. Taguchi design parameters of Suroboyo bus direct observation

Factors	Level		
	1	2	3
Operational Hours	06.00-09.00 or 16.00-19.00	09.00-16.00	19.00-22.00
Working Days	Monday–Thursday	Friday	Saturday and Sunday
Route	East–West	North–South	MERR
Drivers' Age	Under 40 Years Old	Older than 40 Years Old	

4. RESULTS AND DISCUSSION

4.1. Business processes and operational risks identification

Suroboyo Bus business processes can be categorized into pre-trip, bus trip, post-trip, and monitoring activities. Several documentation of Suroboyo Bus business processes can be seen in Fig. 2. The detailed identification of business processes and related risks was conducted through direct observation, analysis of historical data, and stakeholder surveys and interviews. To predict and determine the best option for the observation process, this research uses the design-of-experiment (DOE) method. Direct observation followed the principles of the Taguchi Method (Table 3), utilizing parameters such as Suroboyo Bus operational hours, working days, routes, and drivers, as shown in Fig. 3. The Taguchi experiment design is one of the more efficient DOE methods for designing and optimizing the observation process because it requires fewer trials, saving time and energy [45]. It also simplifies the analysis of the effects of each parameter level on the investigated properties [45], [48].

Fig. 2. Suroboyo bus business process (Bus trip–monitoring–post-trip)

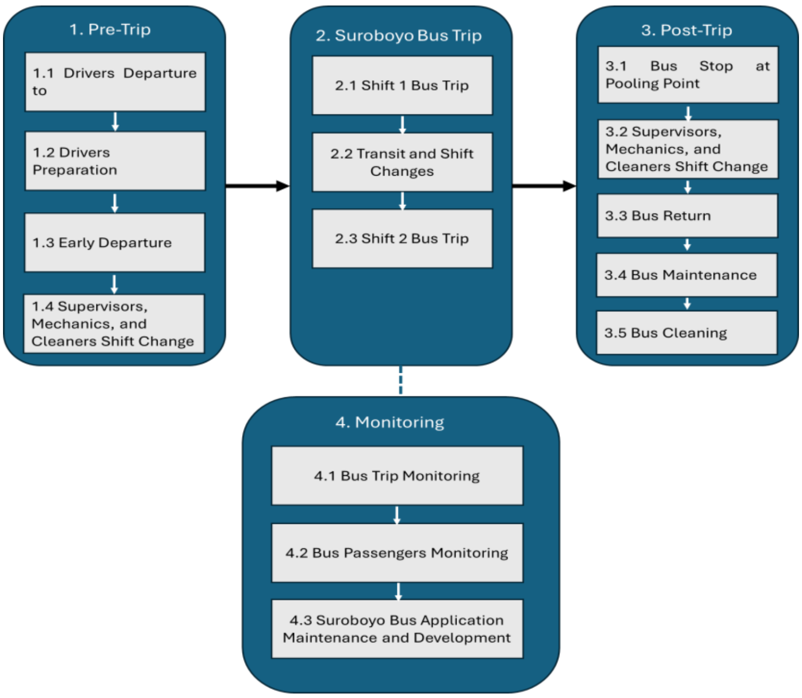

Fig. 3. Suroboyo bus business process

The structure of the Suroboyo Bus operational business process was developed through these activities using this process (Fig. 3). Every aspect of the Suroboyo Bus' operational procedures depicted in Fig. 3 was dissected into its smallest functional components. This was accomplished through a Focus Group Discussion (FGD) involving stakeholders, which consists of SIUTS management who owns and stores the historical data of GOBIS (Suroboyo Bus's digital application), the bus driver who is in charge of operating the bus, the supervisor who oversees the daily business process and the helper who is helping the bus driver in the bus's daily operations. All of the stakeholders chosen as respondents are associated with identified operational risks.

4.2. Operational risk analysis, assessment, and evaluation

Risk analysis, assessment, and evaluation were done to discern the causes and consequences of operational risks and develop a prioritized list for mitigation efforts. Adhering to the ISO 31000:2018 standard, this process established the study's context. The subsequent step involved the risk identification process (Table 4). To conduct risk analysis, assessment, and evaluation, direct observation, analysis of pertinent historical data, and surveys and interviews with stakeholders were employed. It is noteworthy that, up until 2019, Suroboyo Bus lacked a structured risk management record and historical data. Table 5 summarizes the risk analysis results, detailing the

Table 4. Operational business processes and risks

Risk count	Business process code	Business process description	Risk code	Risk description
1	1.1.1	Driver responsible for pickup activities gathered in Bungur Asih Station	R1	Driver's late arrival
2			R2	Driver's absence
3			R3	Pickup car failure
…	…	…	…	…
175	4.3	Suroboyo Bus's application development and maintenance	R112	Unstandardized application's maintenance time
176			R113	Application maintenance errors
177			R114	Error in allocating application's routine maintenance schedule
178			R19	Application error and or out of service

Table 5. Risk analysis

Risk code	Risk cause	Risk consequence code	Risk–impact combination
R1	Driver's indiscipline behavior	R1-1	Bus service delay
		R1-2	Longer passengers waiting Time
R2	Driver's indiscipline behavior	R2-1	Bus service delay
		R2-2	Longer passengers waiting time
		R2-3	Opportunity cost incurred from driver's absence
R3	Incorrect maintenance procedure	R3	Bus service delay
…	…	…	…
R112	Incompetent computer technician	R112-1	Customer's complaint and bad reputation in the media
	Inadequate and unstandardized application maintenance facility	R112-2	Staff's complaint
		R112-3	Loss of data needed for decision making process
R113	Incompetent computer technician	R113-1	Customer's complaint and bad reputation in the media
		R113-2	Staff's complaint
	Error in doing problem identification process for the application	R113-3	Loss of data needed for decision making process
		R113-4	Unexpected additional cost
R114	Computer technician's negligence	R114-1	Customer's complaint and bad reputation in the media
		R114-2	Staff's complaint
		R114-3	Loss of data needed for decision making process

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impact combinations for each risk event identified (Table 4). For example, risk code R1 Driver's indiscipline behavior could lead to two different risk impact combinations, which are R1-1 bus service delay and R1-2 longer passenger waiting time. The risk analysis process seamlessly integrated identified operational risks from the previous phase with the outcomes of the data collection process (Table 5).

The risk assessment process involved merging the outcomes of risk analysis with the findings from the stakeholder survey and interviews to validate and assess severity and likelihood. Severity and likelihood values were determined using a combination of subjective and objective approaches, depending on their applicability to the associated risks. For instance, an objectively calculated risk likelihood was determined by analyzing non-operating buses using statistical methods on Suroboyo Bus historical data from March to November 2019, considering measures such as central tendencies (modes and mean), minimum and maximum values, and standard deviation (Table 6) Meanwhile, a subjectively calculated risk likelihood, like the probability of drivers being late to the park and ride or shelter, relied on interviews and surveys with Suroboyo Bus stakeholders and experts due to the absence of recorded data. This study divides severity into several categories adopted from COSO, determined from the discussion, and validated by Suroboyo Bus stakeholders. The severity category is divided into bus services, employees' health and safety, finance, budget dissipation, customers' health and safety, customer service & reputation, workers' satisfaction, administration, and passengers' waiting time. The outcomes of both approaches yielded severity, likelihood, and overall risk values, as illustrated in the Table. 7.

Risk evaluation involved combining risk assessment results with the calculation of risk values, insights obtained from stakeholder surveys and interviews for validating risk appetite, and the implementation of the Pareto principle. Risk values were computed by multiplying severity and likelihood value, while the stakeholder survey and interview outcomes formed the basis for determining Suroboyo Bus management's risk appetite and corresponding risk level categories. The risk values obtained and summarized in Table 7 will then be sorted based on highest to lowest values, and the cumulative percentage value will be calculated. This cumulative percentage value will be used to determine the risk priority value. Risk priority determination is carried out using the Pareto 80:20 principle. The Pareto principle suggests that roughly 80% of consequences arise from 20% of significant causes [49]. The prioritization results indicate that Suroboyo Bus should focus on operational risks with a risk value of 12 or higher (Table 8).

4.3. Risk mitigation formulation and benefit–cost calculation

Risk mitigation formulation developed according to risk analysis, assessment, and evaluation results. The risk mitigation recommendations encompass four distinct types of risk treatment: avoidance, mitigation, transfer, and acceptance. Within these recommendations, specific treatments for each combination were determined based on the risk level category and their effectiveness in addressing the root cause of the risk. The avoidance, mitigation, and transfer approaches were exclusively applied to prioritized risks, while non-prioritized risks were all addressed through the acceptance policy. The details of this process are illustrated in Table 10. Subsequently, a feasibility study was conducted to assess the viability of the risk mitigation recommendations using the Benefit-Cost Analysis (BCA) approach and the sensitivity analysis principle over two years, starting in 2020. The BCA approach involved determining and calculating the various components of benefits and costs associated with the recommendations. Costs were divided into capital and operational expenditures, while benefits were categorized into primary and secondary benefits based on their financial impact. This analysis included a literature review of benchmarked objects and direct interviews with Suroboyo Bus stakeholders.

Table 6. Objectively calculated risk likelihood example – non-operating buses

Analysis parameter	Variable	Value
Mean	Non-operating buses	4
	%Non-operating buses	19%
Modes	Non-operating buses	2
	% Non-operating buses	10%
Maximum	Non-operating buses	9
	% Non-operating buses	45%
Minimum	Non-operating buses	1
	% Non-operating buses	5%
Standard Deviation	Non-operating buses	2
	% Non-operating buses	9%

Table 7. Risk assessment and Risk value calculation

Risk code	Risk–impact combination code	Severity			Likelihood	Risk Value
		Severity category	Description	Value	Value	
R1	R1-1	Bus service	Subjective	1	1	1
	R1-2	Passengers waiting time	Subjective	3		3
R2	R2-1	Bus service	Subjective	1	5	5
	R2-2	Passengers waiting time	Subjective	5		25
	R2-3	Budget dissipation	Objective	3		15
R3	R3	Bus service	Subjective	1	1	1
…	…	…	…	…	…	…
R112	R112-1	Customer service and reputation	Subjective	2	1	2
	R112-2	Worker's satisfaction	Subjective	3		3
	R112-3	Administrative	Subjective	3		3
R113	R113-1	Customer service and reputation	Subjective	2	1	2
	R113-2	Worker's satisfaction	Subjective	3		3
	R113-3	Administrative	Subjective	3		3
	R113-4	Finance	Subjective	2		2
R114	R114-1	Customer service and reputation	Subjective	2	1	2
	R114-2	Worker's satisfaction	Subjective	3		3
	R114-3	Administrative	Subjective	3		3

Table 8. Risk assessment and risk value calculation

Risk–Impact combination code	Risk value	Cumulative risk value		Risk level category	risk prioritization
		Value	%		
R2-2	25			High	Prioritized risks
R5-2	25			High	
R27-1	20			High	
…	…			…	
R18-1	12	12	2.63%	Moderate	
R18-2	12	24	5.26%	Moderate	
R45-1	12	36	7.89%	Moderate	
…	…	…	…	…	
R101-1	12	144	31.58%	Moderate	
…	…	…	…	…	Non-prioritized risks
R114-3	3	456	100.00%	Moderate	
…	…			…	
R89	1			Low	
R91-2	1			Low	
R98	1			Low	

a sensitivity analysis was performed, considering changes in the impact of the recommendation's benefits. The scenarios developed for this analysis involved varying the potential total benefits resulting from the recommendation while keeping the potential total costs constant, using the formula of Total Benefit divided by Total Cost. The outcomes of this analysis are presented in Table 10 and Table 11.

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Table 9. Risk mitigation analysis

Risk–impact combination code	**Risk value**	**Risk level category**	**Risk mitigation**	
			Type	**Risk treatment**
R2-2	25	High	Avoid	Changes to driver arrival procedure (straight to Tambak Oso Wilangun Station)
R5-2	25	High	Mitigate	Comprehensive performance appraisal system implementation
R27-1	20	High	Avoid	QR code scanner and ticker printer facilities procurement
…	…	…	…	…
R55	12	Moderate	Mitigate	Implementation of the exclusive bus lanes policy for the Surabaya public road
			Mitigate	Develop the estimated travel time and bus arrival schedule through the GoBis application.
R61	12	Moderate	Mitigate	Conducting a digital marketing effort to promote Suroboyo Bus
			Mitigate	Conducting socialization activities to promote Suroboyo Bus public transportation service
			Mitigate	Improvement of the Suroboyo Bus operation business processes
			Mitigate	Procurement of new buses to increase the number of Suroboyo Bus fleet
R101-1	12	Moderate	Mitigate	Construction of a canopy to cover the bus cleaning area

4.4. Discussion

The study results include identifying operational business processes and related risks, the risk profile, risk mitigation recommendations, and the feasibility of implementing Suroboyo Bus operational activities. As highlighted in Section 3.1, Suroboyo Bus's operational business processes are divided into pre-trip, bus trip, post-trip, and monitoring activities. Pre-trip, post-trip, and monitoring activities are managed by Suroboyo Bus staff and stakeholders and involve preparation and daily service execution. The associated risks primarily originate from internal stakeholders of the Surabaya City Transportation Department, specifically operational staff, due to the absence of detailed Standard Operating Procedures (SOP) and insufficient facilities and skilled workforce. Conversely, bus trip activities involve external sources, predominantly passengers, contributing to operational risks. These risks stem from similar deficiencies in SOPs, facilities, and skilled workers, with additional contributions from passenger negligence and a lack of understanding of Health, Safety, and Environment (HSE) procedures. 114 operational risks were identified across all Suroboyo Bus operational business processes.

Suroboyo Bus's operational activities' risk profile was developed through risk analysis, assessment, and evaluation processes. Risk analysis provided a detailed breakdown of risk causes and consequences, resulting in 189 risk–impact combinations. Risk assessment determined each combination's likelihood and severity values, forming the basis for calculating risk values in the evaluation process. Notably, reputation and customer service, bus service, and administrative factors emerged as the most affected severity components. Risk evaluation led to the prioritization of risks based on their values and level categories, categorizing 14.81% as high risk, 46.56% as moderate risk, and 38.62% as low risk. Following the Pareto principle, the top 20% of risks were prioritized, resulting in 81 prioritized risks, including 47 high-risk and 34 moderate risk–impact combinations. The highest prioritized risks centred around the absence of Suroboyo Bus staff, potentially leading to significant increases in passenger waiting times. This underscores the need for improved public transportation management and service from a customer service perspective.

Risk mitigation recommendations were developed from the aforementioned processes, with treatments categorized according to risk level and effectiveness in addressing root causes. Specifically, avoidance, mitigation, and transfer treatments were exclusively applied to prioritized risks for cost efficiency, while non-prioritized risks were addressed through acceptance. As the top priority, avoidance aims to eliminate risks and their consequences, but its implementation is limited due to operational, financial, and social constraints. Mitigation, the most applicable treatment type, focuses on reducing the likelihood, severity, or both aspects of related risks. The results showed a distribution of 5.07% for avoidance, 31.80% for mitigation, 0.46% for transfer, and 62.67% for acceptance in the risk mitigation recommendations.

The feasibility decision for risk mitigation recommendations employed the Benefit-Cost Analysis (BCA) approach and sensitivity analysis principles, considering a two-year planning period from 2020 to 2021. Implied benefits and costs were derived from literature reviews and direct interviews with Suroboyo Bus stakeholders. Costs, including capital and operational expenditures, remained constant, totalling IDR 19,103,960,000. Benefits, comprising primary

Table 10. Benefit–cost identification for risk mitigation recommendations

No	Cost components		Benefit components	
	Capital expenditure	**Operational expenditure**	**Primary benefit**	**Secondary benefit**
1	Canopy construction cost	Routine digital marketing cost	Budget reduction for heavy tire maintenance	Worker's turnover rate reduction
2	Road marking cost	Bus condition examination checklist form procurement cost	Budget reduction for light tire maintenance	Increasing the number of customers served
3	Website development cost	Fuel refill checklist form procurement cost	Budget reduction for heavy Suroboyo Bus facilities maintenance	Productivity improvement through better decision making
4	Bus stop moving cost	Routine server maintenance cost	Budget reduction for heavy machine and or spare part maintenance	Productivity improvement through passenger trust
5	General bus repair tools procurement cost	Reserve helper overtime cost	Budget reduction forlight machine and or spare part maintenance	
6	Handheld QR code scanner and ticket printer device procurement cost	Announcement postersand stickers printing cost	Budget dissipation reduction for driver-related cost	
7	Pedestrian sign procurement cost for Tambak Oso Wilangun station	Routine bus tire maintenance cost	Budget dissipation reduction for helper-related cost	
8	Cleaning service's Safety equipment procurement cost	Routine Suroboyo Bus facilities maintenance cost	Budget dissipation reduction for supervisor-related cost	
9	Vending machine procurement cost	Routine bus machine maintenance cost	Budget dissipation reduction for cleaner-related cost	
10	Integrated database system development cost	Socialization cost	Budget dissipation reduction for mechanic-related cost	
11	GoBis application upgrade cost	Driver training cost		
12	Server upgrade cost	Helper training cost		
13	SIUTS server expert recruitment cost	Server expert salary expense		
14	Zebra cross marking cost			
15	Bus procurement cost			
16	SOP development cost			

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Table 11. Feasibility decision result

Scenario no.	Total benefits	Total costs	BCR	Decision
1	IDR 28,108,394,400	IDR 19,103,960,000	1.471	Feasible
2	IDR 27,706,920,100	IDR 19,103,960,000	1.450	Feasible
3	IDR 27,706,920,100	IDR 19,103,960,000	1.450	Feasible
4	IDR 26,994,485,800	IDR 19,103,960,000	1.413	Feasible
5	IDR 26,994,485,800	IDR 19,103,960,000	1.413	Feasible
6	IDR 19,885,577,200	IDR 19,103,960,000	1.041	Feasible

financial and secondary non-financial benefits, varied across scenarios from IDR 19,885,577,200 to IDR 28,108,394,400. The Benefit-Cost Ratios (BCRs) for all scenarios ranged from 1.041 to 1.471, indicating the feasibility of the proposed risk mitigation recommendations across the covered conditions. This implies that decision sensitivity is not significant within the scope of this research.

The integration of the aforementioned method, ISO 31000:2018, FMEA and BCA are proven to provide a comprehensive analysis and solution, encompassing a feasibility study to help the decision maker. Moreover, the results of this research could be applied to other transportation systems that have similar business processes. However, the result of this research will be valid and relevant, as long as there is no change in business process and policy related to Suroboyo Bus's management.

5. CONCLUSION

The primary objectives of this research were: (1) to identify operational risks within the Suroboyo Bus system, (2) to formulate a risk profile for Suroboyo Bus through a comprehensive risk analysis, assessment, and evaluation processes, (3) to propose risk mitigation recommendations as the foundation for managing operational risks in Suroboyo Bus, and (4) to assess the feasibility of implementing these recommendations by considering the associated benefit and cost aspects. The research revealed the existence of 114 distinct operational risks across 70 different business processes within the Suroboyo Bus system. These risks were further detailed in 189 risk–impact combinations based on the outcomes of the risk analysis.

Applying the ISO 31000:2018 standard and FMEA framework in the risk analysis and assessment processes, the research identified nine severity factors and 22 likelihood factors utilized to determine the risk level. The severity and likelihood values were then employed to calculate the risk value for each risk–impact combination, resulting in 14.81%classified as high risk, 46.56% as moderate risk, and 38.62% as low risk. Subsequently, risk prioritization was conducted based on a policy that prioritizes the high-risk category and includes 30% of the moderate-risk category with the highest cumulative risk value, prioritizing 47 high risk–impact combinations and 34 moderate–risk–impact combinations for mitigation.

The developed risk mitigation recommendations encompassed all risk–impact combinations, with implementation prioritized according to the result of the risk prioritization process. The risk mitigation types for the prioritized risk–impact combinations were categorized into avoid (5.07%), mitigate (62.67%), and transfer (0.46%), while the remaining 31.80% employed an accept-type risk mitigation policy for all non-prioritized risk–impact combinations. Lastly, a benefit-cost analysis was conducted with six different scenarios, employing a sensitivity analysis principle for benefit factors. The resulting benefit-cost ratio ranged from 1.041 to 1.471, indicating the feasibility of implementing the proposed risk mitigation recommendations under the conditions covered by these scenarios.

As a result of the study, the Surabaya Department of Transportation (SubDOT) has undertaken several mitigation efforts to address the identified risks and operational deficiencies. The first mitigation strategy involves introducing a more comprehensive fare payment method. Transit riders are no longer restricted to using recyclable waste as payment but are now able to pay via cash or cashless methods. This expanded payment option increases the convenience and accessibility of the transit system, thereby boosting utilization and laying the groundwork for a more sustainable business model. Additionally, measures have been taken to ensure appropriate storage for recyclable plastic payments. Plastic waste is no longer haphazardly stored within the passenger cabin but is collected according to standard operating procedures at designated stations. It is then gathered weekly by waste management personnel, mitigating safety and sanitation concerns. These initial risk mitigation efforts have been implemented and will continue to be monitored to assess their effectiveness and make further improvements as necessary.

Furthermore, the risk analysis and mitigation strategies employed for Suroboyo Bus in Surabaya can serve as a valuable model for evaluating public transit systems in other cities within developing countries as well as a framework for a proper evaluation of innovative efforts to make public transit more accessible. The emphasis on integrating Health, Safety, and Environment (HSE) factors underscores the importance of holistic planning for sustainable and community-friendly public transportation. The challenges faced by Suroboyo Bus, such as the absence of detailed SOPs, short-sighted strategies and planning, and a shortage of skilled personnel, are common issues encountered by many public transit systems in similar settings. The comprehensive risk analysis conducted in this research provides a structured approach that can be adapted and applied to assess the operational risks of public transit systems in other developing urban areas.

The prioritization and categorization of risks and subsequent development of risk mitigation recommendations offer a systematic framework that can be customized to address the specific needs and challenges of diverse public transportation networks in comparable socio-economic contexts. By sharing insights and methodologies drawn from the Suroboyo Bus case study, this research contributes to the broader discourse on enhancing the resilience and effectiveness of public transit systems in developing countries. While this research provides valuable insights, it acknowledges areas for improvement in future studies. Subsequent research should consider developing a complementary risk management study of Suroboyo Bus's strategic activities with a more comprehensive and complete dataset. Additionally, future investigations should incorporate the calculation of apparent benefit and cost components and a more in-depth analysis of non-financial benefits associated with the risk mitigation recommendations to enhance the feasibility analysis.

REFERENCES

[1] P. Miller, A. G. de Barros, L. Kattan, and S. C. Wirasinghe, "Public transportation and sustainability: A review," *KSCE J. Civ. Eng.*, vol. 20, no. 3, pp. 1076–1083, Apr. 2016, doi: 10.1007/s12205-016-0705-0.

[2] A. E. Ojo, "Sustainable infrastructure for Nigeria's sustainable economic development: whither transportation or electric power supply?," *J. Mega Infrastruct. Sustain. Dev.*, vol. 2, no. 3, pp. 248–261, Nov. 2020, doi: 10.1080/24724718.2021.2012364.

[3] Z. Ma, C. Shao, S. Ma, and Z. Ye, "Constructing road safety performance indicators using Fuzzy Delphi Method and Grey Delphi Method," *Expert Syst. Appl.*, vol. 38, no. 3, pp. 1509–1514, Mar. 2011, doi: 10.1016/j.eswa.2010.07.062.

[4] Y. Shiomi, K. Watanabe, H. Nakamura, and H. Akahane, "Assessing Safety of Signalized Intersections: Influence of Geometric Attributes and Regionality on Traffic Accident Risk," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2659, no. 1, pp. 71–79, Jan. 2017, doi: 10.3141/2659-08.

[5] M. Hosseinpour, A. S. Yahaya, S. M. Ghadiri, and J. Prasetijo, "Application of Adaptive Neuro-fuzzy Inference System for road accident prediction," *KSCE J. Civ. Eng.*, vol. 17, no. 7, pp. 1761–1772, Nov. 2013, doi: 10.1007/s12205-013-0036-3.

[6] M. Gebremichael *et al.*, "Prevalence and determinants of road traffic injuries in Ethiopia: Based on the 2015 STEPS survey findings," *Ethiop. J. Heal. Dev.*, vol. 31, no. 1, pp. 340–347, 2017, [Online]. Available: https://www.ajol.info/index.php/ejhd/article/view/167824

[7] J. Zhang, Y. Tu, J. Liu, L. Liu, and Z. Li, "Regional public transportation safety risk grading assessment under time dimension: A case study of Chinese mainland," *Transp. Policy*, vol. 126, pp. 343–354, Sep. 2022, doi: 10.1016/j.tranpol.2022.08.003.

[8] A. Olechowski, J. Oehmen, W. Seering, and M. Ben-Daya, "The professionalization of risk management: What role can the ISO 31000 risk management principles play?," *Int. J. Proj. Manag.*, vol. 34, no. 8, pp. 1568–1578, Nov. 2016, doi: 10.1016/j.ijproman.2016.08.002.

[9] International Organization for Standardization, *ISO 31000:2009*. Geneva, 2009. [Online]. Available: https://www.iso.org/standard/43170.html

[10] International Standard Organization, "ISO 31000:2018 Risk Management – Guidelines," 2018. [Online]. Available: https://www.iso.org/iso-31000-risk-management.html

[11] K. de Bakker, A. Boonstra, and H. Wortmann, "Does risk management contribute to IT project success? A meta-analysis of empirical evidence," *Int. J. Proj. Manag.*, vol. 28, no. 5, pp. 493–503, Jul. 2010, doi: 10.1016/j.ijproman.2009.07.002.

[12] A. Geramian, A. Shahin, B. Minaei, and J. Antony, "Enhanced FMEA: An integrative approach of fuzzy logic-based FMEA and collective process capability analysis," *J. Oper. Res. Soc.*, vol. 71, no. 5, pp. 800–812, May 2020, doi: 10.1080/01605682.2019.1606986.

[13] M. Hekmatpanah, A. Shahin, and N. Ravichandran, "The application of FMEA in the oil industry: The case of four litre oil canning process," *African J. Bus. Manag.*, vol. 5, no. 8, pp. 3019–3027, 2011, [Online]. Available: https://academicjournals.org/journal/AJBM/article-abstract/96A7F0C30642

[14] X. Qu, Q. Meng, V. Yuanita, and Y. H. Wong, "Design and implementation of a quantitative risk assessment software tool for Singapore

 http://dx.doi.org/10.30656/jsmi.v9i1.10203

road tunnels," *Expert Syst. Appl.*, vol. 38, no. 12, pp. 14664–14675, May 2011, doi: 10.1016/j.eswa.2011.04.186.

[15] P. Liu, M. Shen, and Y. Geng, "Risk assessment based on failure mode and effects analysis (FMEA) and WASPAS methods under probabilistic double hierarchy linguistic term sets," *Comput. Ind. Eng.*, vol. 186, p. 109758, Dec. 2023, doi: 10.1016/j.cie.2023.109758.

[16] Y. Rahimi, R. Tavakkoli-Moghaddam, S. H. Iranmanesh, and M. Vaez-Alaei, "Hybrid Approach to Construction Project Risk Management with Simultaneous FMEA/ISO 31000/Evolutionary Algorithms: Empirical Optimization Study," *J. Constr. Eng. Manag.*, vol. 144, no. 6, Jun. 2018, doi: 10.1061/(ASCE)CO.1943-7862.0001486.

[17] P. Hopkin, *Fundamentals of Risk Management: Understanding, Evaluating, and Implementing Effective Risk Management*. Croydon, UK: Institute of Risk Management, 2017. [Online]. Available: https://books.google.co.id/books?id=NznCjwEACAAJ&dq

[18] J. M. Juran and J. A. Defeo, *Juran's Quality Handbook: The Complete Guide to Performance Excellence*. New York, NY: McGraw-Hill, 2010. [Online]. Available: https://books.google.co.id/books?id=JPCz0LoMnLsC&q

[19] R. Miller and D. Lessard, "Understanding and managing risks in large engineering projects," *Int. J. Proj. Manag.*, vol. 19, no. 8, pp. 437–443, Nov. 2001, doi: 10.1016/S0263-7863(01)00045-X.

[20] R. Dunford, Q. Su, E. Tamang, and A. Wintour, "The Pareto principle," *Plymouth Student Sci.*, vol. 7, no. 1, pp. 140–148, 2014, [Online]. Available: https://pearl.plymouth.ac.uk/cgi/viewcontent.cgi?article=1272&context=tpss

[21] I. Ben-David and T. Raz, "An integrated approach for risk response development in project planning," *J. Oper. Res. Soc.*, vol. 52, no. 1, pp. 14–25, Jan. 2001, doi: 10.1057/palgrave.jors.2601029.

[22] P. X. W. Zou, G. Zhang, and J. Wang, "Understanding the key risks in construction projects in China," *Int. J. Proj. Manag.*, vol. 25, no. 6, pp. 601–614, Aug. 2007, doi: 10.1016/j.ijproman.2007.03.001.

[23] Y. Zhang and Z.-P. Fan, "An optimization method for selecting project risk response strategies," *Int. J. Proj. Manag.*, vol. 32, no. 3, pp. 412–422, Apr. 2014, doi: 10.1016/j.ijproman.2013.06.006.

[24] A. Bosque and F. Schaffner, "Communicating environmental risks in developing countries," in *Environmental and Human Health*, CRC Press, 2010, pp. 27–42. doi: 10.1201/b10540-7.

[25] M. C. Hoyos and V. Silva, "Exploring benefit cost analysis to support earthquake risk mitigation in Central America," *Int. J. Disaster Risk Reduct.*, vol. 80, p. 103162, Oct. 2022, doi: 10.1016/j.ijdrr.2022.103162.

[26] BPS, "Proyeksi Penduduk Kabupaten Kota Provinsi jawa timur 2015-2025," 2019. [Online]. Available: https://jatim.bps.go.id/publication/2019/04/17/12197434047d37c17efe921e/proyeksi-penduduk-kabupaten-kota-provinsi-jawa-timur-2015-2025--hasil-supas2015-.html

[27] J. Farrington and C. Farrington, "Rural accessibility, social inclusion and social justice: towards conceptualisation," *J. Transp. Geogr.*, vol. 13, no. 1, pp. 1–12, Mar. 2005, doi: 10.1016/j.jtrangeo.2004.10.002.

[28] J. McDonagh, "Transport policy instruments and transport-related social exclusion in rural Republic of Ireland," *J. Transp. Geogr.*, vol. 14, no. 5, pp. 355–366, Sep. 2006, doi: 10.1016/j.jtrangeo.2005.06.005.

[29] R. Cascajo and A. Monzon, "Assessment of innovative measures implemented in European bus systems using key performance indicators," *Public Transp.*, vol. 6, no. 3, pp. 257–282, Oct. 2014, doi: 10.1007/s12469-014-0085-0.

[30] A. Candelieri, B. G. Galuzzi, I. Giordani, and F. Archetti, "Vulnerability of public transportation networks against directed attacks and cascading failures," *Public Transp.*, vol. 11, no. 1, pp. 27–49, Jun. 2019, doi: 10.1007/s12469-018-00193-7.

[31] A. Imaz, K. M. Nurul Habib, A. Shalaby, and A. O. Idris, "Investigating the factors affecting transit user loyalty," *Public Transp.*, vol. 7, no. 1, pp. 39–60, Mar. 2015, doi: 10.1007/s12469-014-0088-x.

[32] A. S. Mikhaylov, I. S. Gumenuk, and A. A. Mikhaylova, "Russian public transport system: the customers' feedback on the service provision," *Public Transp.*, vol. 8, no. 1, pp. 125–141, Mar. 2016, doi: 10.1007/s12469-015-0111-x.

[33] U. R. de Oliveira, F. A. S. Marins, H. M. Rocha, and V. A. P. Salomon, "The ISO 31000 standard in supply chain risk management," *J. Clean. Prod.*, vol. 151, pp. 616–633, May 2017, doi: 10.1016/j.jclepro.2017.03.054.

[34] E. Evinia and M. N. N. Sitokdana, "Risk Management Based IT Analysis Using ISO 31000 (Case Study: PT Bawen Mediatama)," *J.*

Inf. Syst. Informatics, vol. 5, no. 1, pp. 380–390, Mar. 2023, doi: 10.51519/journalisi.v5i1.420.

[35] P. Liu, Y. Wu, Y. Li, and X. Wu, "An improved FMEA method based on the expert trust network for maritime transportation risk management," *Expert Syst. Appl.*, vol. 238, p. 121705, Mar. 2024, doi: 10.1016/j.eswa.2023.121705.

[36] S. S. Alizadeh, Y. Solimanzadeh, S. Mousavi, and G. H. Safari, "Risk assessment of physical unit operations of wastewater treatment plant using fuzzy FMEA method: a case study in the northwest of Iran," *Environ. Monit. Assess.*, vol. 194, no. 9, p. 609, Sep. 2022, doi: 10.1007/s10661-022-10248-9.

[37] Institute of Risk Management, *A Risk Practitioners Guide to ISO 31000:2018*. IRM, 2018. [Online]. Available: http://www.demarcheiso17025.com/document/A Risk Practitioners Guide to ISO 31000 %96 2018.pdf

[38] T. Merna and F. F. Al-Thani, *Corporate Risk Management*. Wiley, 2008. [Online]. Available: https://books.google.co.id/books?id=yow0EAAAQBAJ

[39] P. Bhattacharjee, V. Dey, and U. K. Mandal, "Failure Mode and Effects Analysis (FMEA) using interval number based BWM—MCDM approach: Risk Expected Value (REV) method," *Soft Comput.*, vol. 26, no. 22, pp. 12667–12688, Nov. 2022, doi: 10.1007/s00500-022-07264-9.

[40] Z. Hua, X. Jing, and L. Martínez, "An ELICIT information-based ORESTE method for failure mode and effect analysis considering risk correlation with GRA-DEMATEL," *Inf. Fusion*, vol. 93, pp. 396–411, May 2023, doi: 10.1016/j.inffus.2023.01.012..

[41] B. O. Ceylan, "Shipboard compressor system risk analysis by using rule-based fuzzy FMEA for preventing major marine accidents," *Ocean Eng.*, vol. 272, p. 113888, Mar. 2023, doi: 10.1016/j.oceaneng.2023.113888.

[42] H. Reda and A. Dvivedi, "Decision-making on the selection of lean tools using fuzzy QFD and FMEA approach in the manufacturing industry," *Expert Syst. Appl.*, vol. 192, p. 116416, Apr. 2022, doi: 10.1016/j.eswa.2021.116416.

[43] K. A. bin Abdullah, J. bin M. Rohani, and M. S. bin Ngadiman, "Development of FMEA information system for manufacturing industry," in *3rd International Conference on Modeling and Analysis of Semiconductor Manufacturing*, Johor, 2005. [Online]. Available: https://www.researchgate.net/publication/260052683

[44] P. Thomas, R. B. Bratvold, and B. J. Eric, "The Risk of Using Risk Matrices," in *SPE Annual Technical Conference and Exhibition*, SPE, Sep. 2013. doi: 10.2118/166269-MS.

[45] G. Shively, "An overview of benefit-cost analysis," 2012, [Online]. Available: https://www.researchgate.net/publication/255661807

[46] P. Schueler and B. Buckley, *Re-Engineering Clinical Trials*. Elsevier, 2015. doi: 10.1016/C2013-0-09871-4.

[47] M. von Rosing and J. Erasmus, "Variation in Business Processes," in *The Complete Business Process Handbook*, M. Von Rosing and J. Erasmus, Eds., Elsevier, 2015, pp. 459–478. doi: 10.1016/B978-0-12-799959-3.00022-7.

[48] G. de Rus, *Introduction to Cost-Benefit Analysis: Looking for Reasonable Shortcuts*. Edward Elgar, 2021. [Online]. Available: https://books.google.co.id/books?id=WRBJacb0-40C

[49] M. Bonet, "Ley de Pareto aplicada a la fiabilidad," *Ing. Mecánica*, vol. 8, no. 3, pp. 1–9, 2005, [Online]. Available: https://www.redalyc.org/articulo.oa?id=225118188010