Exploration of the Project Risk Management Framework for Information Technology Companies

Eksplorasi Kerangka Manajemen Risiko Proyek Untuk Perusahaan Teknologi Informasi

Isnen Hadi Al Ghozali*[1], Samidi[2], Andy Rio Handoko[3]
[1,2,3] Magister Ilmu Komputer, Universitas Budi Luhur, Jakarta, Indonesia
e-mail: ***[1]2111601163@student.budiluhur.ac.id**, [2]samidi@budiluhur.ac.id,
[3]andy.handoko@budiluhur.ac.id

Abstract

Based on CHAOS 2020: Beyond Infinity Overview, reported by the Standish Group, only 31% of IT projects were successfully implemented, while 50% of projects were challenged and 19% of projects failed. Many project managers less awareness about SRM and have a partial understanding of risk. The purpose of this study is to develop a project risk management framework for listing companies in the information technology sector. The sample for this study is 35 annual reports of technology companies listed on IDX. This study identified 122 types of project risks from 33 companies' annual reports. This study uses an exploratory study approach. The proposed framework includes three stages, namely the root cause, risk assessment, and performance stages. At the root cause stage, the identification of risks from elements of the business environment becomes the basis for measuring risk treatment. In the next stage, the identified risk treatment is measured through identify, analysis, and verification activities with the support of communication, documentation, and evaluation. The measurement results are classified into three major dimensions, namely cost, time, and quality. The final stage of the framework is in the form of residual performance risk and a risk mitigation action plan.

Keywords— Risk Management, Project Management, Project Risk Framework, Listing Company, Project Risk Framework

Abstrak

Berdasarkan laporan CHAOS 2020: Beyond Infinity Review yang diterbitkan Standish Group, hanya 31% proyek TI yang berhasil dilaksanakan, sementara 50% proyek sangat tantangan dan 19% proyek gagal. Banyak manajer proyek yang kurang memiliki kesadaran tentang SRM dan hanya memiliki pemahaman parsial tentang risiko. Tujuan dari penelitian ini adalah untuk mengembangkan kerangka manajemen risiko proyek untuk perusahaan listing di sektor teknologi informasi. Sampel penelitian ini adalah 35 laporan tahunan perusahaan teknologi yang terdaftar di BEI. Penelitian ini mengidentifikasi 122 jenis risiko proyek dari 33 laporan tahunan perusahaan. Penelitian ini menggunakan pendekatan studi eksploratif. Kerangka kerja yang diusulkan mencakup tiga tahap, yaitu tahap akar permasalahan, penilaian risiko, dan tahap kinerja. Pada tahap akar permasalahan, identifikasi risiko dari elemen lingkungan bisnis menjadi dasar pengukuran penanganan risiko. Pada tahap selanjutnya, identified risk treatment diukur melalui kegiatan identifikasi, analisis, dan verifikasi dengan dukungan komunikasi, dokumentasi, dan evaluasi. Hasil pengukuran diklasifikasi menjadi tiga dimensi besar yaitu biaya, waktu, dan kualitas. Tahap akhir dari kerangka tersebut berupa sisa risiko kinerja dan rencana aksi mitigasi risiko.

Kata kunci— Risk Management, Project Management, Project Risk Framework, Listing Company, Project Risk Framework

1. INTRODUCTION

In 1989, Barry W. Boehm pioneered a specific discussion regarding Software Risk management (SRM). The study became the starting point for more in-depth studies in the 1990s. Boehm and Charette's study became the main foundation for the establishment of the Software Engineering Institute (SEI), which currently acts as an archetype in several references in the risk management literature [1]. According to the 2018 Project Management Institute report, on average, for every $1 billion invested in projects, there is a loss of $99 million [2]. Even though risk assessment frameworks such as ISO 31000:2018 have been developed, it is undeniable that most systems are never completed or fail to operate effectively and efficiently [3] [4]. Based on CHAOS 2020: Beyond Infinity Overview, reported by the Standish Group, only 31% of IT projects were successfully implemented, while 50% of projects were challenged and 19% of projects failed [5]. These results are in accordance with a study [6], which found that 80% of ICT projects experience delays in completion, with an average delay of up to 40 months. Many project managers less awareness about SRM and have a partial understanding of risk [7]. This is reinforced by a study [7], which places communication risk as the biggest risk in IT project management. The probability of IT project failure is also influenced by risks that are not measured systematically, even though project risk management is one of the nine knowledge areas in the Project Management Body of Knowledge (PMBOK). Conceptually, the risk assessment framework develops based on current issues. Study resulted in an updated risk assessment framework based on ISO 31000:2018 for virtual/collaborative enterprises. Strategies to overcome problems (risks) with stakeholders can be solved with a game-theory-based intervention framework [8]. The risk project management framework develops along with software development methods such as Distributed software development (DSD) [7]. Scrum development [9], or Exploration, Preparation, Implementation, Sustainment (EPIS) [10].

Software development project risk management is a conceptual framework for identifying software development project risks that are dependent on project characteristics, the project risk management team, risk identification techniques, and project quality at the level of project risk. A study Cai et al. (2022) shows that risk is not a single condition but an aggregation of several conditions [11]. Risk aggregation is defined in the context of a risk scenario as a combination of probabilities and implication consequences, which are described by discrete or continuous parameters. Risk aggregation is described in a risk matrix with the dimensions of likelihood and consequence. To assist management in calculating project risk, several studies offer the use of machine learning algorithms. The techniques used to measure project risk models can be linear regression [12], semi-supervised learning [13], Artificial Neural Networks (ANN) [8] [9] [14]. In addition, decision support models such as the Analytic Hierarchy Process (AHP) can still be used [15].

Based on data from the Indonesia Stock Exchange (IDX) for 2022, there are 41 technology companies listed on the exchange. IDX and the Indonesian Financial Services Authority (OJK) require exposure to corporate governance, including risk management. Listing companies in the technology sector are divided into new, major, development, and accelerated economies. The New Economy Board is a listing board that is equivalent to the Main Board. Companies can be listed on the New Economic Board if they fulfill the requirements for being listed on the Main Board and have special characteristics determined by the Exchange. These unique qualities include high revenue growth, using technology to develop product or service innovations that boost productivity, economic growth, and social benefits, as well as entering the Exchange-designated business sector. The Main Board is intended for prospective issuers who are large companies and already have a good financial track record, while the Development Board is intended for companies that have not been able to meet the listing requirements of the Main Board and have not recorded a net profit. The Acceleration Board is a listing board for companies with small and medium-scale assets (SMEs). This board is to encourage more SMEs to conduct an initial public offering as a form of fundraising for expansion.

The purpose of this study is to develop a project risk management framework for listing companies in the information technology sector. The study [1] builds a risk assessment framework based on project characteristics, the project risk management team, risk identification approaches, and project quality. The framework that the study produced is different from the ISO 31000:2018 framework, which focuses on the identification of risk, the risk analysis, and the risk evaluation The development of the ISO 31000:2018 framework in the Scrum development process identifies six fundamental project risk management areas, namely plan risk management, risk identification, perform qualitative and quantitative analysis, plan risk response, implement risk response, and monitor risk [9]. Meanwhile, the DSD model defines four risk areas, namely communication, cultural differences, knowledge management, and coordination [7]. A study [3] proposed a framework called 4PTRB, which includes people, product, project, risk, process, technology, and business management areas. The framework used in this study is similar to the software risk attributes according to Keil, namely product size, customer characteristics, business impact, process definition, technology to be built, staff size and experience, and development environment [12]. This study continues the study [1] which proposed the SRM conceptual framework. The study focuses on developing a conceptual framework by adapting ISO 31000:2018 and taking into account risk aggregation [11]. This study is expected to produce a conceptual framework that is implementable and more adaptive to environmental conditions. This study used an exploratory technique, in contrast to studies [12], [13], and [14] which extracted data using machine learning algorithms to obtain the most accurate risk measurement results. This study will focus on data extraction to develop a project risk measurement framework.

2. METHODOLOGY

The population of this study is 41 companies that are included in the technology category according to IDX records in 2022. The sample selection technique used purposive sampling with company criteria that include project risk management exposure in the annual report published in 2022. Based on this sample selection technique, 35 annual reports of technology companies listed on IDX were selected. The research variable in this study is project risk management exposure, which is a part of good corporate governance exposure. Project risk management is a conceptual framework for identifying software development project risks that focuses on the identification of risk, the analysis of risk, and the evaluation of risk.

This study uses an exploratory study approach by conducting searches, especially in consolidating concepts that will be used in a broader scope of research with a larger conceptual range. Explorative research is flexible; it tends not to be structured in a standard way, and the sample size is relatively small or limited. The exploratory research in this study combines quantitative methods to measure risk and qualitative methods to extract data to develop a project risk measurement framework.

The study carried out five stages to obtain conclusions, which are shown in Figure 1, namely (1) identification of research problems; (2) literature reviews; (3) data collection and preprocessing; (4) exploration framework analysis; and (5) rebuilding the project risk framework. We identify at least two problems: most systems are never completed or fail even when risk assessment frameworks are developed and risks are not measured systematically. This problem triggered us to explore the literature about SRM, PMBOK, and the project risk management framework. Then, we collect data from IDX and perform data preprocessing (risk identification, summarization, and classification) so that the data is ready for analysis. Exploration Framework Analysis includes project risk review, exploring several project risk management framework's attributes, and then exploring the probability of rebuilding the project risk management framework from the data. In the last stage, we rebuilt the project risk framework, which includes the proposed project risk management framework visualization and evaluation.

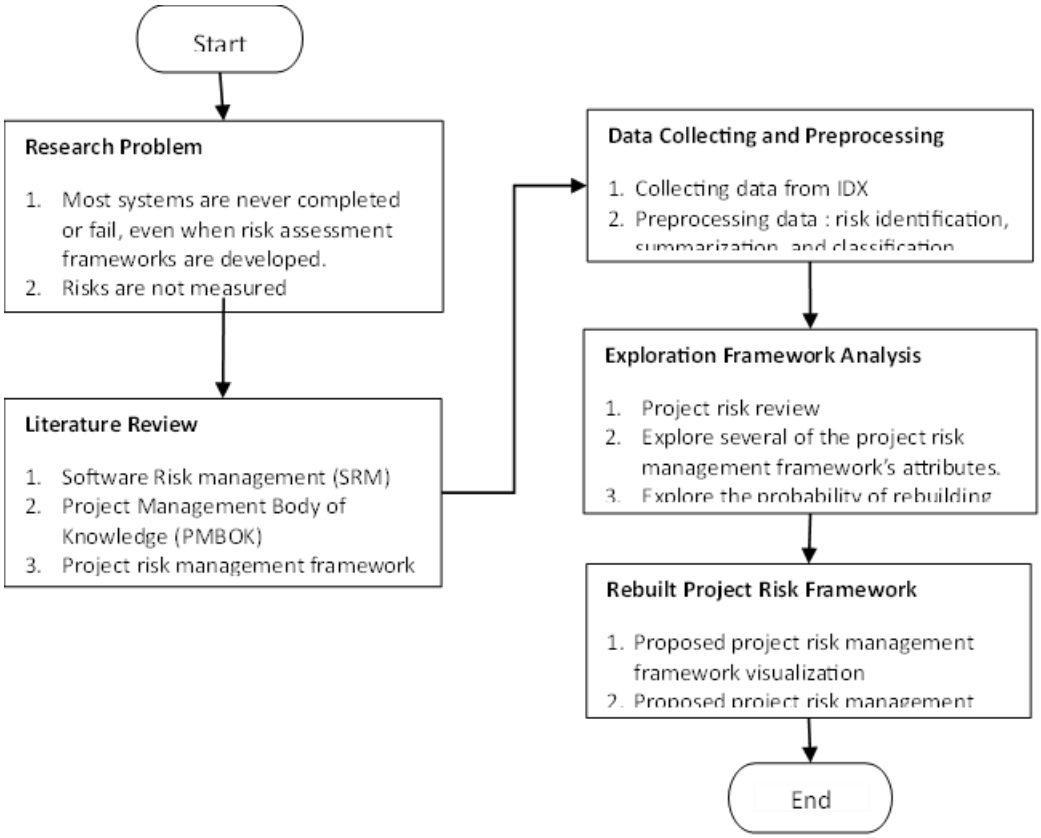

Figure 1. Research Framework

3. RESULTS AND DISCUSSION

We identified two main issues with the project risk framework. First, most systems are never completed or fail even when risk assessment frameworks are developed. A project manager should have the competence to plan and monitor projects carefully using a broad set of knowledge, techniques, and tools. Project management competence is reflected in the maturity model, which describes the level of development of an organization by assessing its current performance [16]. However, many project managers think risk analysis is just an administrative job. Usually, this occurs at the initial and premature level of maturity. Second, risks are not measured systematically. Project management tends to measure risk partially, focusing on one area only so that the risk can be measured. This results in non-comprehensive risk measurement results and risk bias in decision-making.

ISO 31000:2018 stipulates three main parts in project risk management: principle, process, and framework. The risk management process consists of three dimensions: communication and consultation; monitoring and review; and recording and reporting. The risk assessment process consists of three activities: risk identification, risk analysis, and risk evaluation. In its development, this framework is developed into a risk assessment framework that can be implemented in a more specific SDLC method. Table 1 shows the 12 framework areas compiled from previous research. Half of those frameworks can be implemented in the general project management area. Several studies have developed frameworks for more specific fields according to certain system development life cycle (SDLC) methods. For example, study [7] develops a framework for the Distributed Software Development (DSD) method and study [9] specializes in the Scrum development method.

Table 1. Project Risk Framework Literature

Study	Framework area	Framework attributes
[1]	Project Management	project characteristics, project risk management team, risk identification approaches, and project quality on the level of project risk
[3]	Software Project Management	people, process, product, project, technology, risk, and business (4PTRB)
[7]	Distributed software development (DSD)	identify, evaluate, respond, monitor
[8]	Project Management	remember, understand, apply, analyze, evaluate, transfer
[9]	Scrum development	plan risk management, risk identification, perform qualitative and quantitative analysis, plan risk response, implement risk response, and monitor risk
[17] [18] [19]	Agile Project Management	approach risk, organizational risk, process risk, business risk, technology risk, and monitoring and analysis risk
[20]	Software Project Risk Management	analysis risk of product design, communication risk, human resource risk and decision making risk.
[21] [22]	Project Management	complexity, learning, evidence, processes, infrastructure, high-level executive & their decision
[23]	Technological innovation	managerial discretion, risk aversion, and market regime
[24]	Project Management	time, quality, and cost
[25]	Project Management	analysis risk, project communication risk, schedule risk, risk of system design, and risk of project cooperation
[26]	Project Management	risk identification, the risk analysis, and the risk evaluation

This study uses data from the annual reports of companies listed on the Indonesian Stock Exchange. The population of this study is composed of companies listed on the Indonesian Stock Exchange in 2023, totaling 853 companies. To select the research sample, a purposive sampling method was used with the following criteria: 1) companies listed on the Indonesian Stock Exchange for the 2021–2023 period; 2) companies in the IT sector; 3) Companies that publish annual reports for 2022. Based on these criteria, 35 companies were selected.

At the data preprocessing stage, the study will extract information related to risk management exposure from the company's annual report. Exposure risk management is a subsection of Good Corporate Governance. Based on our exploration, there are 33 companies that report risk management exposure, and 2 companies do not mention risk management exposure. This study identified 122 types of project risks from 33 companies' annual reports. The results of this risk identification will be classified into the dimensions of people, process, product, technology, and business [3] [27]. Figure 2 shows the distribution of identified risk types among 33 companies. From 122 distributed risks, there are 63 business risks, 12 people risks, 22 process risks, 9 product risks, and 16 technology risks.

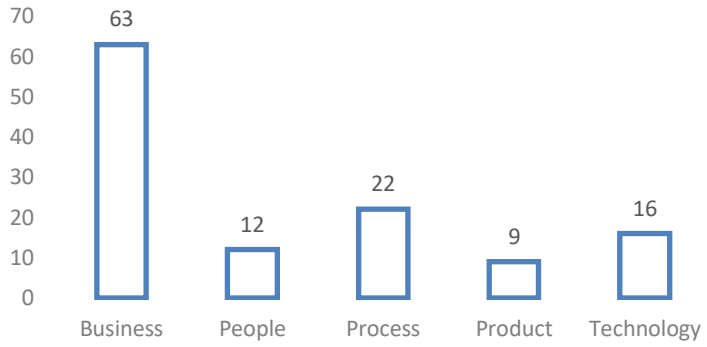

Figure 2. Risk distribution

Software risk management in software design is used to mitigate damage to software modules [27]. Effective project management demands the optimization of project duration to minimize total project time and cost [28]. In addition, the lower the risk of being one of the seven project values, the more likely it is to get the project [29]. One of the classic problems related to risk, namely the risk assessment steps, has not been explained in detail [30]. Though Risk assessment is an important element of risk management, to be effective, it must be an ongoing process [31]. This difficulty can also increase if the project is complex, so the traditional single-company-oriented risk management approach is considered to produce limited solutions [32]. Figure 2 shows that business risk is the highest risk in project management. This risk can be in the form of competition risk, regulatory risk, financial risk, and macro or global economic condition risk. In identifying risks, the project manager needs to consider risk aggregation, where a combination of several areas of risk can accumulate into a larger risk. For example, if foreign exchange risk rates tend to increase, this could be an indication of an increase in global economic risk. In the next stage, this has the potential to increase interest rates so that credit risk increases, which in turn can increase liquidity risk, which has an impact on cutting a lot of costs to fund a project. This will certainly affect the quality of a project. Because they are too preoccupied with user requirements and resources to work on projects, project managers rarely conduct this comprehensive assessment of a number of risks.

To better identify project risks, a framework with a holistic paradigm is needed. In conducting a risk assessment, ISO 31000:2018 uses risk identification, risk analysis, and risk evaluation activities. Even though there are a number of sub-activity lists and a list of questions that go along with this activity, the project manager frequently ignores them because they believe they have already completed the primary risk assessment activity. Before carrying out a risk assessment, an assessment of risk treatment should be carried out based on the condition of the company's business environment. To identify environmental conditions, we can use the attributes proposed by studies [3], [20], dan [27]: people, process, product, technology, and business. The people dimension is related to the human resources to be used, including competence and labor costs. The process dimension is related to project operational risks, including if there is a COVID-19 pandemic condition that changes work procedures. The product dimension is related to the final product produced, the risk of implementation failure, the risk of raw material logistics, brand, reputation, and licenses. The technological dimension includes technological development, technological change, internet connectivity, and system security. Finally, the business dimension is the most extensive dimension that must be identified along with other units within an organization. This dimension includes competition risk, regulatory risk, financial risk, and macroeconomic or global economic condition risk. In quantitatively measuring these risks, there are several alternatives: the use of data-driven or machine learning [33] [34], deep learning [35] [36] [37], a Bayesian approach [38], and decision support systems [15] [39].

ISO 31000:2018 provides three main dimensions in risk assessment: communication and consultation; monitoring and reviewing; and recording and reporting. The communication and consultation dimension aims to make stakeholders understand project risks. A study [40] identifies these communication issues, including geographical distance, socio-temporal distance, socio-cultural distance, team member's attitude, team issues, organizational and architectural issues, and customer issues. The recording and reporting dimension aims to provide documentation of risk management activities so that they can be taken into consideration when making decisions. Meanwhile, the monitoring and review dimension aims to ensure and improve the quality and effectiveness of process design, implementation, and results. This is related to evaluation and continuous improvement so that risks remain at a controlled level. Meanwhile, risk assessment activities include risk identification, risk analysis, and risk evaluation [41]. Identification of risks observes data and then arranges risk priorities [42]. Risk identification activities are efforts to identify, find, and describe the risks that prevent the organization from achieving its goals. Its main activity is identification. Risk analysis activities have a high variance, depending on the complexity, purpose of the analysis, and availability of resources. Risk evaluation verifies the analysis results against established criteria to determine the required additional policies. What has not been included in these three activities is the scope and constraints of the risks being assessed. To overcome this issue, this study proposes three dimensions of time-cost-quality trade-off, which can provide a more easily understood description [24] [43]. Contraint time will certainly increase costs and reduce quality. Meanwhile, the constraint on cost will increase project execution time and potentially reduce quality. Even though the results show that investing more or spending more to get a resource does not always lead to a reduction in recurring risk [44]. However, quality constraints certainly increase the cost and time to work on a project.

Study [1] proposes a framework that does not yet exist in ISO 31000:2018, namely project performance. In the study [45], it is proposed to interlink sustainability in project portfolio management and project management, one of which discusses the concept of the impact of a project. Project managers are encouraged to improve risk management practices so that the average controlled residual risk is expected to decrease. However, as IT projects develop more innovatively and rapidly, massive risks of unexpected uncertainty and chaos can arise. The level of residual performance risk becomes a guide for project managers to formulate the necessary risk mitigation so that project performance remains at an optimal level. Based on this gap, this study proposes a more comprehensive framework for identifying and monitoring risks so that they remain under control and the stages of project completion go according to plan.

After the framework attributes can be identified, the next step is to make the framework visualization easier to understand. Figure 3 shows the visualization of the proposed project risk management framework. The proposed framework consists of three main stages: root cause, risk assessment, and performance. The proposed framework adapts the concept of risk aggregation; each stage of the framework can be aggregated to the next stage so that risk measurement and monitoring are more holistic.

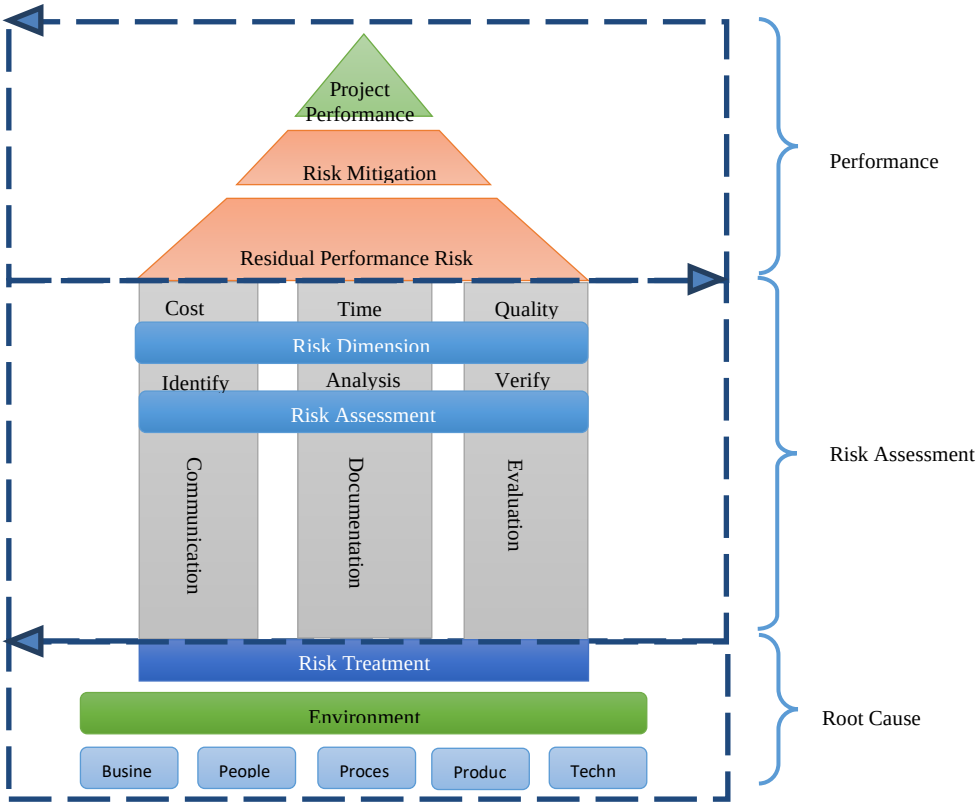

Figure 3. Proposed project risk management framework

At the root cause stage, identification of the business environment is a key factor in finding the right risk treatment. Identification of risks that are inherent in the business environment can be sourced from five clusters: business, people, process, product, and technology. The business cluster is the dimension with the widest coverage. This cluster is closely related to financial risk. The level of depth of the project manager's analysis of business risk is closely related to the time horizon and the company's organisational structure. A study [46] shows that companies with subsidiaries seem to define their risk areas based on a longer time horizon. After the risk treatment can be identified, it is followed by the risk assessment stage. The risk assessment stage includes identification, analysis, and verification activities. These three activities are a summary of the ISO 31000:2018 risk assessment activity. What is different from ISO 31000:2018 is that this framework provides guidelines for risk assessment dimensions including time, cost, and quality. Continuous communication, documentation, and evaluation support the risk assessment activities carried out. The results of the risk assessment are in the form of potential residual performance risks. This residual performance risk results from a combination of unpredictable risk and residual controllable risk. The results obtained from residual performance risk become the basis for formulating appropriate risk mitigation for the project to be implemented. With the right risk mitigation formulation, project performance is expected to be at the level planned. One of the easiest ways to measure performance is to use a cost-benefit analysis (CBA) approach [47] [48]. CBA can be enhanced by evaluating the consequences and probabilities of opportunities and threats in terms of costs, evaluating the cost effects of countermeasures, and identifying key trend indicators. [49]. The proposed framework allows looping within one stage or between stages. The proposed framework allows a project manager to draw connections between the environment and the risk mitigations formulated.

The proposed framework is then tested using the previously collected risk exposures. At the root cause stage, the identified elements are quite diverse. The risks from the business element are the most frequently disclosed. Only one sample does not explicitly disclose business risk. Interestingly enough, as many as 29 sample companies did not explicitly disclose

technology risks. Almost the same thing happened to the people, process, and product elements. This finding indicates that the company has not explored in depth the elements of these risks, focusing more on business risks. Even so, the company can still identify the risk treatment that will be faced, of course, with the note that the measurement is still not holistic. For the risk assessment stage, all samples have disclosed it; this is because all samples have adapted ISO 31000:2018. As an implication of the initial identification, which emphasised too much on the business sector, the risk dimensions that were disclosed were generally limited to the cost dimension; the time and quality dimensions have not been explored in more depth. At the performance stage, the extreme points are found in the residual performance risk and project performance. Data shows that all companies have not disclosed residual performance risk, but still disclose project performance, of course with disclosure standards that emphasise business performance. At the risk mitigation disclosure stage, only 15 samples (45.5%) had documented risk mitigation. As much as 54.5% still rely on leadership discretion in dealing with identified risks. The company still does not have mitigation measures that can be used if the identified risks actually occur.

Table 1. Tables of framework attributes exposed in the sample's annual report

Framework attributes	Exposed	Not Exposed
Root cause:		
Identification of risk elements:		
Business	32	1
People	13	20
Process	9	24
Product	8	25
Technology	4	29
Risk Treatment	33	0
Risk assessment:		
Identifiy	33	0
Analysis	33	0
Verify	33	0
Risk dimension:		
Cost	12	21
Time	0	33
Quality	0	33
Performace:		
Residual performance risk	0	33
Mitigation risk	15	18
Project Performance	33	0

Taking risks is an integral part of human civilization [50]. Even if a project manager does not know the term "risk management" that does not mean that certain risk management practices are not implemented [51]. This is because most risk management models are related to accumulating assets with imperfectly correlated returns, leading to diversification of risk sources [52]. The main focus of risk management is to resolve uncertainties related to the project completion process [53]. One of the things that affects a fairly large level of uncertainty is the scope of work, impact, methods, or results [54]. This uncertainty is represented in the proposed framework by identifying the business environment. The results of the framework

evaluation show that the presentation of risk elements is only focused on business elements. This will make it difficult for the project manager because the operational risk of the project gets less attention. That's why the proposed framework includes technical elements to attract the attention of top managers.

The proposed framework synthesizes ISO 31000:2018 and the study [1]. This study adds root causes and performance stages. The root cause stage is an extraction of risk identification in studies [3] [27]. The performance stage is a study attribute framework [1] that we have developed by adding risk mitigation. At the risk assessment stage, this study adds three dimensions of risk: cost, time, and quality. This is so that the project manager has a guide for classifying risk measurement results that is easier to understand. The results of the framework evaluation indicate that attention to the dimensions of time and quality is still lacking. The same thing also happened with the disclosure of risk mitigation; most companies are still not aware of disclosing risk mitigation and prioritizing management discretion to manage risk. However, overall, the proposed framework is expected to help project managers more easily measure risk, gain a comprehensive understanding, and control risk so that project performance is according to plan.

4. CONCLUSION

This study has extracted risk disclosures from 33 IT companies listed on the Indonesian Stock Exchange. This study identified 122 types of project risks from 33 companies' annual reports. Of the 122 distributed risks, there are 63 business risks, 12 people risks, 22 process risks, 9 product risks, and 16 technology risks. This data forms the basis for developing a project risk management framework. The proposed framework includes three stages, namely the root cause, risk assessment, and performance stages. At the root cause stage, the identification of risks from elements of the business environment becomes the basis for measuring risk treatment. In the next stage, the identified risk treatment is measured through identify, analysis, and verification activities with the support of communication, documentation, and evaluation. The measurement results are classified into three major dimensions, namely cost, time, and quality. The final stage of the framework is in the form of residual performance risk and a risk mitigation action plan. Both of these are used as risk control instruments to ensure that project performance is as planned.

5. SUGGESTION

This study suggests a project risk management framework that IT companies can use. The proposed framework is based on data and information obtained from companies that have been listed on the Indonesia Stock Exchange. In future research, we suggest exploring data and information on Small and medium enterprises (SME) in the IT sector. Exploration related to project performance measurement because this research has not yet proposed a quantitative method of calculating performance.

REFERENCES

[1] L. Sarigiannidis and P. D. Chatzoglou, “Software Development Project Risk Management: A New Conceptual Framework,” *JSEA*, vol. 04, no. 05, pp. 293–305, 2011, doi: 10.4236/jsea.2011.45032.

[2] N. Takagi and J. Varajão, "Integration of success management into project management guides and methodologies - position paper," *Procedia Computer Science*, vol. 164, pp. 366–372, 2019, doi: 10.1016/j.procs.2019.12.195.

[3] M. E. Barghoth, A. Salah, and M. A. Ismail, "A Comprehensive Software Project Management Framework," *JCC*, vol. 08, no. 03, pp. 86–102, 2020, doi: 10.4236/jcc.2020.83009.

[4] A. I. La Paz and R. I. López, "Recommendation method for customized IT project management," *Procedia Computer Science*, vol. 219, pp. 1938–1945, 2023, doi: 10.1016/j.procs.2023.01.493.

[5] H. Portman, "CHAOS 2020: Beyond Infinity," Standish Group, Massachusetts 02109, US, Jan. 2021. [Online]. Available: https://hennyportman.files.wordpress.com/2021/01/project-success-qrc-standish-group-chaos-report-2020.pdf

[6] M. Welde and I. Bukkestein, "Over time or on time? A study of delays in large government projects," *Procedia Computer Science*, vol. 196, pp. 772–781, 2022, doi: 10.1016/j.procs.2021.12.075.

[7] W. S. Wan Husin, Y. Yahya, N. F. Mohd Azmi, N. N. Amir Sjarif, S. Chuprat, and A. Azmi, "Risk Management Framework for Distributed Software Team: A Case Study of Telecommunication Company," *Procedia Computer Science*, vol. 161, pp. 178–186, 2019, doi: 10.1016/j.procs.2019.11.113.

[8] F. Bekius and S. L. Gomes, "A framework to design game theory-based interventions for strategic analysis of real-world problems with stakeholders," *European Journal of Operational Research*, vol. 309, no. 2, pp. 925–938, Sep. 2023, doi: 10.1016/j.ejor.2023.01.046.

[9] S. Chaouch, A. Mejri, and S. A. Ghannouchi, "A framework for risk management in Scrum development process," *Procedia Computer Science*, vol. 164, pp. 187–192, 2019, doi: 10.1016/j.procs.2019.12.171.

[10] P. V. Kukhareva *et al.*, "Evaluation in Life Cycle of Information Technology (ELICIT) framework: Supporting the innovation life cycle from business case assessment to summative evaluation," *Journal of Biomedical Informatics*, vol. 127, p. 104014, Mar. 2022, doi: 10.1016/j.jbi.2022.104014.

[11] M. Cai, C. Bao, and Q. Meng, "Overview of risk aggregation approach in different risk scenarios," *Procedia Computer Science*, vol. 214, pp. 1353–1360, 2022, doi: 10.1016/j.procs.2022.11.316.

[12] A. Aggarwal, K. S. Dhindsa, and P. K. Suri, "An Empirical Evaluation of Assorted Risk Management Models and Frameworks in Software Development:," *International Journal of Applied Evolutionary Computation*, vol. 11, no. 1, pp. 52–62, Jan. 2020, doi: 10.4018/IJAEC.2020010104.

[13] S. Chi *et al.*, "Semi-supervised learning to improve generalizability of risk prediction models," *Journal of Biomedical Informatics*, vol. 92, p. 103117, Apr. 2019, doi: 10.1016/j.jbi.2019.103117.

[14] F. Da, C. Peng, H. Wang, and T. Li, "A risk detection framework of Chinese high-tech firms using wide & deep learning model based on text disclosure," *Procedia Computer Science*, vol. 199, pp. 262–268, 2022, doi: 10.1016/j.procs.2022.01.032.

[15] J. Zhong, J. Lv, and Y. Zhang, "Customized Production Project Risk Management with Analytic Hierarchy Process," *JSS*, vol. 07, no. 01, pp. 85–95, 2019, doi: 10.4236/jss.2019.71008.

[16] L. Domingues and P. Ribeiro, "Project Management Maturity Models: Proposal of a Framework for Models Comparison," *Procedia Computer Science*, vol. 219, pp. 2011–2018, 2023, doi: 10.1016/j.procs.2023.01.502.

[17] M. Elkhatib, A. Al Hosani, I. Al Hosani, and K. Albuflasa, "Agile Project Management and Project Risks Improvements: Pros and Cons," *ME*, vol. 13, no. 09, pp. 1157–1176, 2022, doi: 10.4236/me.2022.139061.

[18] P. Loft, Y. He, I. Yevseyeva, and I. Wagner, "CAESAR8: An agile enterprise architecture approach to managing information security risks," *Computers & Security*, vol. 122, p. 102877, Nov. 2022, doi: 10.1016/j.cose.2022.102877.

[19] S. Beecham, T. Clear, R. Lal, and J. Noll, "Do scaling agile frameworks address global software development risks? An empirical study," *Journal of Systems and Software*, vol. 171, p. 110823, Jan. 2021, doi: 10.1016/j.jss.2020.110823.

[20] J. Wan and Z. Wang, "Case Study on E-Business V Corp. Software Project Risk Management with Interpretive Structural Modeling," *Open Journal of Social Sciences*, vol. 3, no. 4, pp. 1–7, Mar. 2015, doi: 10.4236/jss.2015.34001.

[21] J. Wan and L. Liang, "Risk Management of IT Service Management Project Implementation with Killer Assumptions," *Technology and Investment*, vol. 3, no. 1, pp. 48–55, Feb. 2012, doi: 10.4236/ti.2012.31007.

[22] L. Ika, J. Couillard, and S. Garon, "Coping with Project Complexity: The Complexity Based Project Management Framework," *PM World Journal*, vol. X, no. V, pp. 1–22, 2021.

[23] L. H. Sendstad, M. Chronopoulos, and V. Hagspiel, "Optimal Risk Adoption and Capacity Investment in Technological Innovations," *IEEE Trans. Eng. Manage.*, vol. 70, no. 2, pp. 576–589, Feb. 2023, doi: 10.1109/TEM.2021.3056142.

[24] M. Mrad, K. S. Al-Gahtani, R. Hulchafo, N. Souayah, and K. Bamatraf, "Risk Assessment for Discrete Stochastic Time-Cost-Quality Trade-Off Problem Using Simulation-Based Integer Linear Programming Approach," *IEEE Access*, vol. 7, pp. 32453–32463, 2019, doi: 10.1109/ACCESS.2019.2903229.

[25] J. Wan, Y. Cao, and J. Hou, "Case Study on H Corp. Software Project Risk Management with ISM," *Technology and Investment*, vol. 4, no. 3, pp. 145–152, Jul. 2013, doi: 10.4236/ti.2013.43017.

[26] P. Ávila *et al.*, "Framework for a risk assessment model to apply in Virtual / Collaborative Enterprises," *Procedia Computer Science*, vol. 181, pp. 612–618, 2021, doi: 10.1016/j.procs.2021.01.208.

[27] A. Aggarwal, K. S. Dhindsa, and P. K. Suri, "A Pragmatic Assessment of Approaches and Paradigms in Software Risk Management Frameworks:," *International Journal of Natural Computing Research*, vol. 9, no. 1, pp. 13–26, Jan. 2020, doi: 10.4018/IJNCR.2020010102.

[28] K. B. Bagshaw, "NEW PERT and CPM in Project Management with Practical Examples," *AJOR*, vol. 11, no. 04, pp. 215–226, 2021, doi: 10.4236/ajor.2021.114013.

[29] R. S. Ybañez, L. A. Bautista, and A. R. De La Cruz, "Virtual Project Management (VPM) in Project Execution," *AJIBM*, vol. 12, no. 12, pp. 1867–1912, 2022, doi: 10.4236/ajibm.2022.1212102.

[30] M. A. Fikri, F. A. Putra, Y. Suryanto, and K. Ramli, "Risk Assessment Using NIST SP 800-30 Revision 1 and ISO 27005 Combination Technique in Profit-Based Organization: Case Study of ZZZ Information System Application in ABC Agency," *Procedia Computer Science*, vol. 161, pp. 1206–1215, 2019, doi: 10.1016/j.procs.2019.11.234.

[31] Z. I. Saleh, H. Refai, and A. Mashhour, "Proposed Framework for Security Risk Assessment," *JIS*, vol. 02, no. 02, pp. 85–90, 2011, doi: 10.4236/jis.2011.22008.

[32] L. Pekkinen and K. Aaltonen, "Risk Management in Project Networks: An Information Processing View," *Technology and Investment*, vol. 6, no. 1, pp. 52–62, Jan. 2015, doi: 10.4236/ti.2015.61005.

[33] S.-C. Cha and K.-H. Yeh, "A Data-Driven Security Risk Assessment Scheme for Personal Data Protection," *IEEE Access*, vol. 6, pp. 50510–50517, 2018, doi: 10.1109/ACCESS.2018.2868726.

[34] B. Khan, R. Naseem, I. Alam, I. Khan, H. Alasmary, and T. Rahman, "Analysis of Tree-Family Machine Learning Techniques for Risk Prediction in Software Requirements," *IEEE Access*, vol. 10, pp. 98220–98231, 2022, doi: 10.1109/ACCESS.2022.3206382.

[35] A. Ovsyannikova and J. Domashova, "Identification of public procurement contracts with a high risk of non-performance based on neural networks," *Procedia Computer Science*, vol. 169, pp. 795–799, 2020, doi: 10.1016/j.procs.2020.02.161.

[36] G. Petneházi, "Quantile convolutional neural networks for Value at Risk forecasting," *Machine Learning with Applications*, vol. 6, p. 100096, Dec. 2021, doi: 10.1016/j.mlwa.2021.100096.

[37] V. Polishchuk, Y. Mlavets, I. Rozora, and O. Tymoshenko, "A hybrid model of risk assessment of the functioning of information modules of critical infrastructure objects," *Procedia Computer Science*, vol. 219, pp. 76–83, 2023, doi: 10.1016/j.procs.2023.01.266.

[38] H. Mismar, A. Shamayleh, and A. Qazi, "Prioritizing Risks in Last Mile Delivery: A Bayesian Belief Network Approach," *IEEE Access*, vol. 10, pp. 118551–118562, 2022, doi: 10.1109/ACCESS.2022.3220626.

[39] N. Kim, H. Oh, and J. K. Choi, "A privacy scoring framework: Automation of privacy compliance and risk evaluation with standard indicators," *Journal of King Saud University - Computer and Information Sciences*, vol. 35, no. 1, pp. 514–525, Jan. 2023, doi: 10.1016/j.jksuci.2022.12.019.

[40] G. Ammad, U. Iqbal Janjua, T. M. Madni, M. F. Cheema, and A. R. Shahid, "An Empirical Study to Investigate the Impact of Communication Issues in GSD in Pakistan's IT Industry," *IEEE Access*, vol. 7, pp. 171648–171672, 2019, doi: 10.1109/ACCESS.2019.2953008.

[41] I. Riley, S. Jahan, A. Marshall, C. Walter, and R. F. Gamble, "Evaluating verification awareness as a method for assessing adaptation risk," *Future Generation Computer Systems*, vol. 119, pp. 110–135, Jun. 2021, doi: 10.1016/j.future.2021.01.034.

[42] R. Subramanian, S. Taterh, D. Singh, and H.-N. Lee, "Efficient Fine Tuned Trapezoidal Fuzzy-Based Model for Failure Mode Effect Analysis Risk Prioritization," *IEEE Access*, vol. 10, pp. 50037–50046, 2022, doi: 10.1109/ACCESS.2022.3172513.

[43] E. Masengesho, J. Wei, N. Umubyeyi, and R. Niyirora, "A Review on the Role of Risk Management (RM) and Value Engineering (VE) Tools for Project Successful Delivery," *WJET*, vol. 09, no. 01, pp. 109–127, 2021, doi: 10.4236/wjet.2021.91009.

[44] M. Tsiodra, S. Panda, M. Chronopoulos, and E. Panaousis, "Cyber Risk Assessment and Optimization: A Small Business Case Study," *IEEE Access*, vol. 11, pp. 44467–44481, 2023, doi: 10.1109/ACCESS.2023.3272670.

[45] G. Silvius and C. Marnewick, "Interlinking Sustainability in Organizational Strategy, Project Portfolio Management and Project Management A Conceptual Framework," *Procedia Computer Science*, vol. 196, pp. 938–947, 2022, doi: 10.1016/j.procs.2021.12.095.

[46] R.-P. V. D. Boom, "Financial Risk Management in Dutch SMEs: An Empirical Analysis," *JFRM*, vol. 08, no. 02, pp. 55–72, 2019, doi: 10.4236/jfrm.2019.82005.

[47] H. Berg, K. Holgeid, M. Jørgensen, and G. H. Volden, "Successful IT projects – A multiple case study of benefits management practices," *Procedia Computer Science*, vol. 219, pp. 1847–1859, 2023, doi: 10.1016/j.procs.2023.01.482.

[48] S. Shafiee, E. Sandrin, C. Forza, K. Kristjansdottir, A. Haug, and L. Hvam, "Framing business cases for the success of product configuration system projects," *Computers in Industry*, vol. 146, p. 103839, Apr. 2023, doi: 10.1016/j.compind.2022.103839.

[49] B. Hussein, A. Mallcott, and N. Mikhridinova, "Lessons learned from developing and applying self-assessment instruments for evaluating project management competences in two large organizations," *Procedia Computer Science*, vol. 164, pp. 358–365, 2019, doi: 10.1016/j.procs.2019.12.194.

[50] S. Shankar, "Risk and Rationality," *JFRM*, vol. 08, no. 04, pp. 305–314, 2019, doi: 10.4236/jfrm.2019.84021.

[51] K. Moriya, "The Effectiveness of a Project Manager for Risk Management in a Career Education Project," *Creative Education*, vol. 5, no. 8, pp. 525–532, May 2014, doi: 10.4236/ce.2014.58062.

[52] J. Doering, R. Kizys, A. A. Juan, À. Fitó, and O. Polat, "Metaheuristics for rich portfolio optimisation and risk management: Current state and future trends," *Operations Research Perspectives*, vol. 6, p. 100121, 2019, doi: 10.1016/j.orp.2019.100121.

[53] M. El Khatib, L. Nakand, S. Almarzooqi, and A. Almarzooqi, "E-Governance in Project Management: Impact and Risks of Implementation," *AJIBM*, vol. 10, no. 12, pp. 1785–1811, 2020, doi: 10.4236/ajibm.2020.1012111.

[54] B. Hussein, "The influence of project characteristics on project success factors. Insights from 21 real life project cases from Norway," *Procedia Computer Science*, vol. 164, pp. 350–357, 2019, doi: 10.1016/j.procs.2019.12.193.