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RESEARCH ARTICLE

IMARA: A New Approach to Multi-Attribute Risk Assessment Based on Event Data Weighting (Case Study in a Container Terminal)

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ABSTRACT Many examples tell us that organizations' well-being should be laid upon risk assessments. Typical risk assessments, on the other hand, which produce a list of risk scenarios, more often than not, do not result in enough information for mitigations when it comes to resource limitations such as financial, time, or in this case: delays. Multi-attribute risk assessments give a solid foundation to develop systematic quantitative risk measurements that organizations can use for security mitigations. This study proposes a multi-level and multi-attribute risk assessment method that can be used to prepare mitigations in organization-wide or specific sections of a company. This study presents the evaluation process and results from a case study of a container terminal to evaluate delay risks in its dwelling time processes and to prepare requirements on mitigations based on the risk projections. The proposed method in this study mainly operates within the risk evaluation stage in the risk management lifecycle to complement other methods such as FMEA, FTA, and DEMATEL, which mainly operate within the risk identification and risk analysis stages of risk management. The evaluations in this case study address the efficiency of business process risk factors in a container terminal, not the safety-related risk factors. The proposed method takes event logs from information systems as input to evaluate the risk performances by computing the attributes of the event data. The method also offers risk projections to be treated as a reference to plan for mitigations and determine the likelihood of risk factors. The evaluation results from this case study have provided insights for operation managers and management to perceive and address risks within TPS Surabaya container terminal's business processes. The proposed method is called Improved Multi-Attribute Risk Assessment (IMARA.)

INDEX TERMS Risk assessment, multi-attribute, container terminal, risk evaluation, risk projection.

I. INTRODUCTION

The Concepts of risk management and risk assessment have been around for more than 2400 years since the Athenians were known to advise risk calculations before making decisions [1]. Nevertheless, risk management and risk assessment as science are relatively young. It was not more than 40 years since the first studies discussing the fundamentals and principles of the subjects have been published [2]. According to [3] risk management is the

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process to identify, quantify, and respond to the risk without impacting the objectives. Another research paper [4] also similarly argues that risk management relates to the process of identifying, analyzing, and responding to risk factor during project implementation. However, today's general perspective on risk management tends to align with what Dinsmore and Cabanis-Brwein argued in [5] that the concerns of risk management is on conducting risk identification, analysis, monitoring, and control.

On the other hand, risk assessment, which is a part of the risk management activity chain, is an overall process to identify, analyze, and evaluate risks according to [6]. Risk assessment influences probable risks, their likelihoods and impacts, and acceptance of the risks [7]. Risk assessment focuses on evaluating risks where the uncertainties and unexpected are objectively considered. This includes risks identifications, risks consequences, risks probability, and the tolerability of the assumed risks [8].

Risks in port terminals are categorized as state risk, social risk, operational risk, environmental risk, financial risk, commercial risk, and monetary risk [9]. Basel II Capital Accord defines operational risk as the risk of loss arising from the failure or inadequacy of internal processes, human, external systems or events. Operational risks arise due to poor work culture, lack of management oversight, errors, malice, fraud, poor occupational safety and health, failure to meet environmental requirements, physical disaster, and weak internal control [10]. Operational risks in port terminals mostly include the dwelling time processes.

Dwelling time plays crucial role in determining a port terminal performance. According to [11], dwelling time is the entire time a container waits in one or more port terminal stacks. Similarly, [12] defined dwelling time as the total time a container spends between the unloading to the leaving in a port terminal. Hummels, explained that if dwelling time can be managed to be shorter, then port terminals would store fewer containers (no congestion), which enables the port terminal to accommodate much more transactions [13]. Dwelling time is influenced by many factors; one of the factors is the port operation processes.

Many studies discussed risk management in port terminal using certain frameworks and methodologies to address the issue of operational risk. However, Most of the studies focused on the health and safety risk factors in port terminal operations. Only a few discuss risks from the process perspective. The case study of this paper focuses on the operational risks of dwelling time in a port terminal, i.e., TPS Surabaya, Indonesia, from the process perspective. This study offers a new method primarily to evaluate and secondarily identify and analyze risks using mainly event data (event logs) from information systems. The proposed method in this study mainly operates on the risk evaluation stage in the risk management lifecycle. This proposed new technique aims to complete and complement the other frequently used risk assessment methods, which operate mainly on risk identification and analysis stages.

Conventional risk assessments that include financial loss calculation more often than not miss the quintessence of the hidden threats. It is frequently challenging for a container terminal operator to calculate the loss of a delayed dwelling time to its finances and reputation. Nevertheless, this loss to the operator's reputation could be far more harmful to the company than the actual financial loss caused by the delays in dwelling time. This outlook is further convoluted when the impact and likelihood of the delays are unpredictable.

Risk assessments that take into account attributes which are not normally included in conventional assessments offer many benefits. In particular, multi-attribute risk assessments let managers identify their operational risks, express their opinions about the severity of the impacts of certain risks, and put forward their point of view about how the unpredictability of risk can affect the risk mitigation priorities. Into the bargain, multi-attribute risk assessments bring forth structured and adaptable frameworks for calculating a company's threats utilizing the already available risk information. Because operational managers have access to the best threat information, the risk assessment method can easily be adapted to new event data, and the changes in their risk mitigation strategy can be adjusted. The benefit of a multi-attribute risk assessment is not limited to the quantifications it produces but also in the apprehension that the operation managers obtain during the identification and analysis stages in the risk management process [14].

This study is based on event data captured from information systems used at PT. Terminal Peti Kemas Surabaya, as the main input, and interviews with operational and information technology managers, as the secondary input, in Indonesia's Surabaya container port terminal.

A time-dependent environment that changes over time is one of the examples of such unique behaviors [15]. Consequently, over many years of developments, researchers have proposed many dynamic modeling methods [16] that offer operability in modeling and simulation of the time-series behaviors in complicated systems [17] such as real-world dynamic environments of port handling in container terminals [18].

This study offers contributions to the topic of IT-assisted risk assessment. The contributions are as follows:

1) In this study, we propose a new method of risk assessment, mainly in the risk evaluation stage, which complements other methods that are mainly used in the stages of risk identification and risk analysis such as Fault Tree Analysis (FTA), Failure Modes, Effects, and Analysis (FMEA), and Decision Making Trial and Evaluation Laboratory (DEMATEL). The proposed method is adaptable to any organization that uses information systems in its daily operations and can be implemented in complex and multi-dimension environments.
2) In this study, we propose a heavily quantified risk assessment technique that largely uses historical event data rather than expert judgments, although expert

judgments are still minimally used. Risk evaluation using the proposed method is data-driven, relatively more accurate, picturing real-life conditions, can be implemented into inter-systems environments, and is less subjective.

3) In this study, we also include a prediction technique in the proposed method which offers risk trends so that managers and persons in charge can take preventive actions to mitigate the potential risks.

The next sections of this paper will discuss the related works in section II, the proposed method in section III, results and discussion in section IV, and conclusions and potential directions of future studies in section V.

II. RELATED STUDIES

There are countless studies on risk management. Literatures studying risk assessment mainly fall into two categories of topics, which are: First, reviewing or proposing new risk assessment methodologies and; second, attributing to risk analysis and application of risk assessments. This study can be categorized into the second topic because it proposes a new risk assessment technique, particularly in the risk evaluation stage.

Explorations on the first group of studies [2], [19], [20] revealed that risk analysis methodologies classically started with the analysis and statistical reviews of incidents in work environments. Research in [21] reported that the analysis and data statistics are mainly received and accepted for describing incidents in work environments among countries in the EU. Aside from legislative initiatives and statistics are crucial to improve working conditions, other mechanisms are also prerequisites for monitoring the processes and ensuring that the improvement targets have been achieved [22]. As a result, several methods have been proposed to conduct risk identification and risk analysis, such as FTA, FMEA, and DEMATEL [23], [24], [25].

A study in [26] explored as many as 62 risk assessment methodologies to analyze their shortcomings and performances in real-world settings. The study also suggested that using one general methodology to overcome the risks of problematic environments should not be sufficient. The characteristics of the work environment to be assessed and its unique problems of risk exposures determine what risk assessment methods are required. Complications in risk assessment scenarios result in the need to develop alternative methods. [27]. Uniformly, in documents that regulate risk assessment, many observers have expressed their skepticism on the validity and verification of qualitative risk assessments [28], [29], [30]. This skepticism is despite the lack of definite requirements and regulations regarding risk management [31].

The second group of researchers focuses on the application of risk assessment methods. However, most studies on risk assessments in port container terminals applied the more traditional qualitative techniques, which rely heavily on human judgments. As one of the methods from Multi Criteria Decision Making technique, DEMATEL is heavily reliant on human judgments and participation. Due to its nature (primarily focusing on making cause and effect diagrams), DEMATEL often needs to be combined with other methods when used in risk management, particularly at risk identification. DEMATEL and Analytical Network Process (ANP) are integrated for the first time to evaluate an e-learning application's intertwined effects in [32]. The DEMATEL-ANP technique, in the topic of risk assessment, is applied in the supply chain of crude oil within gas and oil construction projects in [33] and [34]. Fuzzy versions of DEMATEL-ANP technique were applied for construction projects in [35].

In one study [36], the proposed risk assessment technique was based on the Failure Mode and Effect Analysis (FMEA), which uses three fundamental attributes, namely likelihood (L), consequence severity (C), and the possibility of risk being undetected (P). FMEA for risk assessment was also used interestingly in [37] combined with AHP SAW based on CObIT 5 standard. Other researches in [38] and [39] that combined Fuzzy AHP and Fuzzy TOPSIS on risk assessment for IT Governance also offer interesting angles to apply in port container terminal risk assessment context.

Researches on risk assessment using FTA method are also plentiful and offer interesting perspectives when used in the risk analysis stage. For example, a study in [40] discusses a quantitative risk analysis in construction projects using FTA method. Another study in [41] discusses how FTA technique is used to assess risks on public transportations.

Common risk management lifecycle activities consist of risk identification, risk analysis, risk evaluation, risk treatment, and risk monitoring. Risk assessment comprises the first three activities of the lifecycle, i.e. risk identification, risk analysis, and risk evaluation. Most commonly used methods to conduct risk assessment are concerned with risk identification and risk analysis. FMEA and DEMATEL methods are mostly used in risk identification, while FTA method is mainly used in risk analysis. However, very limited numbers of methods are dedicatedly concerned with risk evaluation. This study attempts to fill the gap by offering a new method that primarily designed for risk evaluation. The new method proposed by this study is named Improved Multi-Attribute Risk Assessment (IMARA). Table 1 compares the implementations of FMEA, DEMATEL, FTA, and IMARA methods.

Figure 1 shows the primary implementation of FMEA, DEMATEL, FTA, and IMARA methods within the formal risk management lifecycle. It is important to note that the proposed method in this study was not developed to improve the existing methods; rather, it was designed to complement the assessment results from those methods which operate in the earlier stages of risk management activities.

III. THE PROPOSED METHOD

The method presented in this study proposed an alternative approach to risk evaluation by applying quantitative attributes measurements of event data from information systems. Event

TABLE 1. The roles and the differences of the implementations of FTA, FMEA, DEMATEL, and IMARA methods in risk assessment.

	METHOD			
	Fault Tree Analysis (FTA)	**Failure Mode and Effect Analysis (FMEA)**	**Decision Making Trial and Evaluation Laboratory (DEMATEL)**	**Improved Multi-Attribute Risk Assessment (IMARA)**
Purpose	Evaluation of failures in which an undesired state of a system is examined by understanding how systems can fail, to identify the best ways to reduce risk and to determine event rates of a safety accident or a particular system-level failure.	Identification of potential failure modes in a system and their causes and effects by reviewing as many components, assemblies, and subsystems as possible.	Identification of cause-effect chain components of a complex system by evaluating interdependent relationships among factors and finding the critical ones through a visual structural model.	Evaluation of risk performance in a certain period of time based on historical data and provision of projections of future risk trends to be used as the basis for risk mitigation planning.
Primary Data Input	Expert judgment (mostly qualitative)	Expert judgment (mostly qualitative)	Expert judgment (mostly qualitative)	Event data/event log (mostly quantitative)
Primary Data Acquisition Tool	Questionnaires	Questionnaires	Questionnaires	Information systems
Primary Scope in Risk Management Stages	Risk analysis	Risk identification	Risk identification	Risk evaluation
Best Implementation Approach	Top-down	Bottom-up	Top-down	Bottom-up
Implementation Steps	<u>5 steps</u>: 1) Define the undesired event; 2) Obtain an understanding of the system; 3) Construct the fault tree; 4) Evaluate the fault tree; and 5) Control the hazards identified.	<u>7 steps</u>: 1) List failure modes; 2) Describe the failure effect; 3) Determine severity; 4) List root causes; 5) Determine occurrence; 6) Determine detection rating; and 7) Calculate the Risk Priority Level (RPN).	<u>4 steps</u>: 1) Generate direct-influence matrix; 2) Establish the normalized direct-influence matrix; 3) Construct the total-influence matrix; and 4) Produce the influential relation map.	<u>7 steps</u>: 1) Data preparation; 2) Attribution, weighting, and crisping; 3) Data scoring; 4) Risk performance measure; 5) Risk profiling; 6) Analysis and evaluation; and 7) Risk forecasting.
Implementation Cycle	One time (repeatable when needed)	One time (repeatable when needed)	One time (repeatable when needed)	Periodical
Implementation Scenario	Ideally used to diagnose the root cause of a failure and understand what can cause a system to break.	Ideally used to analyze and assess functions, processes, designs, and regulations.	Ideally used to visualize the structure of complicated causal relationships into an intelligible structural model of the system.	Ideally used to evaluate the actual process risks performances and provide risk projections for mitigation plans.
Complexity in Implementation	High	High	High	High
Advantages	1) Allows assessment of the relationship between failures in different systems; 2) Improves compliance with the regulation.	1) Prioritizes failures; 2) Improves security.	1) Distinguishes complex factors into a visual cause-and-effect relationship diagram; 2) Investigates complicated and intertwined problems.	1) Provides actual risk performances based on historical data; 2) Inter-systems implementation; 3) Provides risk projections for mitigation planning.
Limitations	1) Rigid, since it works on a binary system: 2) Not good at determining the risk probabilities	1) Very complex; 2) Time-consuming; 3) Risk underestimation	1) Prone to different perspectives from one expert to another; 2) Needing to be combined with other methods for practical risk identification.	1) Only addresses risk factors that are registered on information systems used; 2) Unsuitable to assess risk environments that rely heavily on human judgment.

data is usually overlooked and not covered in the more traditional qualitative risk evaluation methods.

The proposed method is called IMARA (Improved Multi Attributes Risk Assessment). The implementation of IMARA is designed to be able to operate in multi-layers (levels) within an organization. This case study was conducted in a port terminal. However, the proposed method in this study is supposed to be applicable to any type of organization as long

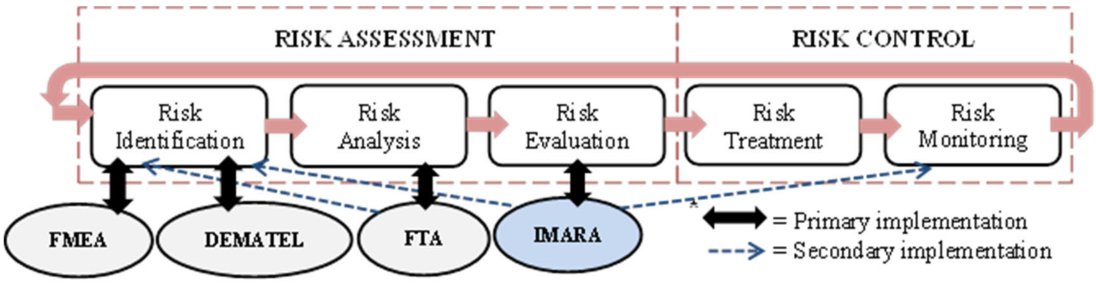

FIGURE 1. Implementation of FMEA, DEMATEL, FTA, and IMARA within the Risk Management Lifecycle.

as it uses information systems to conduct its daily operations. The next sections of this paper will discuss the proposed method in detail.

A. CASE STUDY

This paper used a case study from a container terminal in Surabaya, Indonesia (PT. Terminal Peti Kemas Surabaya or more commonly known as TPS Surabaya). This case study focuses on the delay risks of dwelling time in the container terminal. According to the guideline issued by the Indonesian government, the maximum dwelling time in container terminals in all ports across Indonesia is three working days. However, there are times when dwelling times in TPS Surabaya exceed three working days. These occurrences are due to many contributing factors. Non-technical factors such as the deliberate delay by importers to pick up their containers to use the terminal as a cheap and economical storage area have been anticipated by imposing a progressive tariff of 900% increase on the fourth day a container stored within the terminal area, thus significantly reduce these practices. However, technical factors such as unexpected failures of equipment, prolonged custom processing, or abnormal lack of workers in particular times are more diffi- cult to predict and anticipate. This study is focused to evaluate the risks performances from the latter scenario.

In this case study, as suggested by TPS Surabaya, the IMARA method was implemented only in two levels of perspectives (out of three levels to reach the enterprise-wide measurements), namely unit level (Level 0) and department level (Level 1). This is due to data security reasons for the TPS Surabaya. In this study case, we only had access to the operational data of January 2022. In other organizations' implementations, the levels of this proposed method could be more than Level 2 or could be less depending on the complexity and the need of their business processes. Table 2 shows the risk categories of dwelling time delays in TPS Surabaya.

TABLE 2. Dwelling time delay risk categories in TPS surabaya.

No	Unit Level (LEVEL 0)	Department Level (LEVEL 1)	Enterprise Level {LEVEL 2)
1	Required documents	Discharge (DC)	Pre-clearance delay
2	Equipment to incoming ratio (EIR)		
3	Human resource to incoming ratio (HRIR)		
4	Yard Occupancy Rate (YOR)	Main yard (MYS)	
5	Stacks average (SA)		
6	Main yard EIR		
7	Main yard HRIR		
8	Quarantine notice	Quarantine (QR)	Customs clearance delay
9	Quarantine YOR		
10	Quarantine SA		
11	Quarantine EIR		
12	Quarantine HRIR		
13	Quarantine inspection		
14	Quarantine job delivery		
15	Red line notice	Customs (CD)	
16	Customs HRIR		
17	Customs inspection		
18	Customs job delivery		
19	Customs clearance	Post clearance (PC)	Post clearance delay
20	Post service payment		
21	Gate yard SA		
22	Gate yard EIR		
23	Gate yard HRIR		
24	Truck in time		
25	Truck out time		

B. THE IMARA METHOD

The roles and implementations of IMARA method are described in Table 2 above. The main objective of this proposed method is to provide a helpful tool to conduct risk evaluation activities (the third stage of the risk management lifecycle.) DEMATEL, FMEA, and FTA are mainly used in the risk identification and risk analysis activities (the first and second stages of the risk management lifecycle.) In essence, the IMARA model is supposed to be able to conduct any multi-layer and multi-dimensional risk evaluation activities by applying levels of processes risks assessments as long as any organization to implement the proposed method uses information systems to conduct their daily operations; hence all the event data are recorded in their systems. Implementing information systems (although not necessarily integrated) in the business processes is a requirement to adopt IMARA, for this method works by doing computations to the event data (event logs) gathered from the information systems.

IMARA starts with the lowest-level assessment (unit level/level 0) covering detailed evaluations of every activity in the business process, then goes up to level n for more holistic

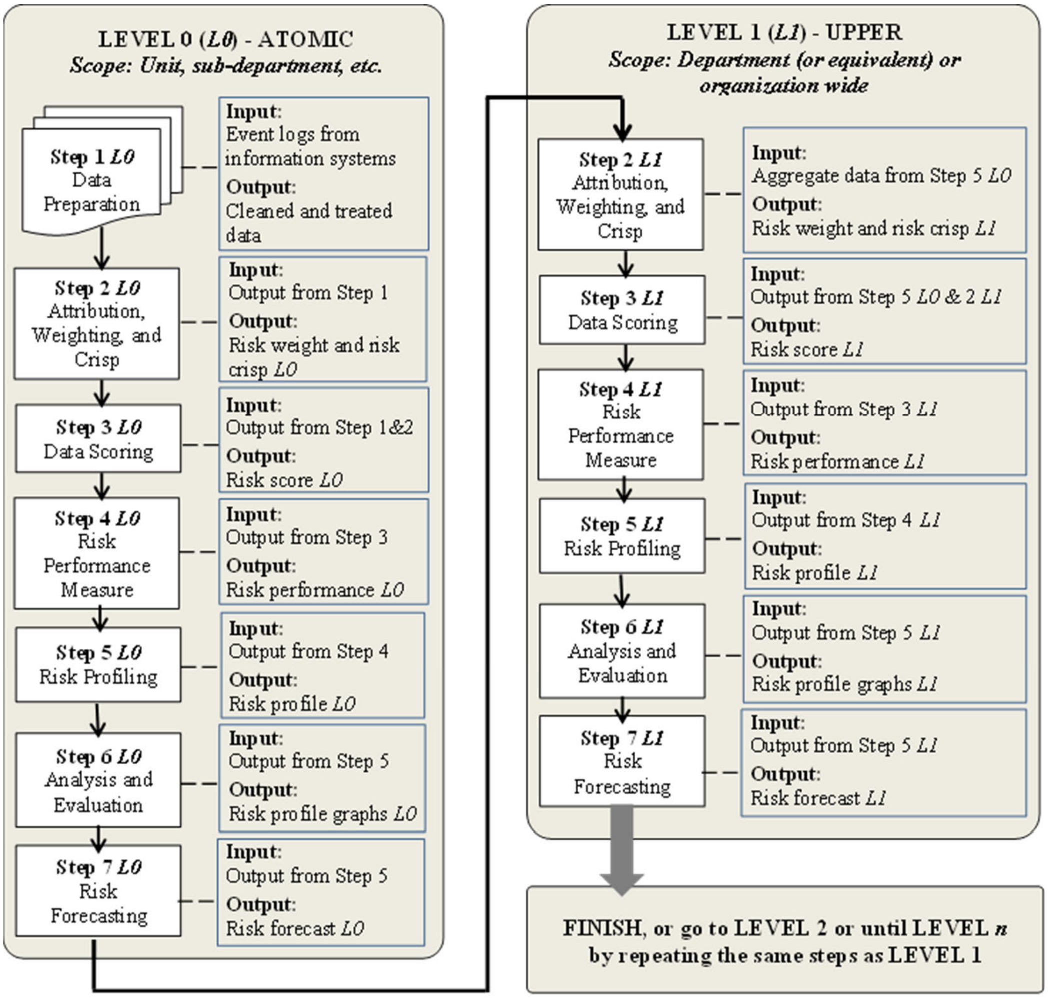

FIGURE 2. The IMARA framework.

evaluation depending on the complexity of the business process. There are seven steps in the IMARA model. They are: 1) Step 1: data preparation; 2) Step 2: attribution, weighting, and crisp; 3) Step 3: data scoring; 4) Step 4: risk performance measure; 5) Step 5: risk profiling; 6) Step 6: risk analysis, and: 7) Step 7: risk forecasting.

The outputs from IMARA evaluations are expected to be useful for conducting the next stage of the risk management lifecycle, risk treatment.

Figure 2 below describes the framework of the IMARA method.

1) STEP 1: DATA PREPARATION

Data preparation only applies to Level 0 assessment of the IMARA model. This phase gathers operational data from information systems for all of the process activities within a period of time. The time period for the input data depends on the activity life cycle of the organization. It can be yearly data, monthly data, or even daily data. This phase includes data cleansing to improve the quality of the data. In this paper, we use the selective data from the Discharge department and all of its three units to demonstrate the Level 0 of the IMARA method.

Table 3 shows the selective processed data of discharge activities gathered from the information systems of TPS Surabaya for demonstration purposes. This processed data would then be used as input for the next evaluation steps.

Definition 1: Let CONT_KEY = container number, RD = required document, EIR = equipment to incoming ratio, and HRIR = human resource to incoming ratio.

In Table 3, the value of "1" in the DOC (required documents) suggests that all of the needed documents are present. In events where the required documents are not available or incomplete, the value would be "0".

In this Step 1, we did not make any calculation for values in Table 3. All of the data values are provided by TPS Surabaya from its information systems using their calculation methods. We conducted data-cleaning procedures on the raw data before we used the data to test the proposed method. In this paper, we use a small sample and selective data to easily demonstrate our proposed method.

TABLE 3. Discharge data for selective weekdays period from TPS surabaya's information systems.

DISCHARGE (JAN-2022)				
CONT_KEY	DATE	RD	EIR	HRIR
AAAU9001220	01/01/2022	1	0.27	0.18
AAMU4003031	02/01/2022	1	0.28	0.17
AAMU4004969	03/01/2022	1	0.28	0.18
AAMU4008291	04/01/2022	1	0.28	0.18
ACCU2049701	05/01/2022	1	0.27	0.19
AKLU6025756	06/01/2022	1	0.27	0.21
AKLU6300349	07/01/2022	1	0.27	0.21
AKLU6504173	08/01/2022	1	0.27	0.19
AMCU2500292	09/01/2022	1	0.28	0.17
AMCU9262452	10/01/2022	1	0.28	0.25
AMCU9265446	11/01/2022	1	0.26	0.28
AMCU9269919	12/01/2022	1	0.26	0.22
AMCU9271304	13/01/2022	1	0.28	0.27
AMCU9272276	14/01/2022	1	0.17	0.26

TABLE 4. Sub-attributes weighting for discharge delay risk attribute (level 0).

(a_i)	Sub-Attribute	*WoWD*	*WoWE*	*WoPS*
(a_1)	RD	35%	45%	40%
(a_2)	EIR	33%	28%	30%
(a_3)	HRIR	32%	27%	30%

2) STEP 2: WEIGHT AND CRISP

This second phase of the method has two activities: weighting the sub-attributes and making crisp matrices for each sub-attribute. This phase applies to all assessment levels from Level 0 to Level *n*except for the attribute type normalization. Normalizing attribute type is only conducted in Level 0. In the first activity, we weighed each sub-attribute according to its impacts on the attribute's overall risk. Using quantitative assessment, we used weightings based on workloads in certain periods. The formula used for weighting in this study can be described as follows.

$$W_a = \sum\nolimits_{i=1}^{n} \frac{x_i}{t} 100\,(\%) \tag{1}$$

where:

W_a: weight of given attributes

x_i: containers with incidents caused by processes of an attribute

t: total number of containers with incidents during a window of time

Table 4 describes the Level 0 weighting for the discharge delay risk using the rules above.

Definition 2: Let *WoWD* = weight on weekdays (Monday-Friday), *WoWE* = weight on weekends (Saturday-Sunday), and *WoPS* = weight on peak season (July-August).

The weights of some sub-attributes in Table 4 and Table 6 on certain time period tend to be higher than the others. This might be due to some administrative staff (especially in customs and quarantine) being allowed to take two days off during weekends (depending on his/her position), while the traffics are usually normal or even higher. However, the weighting results in this case study were obtained by computing the data input using (1), not by field interview. Hence, the actual operational reasons are unexplored.

TABLE 5. Sub-attribute score matrix for discharge delay risk (level 0).

(a_i)	Sub-Attribute	Score (Crisp)					*AT*	*NAT*
		1	2	3	4	5		
(a_1)	RD	0	-	-	-	1	*Benefit*	Cost
(a_2)	EIR	0-0.20	-	-	-	0.21-1	*Benefit*	Cost
(a_3)	HRIR	0-0.20	-	-	-	0.21-1	*Benefit*	Cost

TABLE 6. Main attributes weighting for every risk sub-category (level 1).

(a_i)	Attribute	WoWD	WoWE	WoPS
(a_1)	DC	15%	8%	13%
(a_2)	QR	25%	35%	30%
(a_3)	MYS	20%	10%	15%
(a_4)	CD	35%	45%	40%
(a_5)	PC	5%	2%	2%

Table 5 explains the Level 0 score matrix (crisp) for the discharge delay risk.

Definition 3: Let *AT* = attribute type and *NAT* = normalized attribute type.

In Table 5, the crisp values are pre-determined by the operation managers, who set the value according to the risk policies implemented in TPS Surabaya. The crisp values for all levels in this study (from Level 0 to Level 1 or Level *n*) are pre-determined. We set all of the values according to the risk analysis documents of TPS Surabaya.

To avoid confusion, let's first clarify the meaning of the attribute types in this paper. The benefit type of attribute means the higher the score, the better. While the cost type of attribute means the lower the score, the better.

In this Step 2, all *AT* (attribute type) are normalized to become *NAT* (normalized attribute type) by reversing the attribute types to the opposite types (from benefit to cost, or otherwise.) In Table 5's case, the actual *AT*s of all sub-attributes are the benefit types (meaning the higher the value, the better or more desirable). However, in risk assessment, a value that is desirable/good means it has lower risk score (and so is the opposite: less desirable = higher risk score). This is the reason why in this proposed technique, the *AT*s need to be normalized (reversed) to the opposite type first (to become *NAT*s) before further calculations. In Table 5's example, they are from the benefit type of attributes to the cost type of attributes (meaning the less the value, the better or more desirable.)

Table 6 describes the Level 1 risk weighting, while Table 7 shows the Level 1 score (crisp) matrix of the main attributes for terminal overall delay risk.

Definition 4: Let DC = discharge delay, QR = quarantine delay, MYS = Main yard stack delay, CD = customs duty delay, and PC = post clearance delay.

In Table 7, the crisp values are also pre-determined by operation managers accordingly to the risk management practices in TPS Surabaya.

The crisp value is one of the few elements in this study that still need human judgment instead of based on the operational event data. The other elements are Likelihood (L) and Impact (I) - which will be discussed in Step 5: Risk Profiling - and the

TABLE 7. Attribute score matrix for holistic terminal dwelling time delay risk (level 1).

(ai)	Attribute	Crisp 1	2	3	4	5
		Score				
(a1)	DC	< 2	2 - 3	3 - 4	4 - 5	> 5
(a2)	QR	< 2	2 - 3	3 - 4	4 - 5	> 5
(a3)	MYS	< 2	2 - 3	3 - 4	4 - 5	> 5
(a4)	CD	< 2	2 - 3	3 - 4	4 - 5	> 5
(a5)	PC	< 2	2 - 3	3 - 4	4 - 5	> 5

TABLE 8. Discharge delay risk data scoring for selective weekdays period of january 2022 (level 0).

Date	RD		EIR		HRIR	
	Bs	*Sc*	*Bs*	*Sc*	*Bs*	*Sc*
03/01/2022	1	5	0.27	5	0.18	1
04/01/2022	1	5	0.28	5	0.17	1
05/01/2022	1	5	0.28	5	0.18	1
06/01/2022	1	5	0.28	5	0.18	1
07/01/2022	1	5	0.27	5	0.19	1
10/01/2022	1	5	0.27	5	0.21	5
11/01/2022	1	5	0.27	5	0.21	5
12/01/2022	1	5	0.27	5	0.19	1
13/01/2022	1	5	0.28	5	0.17	1
14/01/2022	1	5	0.28	5	0.25	5
17/01/2022	1	5	0.26	5	0.28	5
18/01/2022	1	5	0.26	5	0.22	5
19/01/2022	1	5	0.28	5	0.27	5
20/01/2022	1	5	0.17	1	0.26	5
Weight	35%		33%		32%	
Attribute	*Benefit*		*Benefit*		*Benefit*	
Normalized	Cost		Cost		Cost	

risk acceptance threshold - which will be discussed in Step 6: Analysis and Evaluation.

3) STEP 3: DATA SCORING

In this phase, the data which has been through data-cleaning, was given scores using the attribute score matrix from the previous step. Table 8 shows the scoring results of selective data from January 2022's weekdays discharge delay risk (Level 0), while Table 9 describes the scoring results of overall terminal dwelling time delay risk (Level 1) selective data for the same time period.

Definition 5: Let Bs = base score and Sc = converted score.

4) STEP 4: RISK PERFORMANCE MEASURE

In the fourth step, we calculate the normalized performance score for risks per attribute using a calculation method proposed in this study. The calculation method is explained as follows.

a) Atomic level (Level 0)

$$S_a = \sum_{a=1}^{n} \frac{X_{iatb}}{X_{iatb}^{max}} W_{iatb} + \frac{X_{iatc}^{min}}{X_{iatc}} W_{iatc} \quad (2)$$

where

S_a: Normalized risk performance score
X_{iatb}: Assessed attributes with benefit type
X_{iatb}^{max}: Highest score range (crisp) of an assessed attribute
W_{iatb}: Weight for the assessed attributes with benefit type

TABLE 9. Overall terminal dwelling time delay risk data scoring for selective weekdays period of january 2022 (level 1).

Date	DC		QR		MYS		CD		PC	
	Bs	*Sc*	*Bs*	*Sc*	*Bs*	*Sc*	*Bs*	*Sc*	*Bs*	*Sc*
3/1/22	3.2	3	5.22	5	2.64	2	3.42	3	3.15	3
4/1/22	3.2	3	5.22	5	2.64	2	3.42	3	2.88	2
5/1/22	3.2	3	4.68	4	2.64	2	4.86	4	2.43	2
6/1/22	3.2	3	4.86	4	4.08	4	2.25	2	2.88	2
7/1/22	3.2	3	4.14	4	2.4	2	1.8	1	2.61	2
10/1/22	1.6	1	5.76	5	2.16	2	1.8	1	2.61	2
11/1/22	1.6	1	3.42	3	2.16	2	2.25	2	4.05	4
12/1/22	3.2	3	3.06	3	1.68	1	2.25	2	3.96	3
13/1/22	3.2	3	2.52	2	1.92	1	1.8	1	3.33	3
14/1/22	1.6	1	2.52	2	2.16	2	1.8	1	3.96	3
17/1/22	1.6	1	2.52	2	2.64	2	3.96	3	4.14	4
18/1/22	1.6	1	2.7	2	2.4	2	2.25	2	3.96	3
19/1/22	1.6	1	4.14	4	2.64	2	1.8	1	2.43	2
20/1/22	3.2	3	3.06	3	2.88	2	1.8	1	2.43	2
Weight	15%		25%		20%		35%		5%	

X_{iatc}: Assessed attributes with cost type
X_{iatc}^{min}: Lowest score range (crisp) of an assessed attribute
W_{iatc}: Weight for the assessed attributes with cost type

b) Subsequent level (Level 1, Level n)

$$S_a = \sum_{a=1}^{n} \frac{X_{ia}}{X_{ia}^{max}} W_{ia} \quad (3)$$

where

S_a: Normalized risk performance score
X_{ia}: Assessed attributes
X_{ia}^{max}: Highest score range (crisp) of an assessed attribute
W_{ia}: Weight for the assessed attributes

5) STEP 5: RISK PROFILING

At this phase, we made the risk profile assessment for the selective period of time. The assessment also used a new method we proposed in this study which is applicable for all levels of assessment, i.e. Level 0 and Level 1 in our study (or to Level n for other cases where it is appropriate). The formula for risk profiling is explained as follows.

$$R_p = \sum_{1}^{n} (S_a L) I \quad (4)$$

where

R_p: Risk profile
S_a: Risk performance normalized score
L: Likelihood
I: Impact

The values of likelihood (L) and impact (I) are pre-determined by TPS Surabaya. In this study, we used all of the values of L and I as documented in the TPS Surabaya Risk Evaluation documents for both Level 0 and Level 1. TPS Surabaya seemed to determine the likelihood scores based on the frequency of risk occurrences within time periods in the past years. And, in determining the likelihood, TPS Surabaya calculated the financial loss of such risk occurrences by using impact matrices.

Table 10 shows the calculation results using Step 4 and Step 5 methods for Level 0 measurements of the DC (discharge delay.) The calculation results from Step 4 by

TABLE 10. Discharge delay risk performance and risk profile for selective weekdays period of january 2022 (level 0).

Date	Attributes (a)						DC Risk Performance and Risk Profile Level 0			
	RD (a_1)		EIR (a_2)		HRIR (a_3)					
	Normalized Type (tb|tc)									
	tc		tc		tc					
	Weight (W)									
	0.35		0.33		0.32		S_a	L	I	R_p
	Sc	X_{a1}	Sc	X_{a2}	Sc	X_{a3}				
3/1/22	5	0.1	5	0.05	1	0.25	0.40	2	4	**3.20**
4/1/22	5	0.1	5	0.05	1	0.25	0.40	2	4	**3.20**
5/1/22	5	0.1	5	0.05	1	0.25	0.40	2	4	**3.20**
6/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
7/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
10/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
11/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
12/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
13/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
14/1/22	5	0.1	1	0.25	5	0.05	0.40	2	4	**3.20**
17/1/22	5	0.1	1	0.25	5	0.05	0.40	2	4	**3.20**
18/1/22	5	0.1	1	0.25	5	0.05	0.40	2	4	**3.20**
19/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**
20/1/22	5	0.1	5	0.05	5	0.05	0.20	2	4	**1.60**

using (2) are shown in the column "S_a" of Table 10, while the calculation results from Step 5 by using (4) are shown in the column "R_p" of Table 10. The symbols used in Level 0 calculations for Discharge Delay risk performance and risk profile are explained in Definition 6 below.

Definition 6: In Table 10 (Level 0), let a = attribute, a_1 = the attribute of required document, a_2 = the attribute of equipment to incoming ratio, a_3 = the attribute of human resource to incoming ratio, tb = the attribute type of benefit, tc = the attribute type of cost, W = weight, X_{a1} = calculation result of a_1 by using (2), X_{a2} = calculation result of a_2 by using (2), X_{a3} = calculation result of a_3 by using (2), S_a = Normalized risk performance score of Discharge Delay risk by using (2), L = likelihood score, I = impact score, and R_p = Risk Profile score of Discharge Delay risk by using (4).

In Level 0 assessment, let us take X_{a1} from Table 10 as an example to explain about the assessed attribute (X_{ia}). From Table 10, it is known that the normalized attribute type of a_1 is cost (tc), the weight of a_1 (W_{iatc}) is 0.5, while the score (Sc) in this case is the assessed attributes with cost type (X_{iatc}). Hence the $X_{a1}$is obtained by treating X_{iatc}^{min} / $X_{iatc}* W_{iatc}$ (see (2)). According to the crisp matrix of a_1 (Discharge Delay) in Table 5, the lowest score range of the cost tipe attribute of a_1 (X_{iatc}^{min}) is 1. And in the case of 3/1/22 date in Table 10, the Sc (X_{iatc}) is 5. Thus the Xa_1 of 3/1/22 date according to (2) is $1/5 * 0.5 = 0.1$.

Let us take the 3/1/22 row as an example to explain S_a. We simply add X_{a1}, X_{a2}, and X_{a3} to obtain the S_a value in Table 10 as suggested in (2). Because there is no normalized attribute type of benefit (tb) in DC (Discharge Delay), the X_{iatb}/ $X_{iatb}^{max} * W_{iatb}$is equal to 0. Hence, by running (2), the S_a value for 3/1/22 date is $(0) + (0.5 + 0.05 + 0.25) = 0.40$.

Let us also take the 3/1/22 row as an example to explain risk profile (R_p) by using (4). For 3/2/22 date in Table 10, it is known that the value of $S_a$is 0.40, the likelihood (L) for DC risks is 2, while the impact (I) of DC risks is 4. Hence, the calculation result of R_p for 3/2/22 date by using (4) in Table 10 is $(0.40 * 2)\ 4 = 3.20$.

In this proposed method, the R_p calculation results from Level 0 assessment are then used as the input for Step 2 of Level 1, which the actually the first step of Level 1 (see Figure 2).

The calculation method in Level 1 uses the equation (3). In principle, it is the same calculation method as in (2). However, the Level 1 computations omit the attribute type variables unlike in Level 0 computations. Table 11 shows the results of Level 1 assessment for this study case.

Definition 7: In Table 11 (Level 1), let a = attribute, a_1 = the attribute of discharge delay, a_2 = the attribute of quarantine delay, a_3 = the attribute of main yard stack delay, a_4 = the attribute of customs delay, a_5 = the attribute of post clearance delay, W = weight, Sc = score, X_{a1} = calculation result of a_1 by using (3), X_{a2} = calculation result of a_2 by using (3), X_{a3} = calculation result of a_3 by using (3), X_{a4} = calculation result of a_4 by using (3), X_{a5} = calculation result of a_5 by using (3), S_a = Normalized risk performance score of Level 1 by using (3), L = likelihood score, I = impact score, and R_p = Risk Profile score of Level 1 by using (4).

6) STEP 6: ANALYSIS AND EVALUATION

At this stage, we evaluate the assessment results using a simple graph to enable the managers and non-technical persons to analyze the risk profiles within a certain period of time. The risks profiles are then compared with the risk acceptance thresholds. In this study, we did not set the risk acceptance threshold for TPS Surabaya. TPS Surabaya determines the risk acceptance thresholds for its business processes through its yearly risk evaluation activities. For example, TPS Surabaya in the year of 2022 set the thresholds at 4.1 for Discharge Unit, but at 3.5 for the overall dwelling time process. We set the thresholds for all analysis and evaluation in this step according to the Risk Evaluation documents of TPS. Surabaya.

In this Step 6, the assessment results are evaluated using graphical charts. This approach can easily highlight which attribute or sub-attribute contributes the most to delays. These graphical representations are easy to be understood even by field operators. Figure 3 shows the graphical representation of the discharge delay risk of January 2022 (Level 0), while Figure 4 shows the overall dwelling time delay risk for the same time period (Level 1.)

7) STEP 7: RISK FORECASTING

In this final phase, we forecasted the next period's risk projections. We used time-series prediction based on linear regression in this proposed method. Our forecast used the formula described below.

$$Y = mx + c \tag{5}$$

where

Y: Forecast

m: The value of the *slope* from the historical data

TABLE 11. Dwelling time delay risk performance and risk profile for selective weekdays period of january 2022 (level 1).

Date	Attrubutes (a)										Risk Performance and Risk Profile Level 1			
	Discharge (a_1)		Quarantine (a_2)		Main Yard Stack (a_3)		Customs Duty (a_4)		Post Clearence (a_5)					
	Weight (W)													
	0.15		0.35		0.15		0.30		0.05					
	Sc	*Xa1*	*Sc*	*Xa2*	*Sc*	*Xa3*	*Sc*	*Xa4*	*Sc*	*Xa5*	*Sa*	*L*	*I*	*Rp*
03/01/2022	3	0.12	4	0.16	2	0.08	4	0.16	2	0.08	0.6	2	3	**3.6**
04/01/2022	3	0.12	4	0.16	4	0.16	2	0.08	2	0.08	0.6	2	3	**3.6**
05/01/2022	3	0.12	4	0.16	2	0.08	1	0.04	2	0.08	0.48	2	3	**2.88**
06/01/2022	1	0.04	5	0.2	2	0.08	1	0.04	2	0.08	0.44	2	3	**2.64**
07/01/2022	1	0.04	3	0.12	2	0.08	2	0.08	4	0.16	0.48	2	3	**2.88**
10/01/2022	1	0.04	2	0.08	2	0.08	1	0.04	3	0.12	0.36	2	3	**2.16**
11/01/2022	1	0.04	2	0.08	2	0.08	3	0.12	4	0.16	0.48	2	3	**2.88**
12/01/2022	1	0.04	2	0.08	2	0.08	2	0.08	3	0.12	0.4	2	3	**2.4**
13/01/2022	1	0.04	4	0.16	2	0.08	1	0.04	2	0.08	0.4	2	3	**2.4**
14/01/2022	3	0.12	3	0.12	2	0.08	1	0.04	2	0.08	0.44	2	3	**2.64**
17/01/2022	3	0.12	2	0.08	5	0.2	3	0.12	4	0.16	0.68	2	3	**4.08**
18/01/2022	3	0.12	5	0.2	5	0.2	3	0.12	3	0.12	0.76	2	3	**4.56**
19/01/2022	1	0.04	5	0.2	5	0.2	3	0.12	3	0.12	0.68	2	3	**4.08**
20/01/2022	1	0.04	2	0.08	5	0.2	4	0.16	4	0.16	0.64	2	3	**3.84**

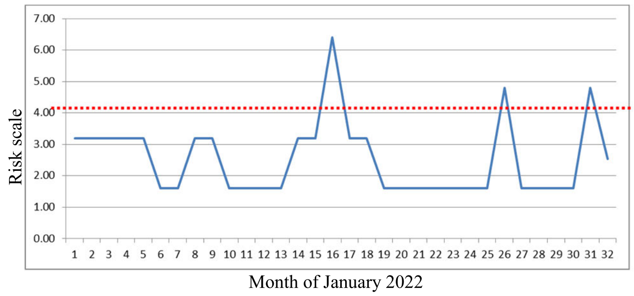

FIGURE 3. Risk performance of the attribute discharge delay (level 0) for the selective weekdays time period of january 2022 where the dashed red line indicates risk acceptance threshold.

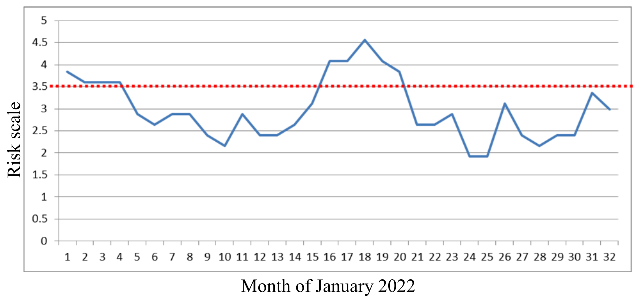

FIGURE 4. Risk performance of dwelling time delay (level 1) for the selective weekdays time period of january 2022 where the dashed red line indicates risk acceptance threshold.

x: The future time period to be predicted

c: The value of the *intercept* from the historical data

The learning approach to estimate the parameters of slope (m) and intercept (c) in this study falls within the 'ordinary least squares' (OLS) regression algorithm. The main objective of this regression is to minimize the sum of the squared differences between the observed dependent variable (risks profiles of i month/period) values and the predicted values (risks trends forecast (Y) for the next month/period) based on the linear equation.

In obtaining the slope (m) value, we used the following method.

$$m = \sum \frac{((a-\bar{a})\,(e-\bar{e}))}{\left((a-\bar{a})^2\right)} \tag{6}$$

where

m : Slope

a : Dates values

e : Risk profile (R_p) values

$\bar{a}$: Mean of a values

$\bar{e}$: Mean of e values

In obtaining the intercept (c) value for the regression, we used the following formula.

$$c = \bar{e} - m\bar{a} \tag{7}$$

where

c : Intercept

$\bar{e}$: Mean of risk profile (R_p) values

m : Slope

$\bar{a}$: Mean of dates values

The results of risk trends forecasting for each department in TPS Surabaya are shown as graphs in the next section of this paper.

IV. RESULTS AND DISCUSSION

In this paper section, we discuss the recapitulation of risk assessment from the case study using our proposed method. The data set used in this case study was taken from field data of January 2022 period. However, the full assessment results from the data set for all of the units in this case study of dwelling time risk evaluation at PT. Surabaya Container Terminal by using the IMARA method are not included in this report due to the space limitations.

A. UNIT LEVEL (LEVEL 0)

The summary of our risk assessment results for each unit at Level 0 for the time period of January 2022 from our case

TABLE 12. Discharge delay (DC) risk profile performance.

No	Attribute	*RPA*	*PS*	R_p
1	Required Documents	0.13		
2	Equipment to Incoming Ratio	0.09	0.32	2.53
3	Human Resource to Incoming Ratio	0.10		

TABLE 13. Quarantine delay (QR) risk profile performance.

Num	Attribute	*RPA*	*PS*	R_p
1	Quarantine Notice	0.07		
2	% of Yard Occupancy Rate	0.07		
3	Stacks Average	0.07		
4	Equipment to Incoming Ratio	0.04	0.39	3.47
5	Human Resource to Incoming Ratio	0.04		
6	Inspection Time	0.06		
7	Quarantine Job Delivery	0.05		

TABLE 14. Main yard stack (MYS) delay risk profile performance.

Num	Attribute	*RPA*	*PS*	R_p
1	% of Yard Occupancy Rate	0.14		
2	Stacks Average	0.14		
3	Equipment to Incoming Ratio	0.11	0.50	2.97
4	Human Resource to Incoming Ratio	0.11		

TABLE 15. Custom duty (CD) delay risk profile performance.

Num	Attribute	*RPA*	*PS*	R_p
1	Red Lane Notice	0.08		
2	Human Resource to Incoming Ratio	0.06	0.29	2.64
3	Inspection Time	0.08		
4	Job Delivery	0.07		

TABLE 16. Post clearance (PC) delay risk profile performance.

Num	Attribute	*RPA*	*PS*	R_p
1	Customs Clearance	0.07		
2	Port Service Payment	0.07		
3	Stacks Average	0.07		
4	Equipment to Outgoing Ratio	0.05	0.36	3.27
5	Human Resource to Outgoing Ratio	0.06		
6	Truck In	0.02		
7	Truck Out Time	0.03		

study is described as follows. Table 12 summarizes the risk profile performance of discharge delay (DC), Table 13 for quarantine delay (QR), Table 14 for main yard stack delay (MYS), Table 15 for custom duty delay (CD), and Table 16 for post clearance delay (PC).

Definition 8: Let RPA = risk profile average, PS = performance score, and R_p = risk profile.

The following five figures will illustrate the results of our risk trends forecasting for each unit at Level 0 for the time period of February 2022. Figure 5 illustrate the risk forecasting of discharge delay (DC), Figure 6 for quarantine delay (QR), Figure 7 for main yard stack delay (MYS), Figure 8 for custom duty delay (CD), and Figure 9 for post clearance delay (PC). In Figure 5 to Figure 9, the blue lines indicate the aggregate risk profile for each department in

TABLE 17. Level 1 dwelling time delay risk profile performance at tps surabaya.

Num	Attribute	RPA	PS	R_p
1	Discharge Delay	0.08		
2	Quarantine Delay	0.13		
3	Main Yard Stack	0.10	0.50	2.98
4	Customs Duty Delay	0.08		
5	Post Clearance Delay	0.11		

January 2022, while the red dashed lines indicate the risk trends for each unit from January 2022 to February 2022.

B. DEPARTMENT LEVEL (LEVEL 1)

Our risk assessment results for Level 1 (department level) from our case study for the time period of January 2022 can be analyzed in Table 17 and Figure 10. Table 17 describes findings on the risk profile performance of the overall dwelling time delay at TPS Surabaya, while Figure 10 shows the risk forecasting of dwelling time delay at TPS Surabaya for the February 2022 time period. For the terms and abbreviations used in Table 17, see Definition 8.

C. CASE STUDY IMPLICATIONS

The risk evaluation report from this case study has provided a beneficial reference for operation managers and management to perceive and address risks within TPS Surabaya. Key managerial insights that can be derived from this evaluation report include:

1) *Risk prioritization*: This risk evaluation helps identify and prioritize risks based on their potential likelihood as suggested by the risk trends acquired from the risk forecasting. This allows managers to focus their attention and resources on the most potential risk occurrences.
2) *Risk mitigation strategies*: This assessment highlights specific risks and provides insights into potential mitigation strategies. Managers can use this information to develop risk management plans, implement controls, and take proactive measures to reduce the likelihood of identified risks.
3) *Resource allocation*: By understanding the risks performance, risks profile, and risks trends, operation managers in TPS Surabaya can allocate resources effectively. They can prioritize risk mitigation activities by allocating equipment and personnel based on the risks trends to anticipate the likelihood.
4) *Decision-making*: The insights from this assessment provide operation managers better understanding of the risks associated with various decisions and actions. This enables them to make more informed decisions by considering the risk profile and risk trends and weighing them against the expected results.
5) *Compliance and regulations*: The evaluation results can help identify risks that may have compliance implications or legal/regulatory requirements. Managers can ensure that the organization's activities align with

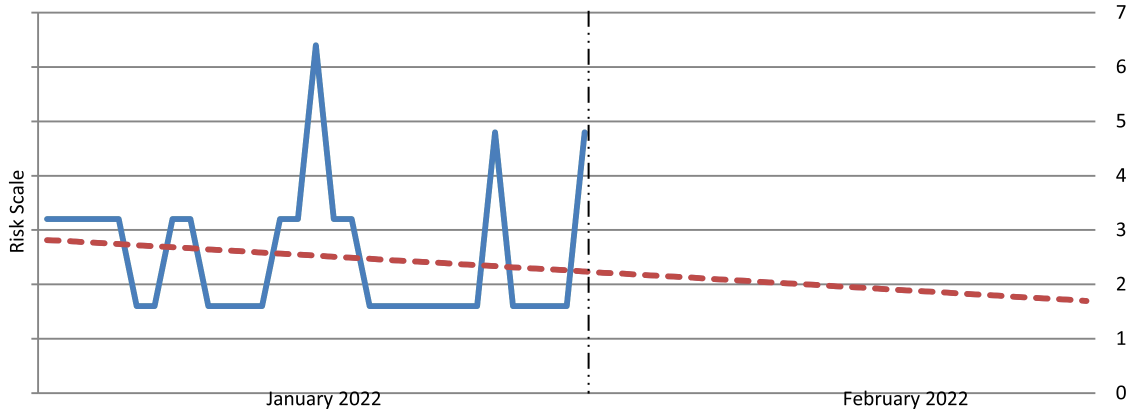

FIGURE 5. Level 0 risk trend forecasting of discharge delay (DC) for the time period of February 2022 where the blue line indicates risk profile, while the dashed red line indicates the risk trend.

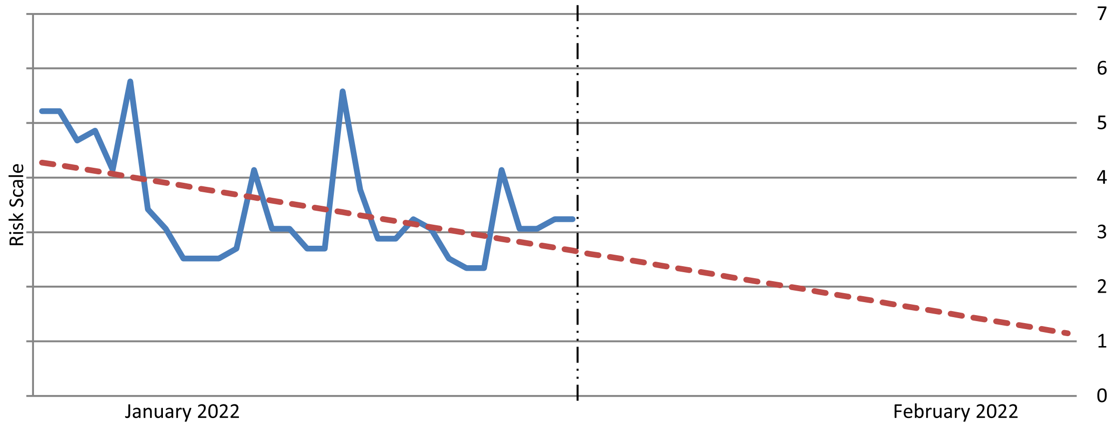

FIGURE 6. Level 0 risk trend forecasting of quarantine delay (QR) for the time period of february 2022 where the blue line indicates risk profile, while the dashed red line indicates the risk trend.

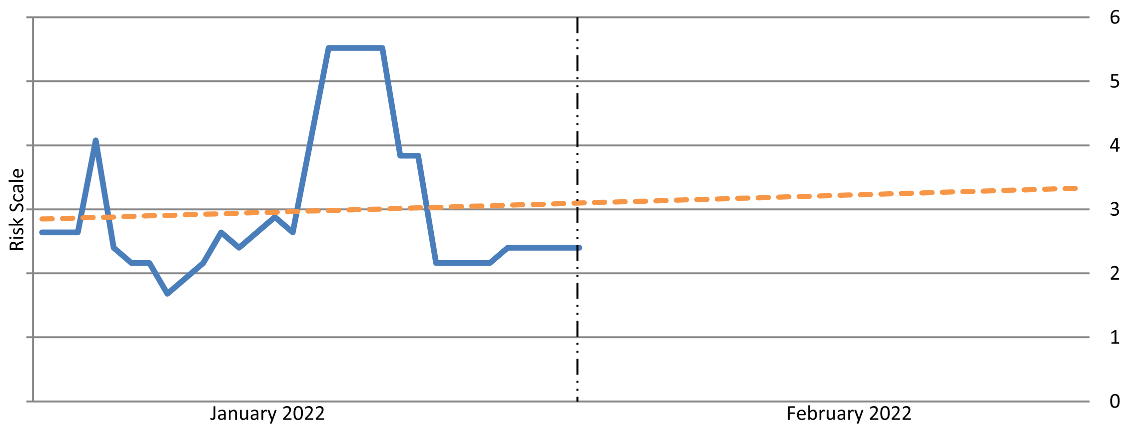

FIGURE 7. Level 0 risk trend forecasting of main yard stack delay (MYS) for the time period of february 2022 where the blue line indicates risk profile, while the dashed red line indicates the risk trend.

relevant laws and regulations, reducing the risk of non-compliance and associated consequences.

6) *Communication*: The assessment result can serve as a communication tool to engage stakeholders, including employees, investors, customers, and regulators. It provides a comprehensive view of the risks and demonstrates the organization's risk performance.

7) *Continuous improvement*: A risk evaluation report allows operational managers to assess the effectiveness of existing risk management practices and identify areas for improvement. The result from the case study can promote a culture of continuous improvement by implementing the proposed method periodically, as encouraged by IMARA lifecycle.

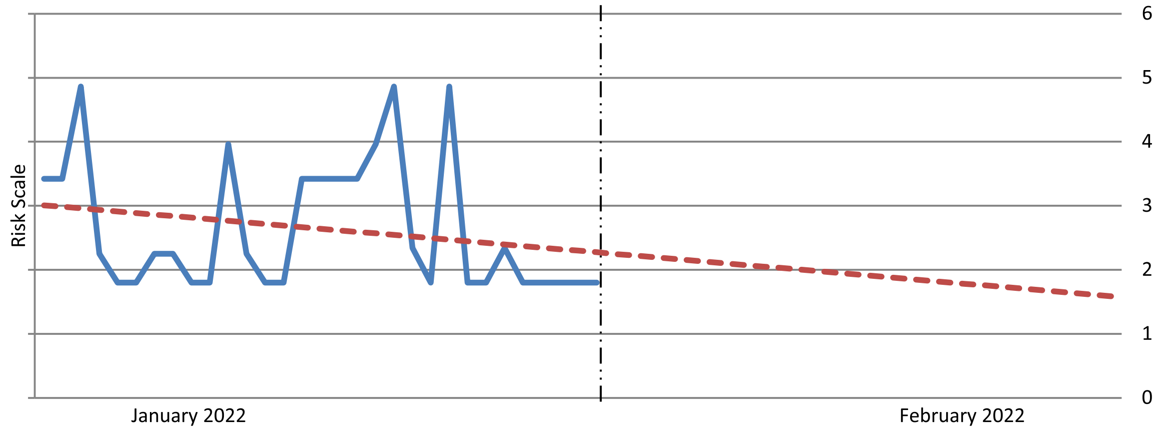

FIGURE 8. Level 0 risk trend forecasting of customs duty delay (CD) for the time period of february 2022 where the blue line indicates risk profile, while the dashed red line indicates the risk trend.

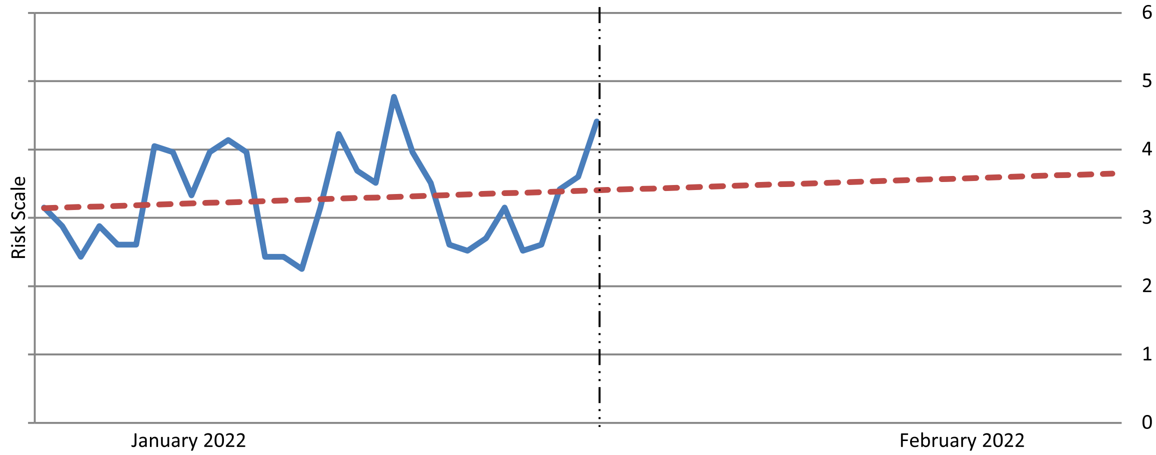

FIGURE 9. Level 0 risk trend forecasting of post clearance delay (PC) for the time period of february 2022 where the blue line indicates risk profile, while the dashed red line indicates the risk trend.

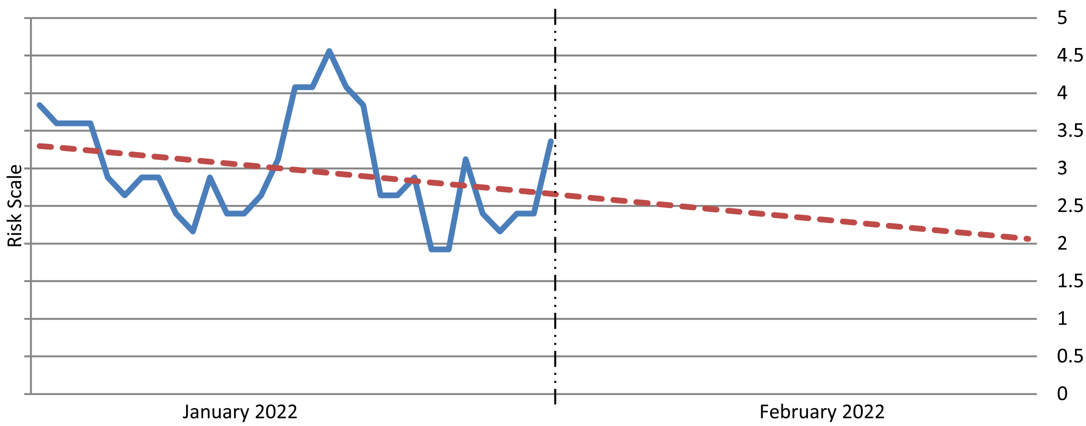

FIGURE 10. Level 1 risk trend forecasting for dwelling time delay (Level 1) at TPS Surabaya for the February 2022 time period where the blue line indicates risk profile, while the dashed red line indicates the risk trend.

8) *Easier risk evaluation process*: By implementing the proposed method, operational managers can have a faster, easier, and more reliable way to conduct risk evaluation activities as opposed to conducting it by using the more conventional way which needs a lot of paper works and interviews. The risk trends resulted

from this method activity can be used as the basis to determine the likelihood of a risk factor for future implementations.

V. CONCLUSION AND FUTURE WORKS

Risk assessment is an important step toward enhancing the business processes in an organization or industry. In this study, we proposed a new method to resolve the deficiencies of the traditional risk evaluation, evaluate the risks more accurately, and make the results more consistent with reality. The proposed IMARA method also offers risks trends projections based on forecasting which can be useful for managers to determine the likelihood of risk factors in the future. The result from this study case provides some useful references to improve the risk management practices in TPS Surabaya.

This proposed method's intended primary implementation is in the risk evaluation stage within the risk management lifecycle. The proposed method is designed to be applicable in multi-layer and inter-systems of various organization types. In the case study at the TPS Surabaya, the proposed method was implemented in two layers out of the three possible layers that can be covered by the proposed method. The implementation of the proposed method to the two layers in TPS Surabaya is presented as Level 0 and Level 1 in this paper.

The IMARA method proposed in this study is still in its early stage of development. It is understood that the proposed method is open to improvements. The IMARA still needs to be confirmed through other sensitivity analysis in other types and scales of organizations to reach its maturity.

Based on the results from the case study in this paper, future projects on IMARA will be focused on the methods to fully quantify the inputs for the calculation method. In this case study, some variables still rely on human judgments, i.e. determining the crisp, likelihood, impact, and risk acceptance threshold values. In future studies, we will also look for ways to apply better machine learning techniques in the risk forecasting step to improve the accuracy of the prediction. We aim to be able to predict individual risk occurrences rather than just to offer risk trends. On the other hand, the risk projections provided by this method are also very useful to determine and quantify the risk likelihood of risk factors for future risk assessment periods.

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