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Article

Enhancing innovation competitiveness spun pile method risk: Insights from ISO 56002:2019

Ranti Hidayawanti[1,2,*], Yusuf Latief[2], Iriansyah Sangadji[3], Teuku Yuri Zagloel[4], Mohd Zakwan Ramli[5], Hasan Mohamed[6], Daud Mohamad[5]

[1] Department of Civil Engineering, Institut Teknologi PLN, Jakarta Barat 11750, Indonesia
[2] Department of Civil Engineering, Universitas Indonesia, Depok 16424, Indonesia
[3] Department of Telematica Energy, Institut Teknologi PLN, Jakarta Barat 11750, Indonesia
[4] Department of Industrial Engineering, Universitas Indonesia, Depok 16424, Indonesia
[5] Institute of Energy Infrastucture, Universiti Tenaga Nasional, Kajang 43000, Malaysia
[6] Institute of Sustainable Energy, Universiti Tenaga Nasional, Kajang 43000, Malaysia
*** Corresponding author:** Ranti Hidayawanti, ranti@itpln.ac.id

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Abstract: Integrated risk value response is designed to reduce threats and increase opportunities, especially in terms of running the spun pile method innovation process in accordance with the ISO 56002:2019 standard. Implementing innovation can reduce risks and increase the competitiveness of the company. The method of making or producing spun piles is the research area examined in this study. Questionnaires were distributed to workers in precast concrete companies and most of them were involved in each spun pile production line in the company in order to identify the risk factors that existed in the production line for the spun pile manufacturing method. 30 respondents were workers from organizations in the positions of Director, Manager and Staff. The risk values and impacts are mapped for each dimension to the activity details and it is found that there are 5 high risks as dominant ones, mainly risks with codes R41, R10, R4, R37, and R36. Based on a survey, the highest risk of 30% was found in the stressing & spinning dimension, which is recommended for the innovation process. Innovation is conducted with 5 innovation processes, mainly identifying opportunities, creating concepts, validating concepts, developing solutions, and deploying solutions. Recommendations for improvements are made with preventive and corrective actions that must be taken from every aspect of the spun pile production method activities. Innovation recommendations are also proposed to monitor production activities in real-time utilizing existing information and communication technology. Handling of spun pile waste material must also be implemented with certain methods and produce products that add value for the company. Ultimately, to increase the company's competitiveness by increasing assets, it is recommended to increase the company's intangible assets. The company's intangible assets encompass IPR ownership in the form of Patents and Copyrights.

Keywords: innovation; competitiveness; spun pile; risk; ISO 56002:2019

1. Introduction

Organizations have traditionally used new product development frameworks to improve the effectiveness of their innovation programs. These strategies have been successful in the past but are increasingly challenged by developments in today's markets and technology. This has led companies in several sectors to shift to a new competitiveness paradigm, specifically innovation solutions (Shepherd and Ahmed, 2000). Today, innovation has become essential for small, medium, and large companies and if it can be applied correctly, it enables their growth and sustainability

(Gómez Montoya et al., 2015). In the field of construction, precast and prestressed concrete systems have been implemented since 2007, but unfortunately, the implementation has not been optimal because the construction method is not conducted integrally (Nurjaman et al., 2017). The quality of precast products in a production company is determined and monitored from prefabrication (Benjaoran and Dawood, 2006) and production to stockyard (Marasini et al., 2001). The quality of the product must be guaranteed, especially if it goes through a long supply chain until it reaches the consumer. The precast concrete supply chain has a long process and timeframe and this is often an obstacle in its implementation. The long supply chain process often causes problems or risks in its performance. In order to know what risks arise in the process of the supply chain stages, it is necessary to analyze the risks in the supply chain of the precast concrete industry. Risk analysis is implemented by first identifying potential risks, and then calculating the analysis by multiplying the probability and impact of the risks that arise (Arthaningtyas et al., 2023).

There are many precast products that are produced and used today and one of these products is spun pile. Utilization of product spun pile are used to carry relatively heavy loads into fairly deep soil layers. In a study, it was found that there were problems in the production of spun piles; the average percentage of spun pile defects was 0.71%, exceeding the company standard, which is 0.5%. The five dominant defects that occur are fin, peeling, sticky skin, warping, and breaking. Based on the analysis of the Spun Pile production process, the DPMO is 617, and the sigma level value is 4.73 (Arizka et al., 2022). Defects in spun pile products are still discovered, so it is necessary to study and identify the current method of manufacturing spun pile products in Indonesia to improve product competitiveness, product attractiveness, product quality, and price competitiveness. The use of products, methods, and technologies in the precast concrete industry in Indonesia is expected to have a corporate strategy, specifically innovation in precast concrete manufacturing methods for buildings and infrastructure. Work methods greatly influence changes in quality with increasingly tight competition between companies, encouraging each company to create products that improve product quality, estimate material availability, and determine production schedules according to demand (Noerpratomo, 2018). A good manufacturing planning method will drive the marketing strategy to be competitive. Long-term marketing strategies must pay attention to how the product and production technology, as well as the methods used in order to control the production process, are the characteristics of the company from competing companies. One form of competition from modern marketing is the process of developing innovative products with new services, new methods, new technologies, and new processes (Li et al., 2020). The innovation process that will be carried out in the research aims to improve spun pile production methods and recommendations for intellectual property rights based on risk identification which is surveyed on all manufacturing employees which are involved in the spun pile production line. Employee survey involvement covers all positions of Director, Manager and staff who are directly involved in the spun pile assembly line (30 people), so that data validation will be accurate. survey was carried out by filling in online (Google form) for director level, filling in online files and interviews for manager and staff levels. The Questionnaire will determine the respondent's perception of the frequency of recurrence of risk that will be measured and calculated.

The purpose of this study is to identify risks in the spun pile production line and then calculate the impact that will arise. Based on the proposed risk analysis mapping, it will be integrated to provide innovation recommendations for the spun pile production line that will increase the company's competitiveness based on the 56002 innovation process. The proposed innovation development is in the form of improvements to work methods and standards (Standard Operation Procedure) and potential intellectual property rights in the form of Patents and Copyrights.

2. Study literature

2.1. Innovation management system

Organizations have several goals, including competitiveness, high profits, and long-term survival. However, sustainability has become a standard practice for both business and non-business organizations as it leads to better performance. The sustainability process does not come naturally; this manner requires adequate resources and capabilities. Existing studies have looked at the factors that influence and uphold the principle of sustainability, but rarely address the aspect of innovation in this regard (Y. Zhang et al., 2019). Innovation is considered to be the main driving force of business growth and prosperity. Consequently, numerous efforts are made to develop new technological knowledge, new process technologies, and new products (Volberda et al., 2013). Organizations with the proper human resources can play a role in developing their employees' innovativeness. Despite the existence of some literature on organizational innovation management, in some scenarios, there are some organizations that have the tendency to inhibit employee growth and innovation in the workplace (Khan, 2021). In the end, the implementation of an innovation management system is still being implemented due to the need for company growth. Aspects that need to be considered are related to products or services, information and communication technology, technological issues, leadership, organizational structure, work processes, employee skills, working conditions, teamwork, cooperation with other companies, and wage systems. Of course, everything must be developed to encourage innovation (Tudor et al., 2014).

In 2019, the ISO Technical Committee 279 released a new international standard for innovation management systems called ISO 56002:2019 (Tidd, 2021; Tidd and Bessant, 2018). The purpose of this standard is to provide a framework for building an innovation ecosystem that can remain relevant (Hyland and Karlsson, 2021). Similar to the quality management systems established by ISO decades ago, this innovation standard provides instructions relating to best practices on how to manage innovation activities, projects, and programs. It has been estimated that over 75% of innovative projects initiated through an Innovation Management System (IMS) fail or fail to produce the desired outcomes. This underlies the inquiry as to why this standard is necessary and needed. The greatest waste that occurs in most medium to large organizations is due to the waste of money, time, reputation, opportunities, and revenue that leads to failure (Benraouane and Harrington, 2021; Harrington and Benraouane, 2022). The implementation of ISO 56002:2019 is necessary to cut down on waste of money, time, reputation, opportunities, and revenue. The implementation is conducted by adhering to and following the innovation process based on ISO 56002:2019 clause 83 as shown in **Figure 1**.

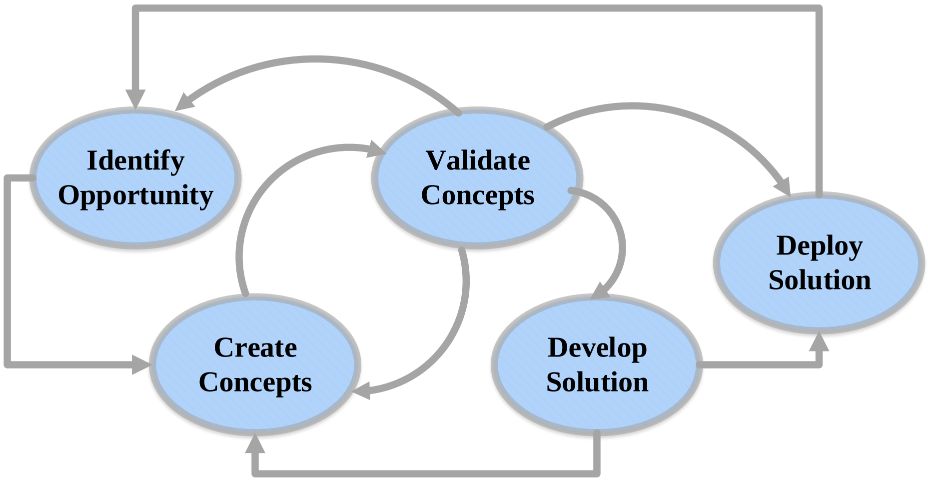

Figure 1. Innovation process based on ISO 56002:2019.

In-service innovation activities also tend to be a continuous process as shown in **Figure 1**, consisting of a series of incremental changes in products and processes. Five dimensions of the innovation process which include identity opportunities, create concepts, validate concepts develop and deploy solutions will be implemented continuously. This approach can sometimes be challenging in order to identify in-service innovation in terms of a single event, such as the implementation of significant changes in products, processes, or other methods.

Innovation is the implementation of new or significantly improved products in the form of goods or services, processes, new marketing methods, or new organizational methods in business practices, workplace organization, or external relations. Innovative companies are those that have implemented innovation during the period being reviewed (Gault, 2013). Innovation is the process of discovering new ideas, methods, tools, or things that need to be managed in innovation management to improve human life. An innovation process is a change that affects the way output is produced, while product innovation has the opposite definition. Specifically, product innovation is a change in the actual output of the products and services itself (Bateman, 2019). Innovation management should provide a common framework for developing and deploying innovation capabilities, evaluating performance, and achieving desired outcomes.

2.2. Innovation and design

Innovation is the key aspect for productivity improvement and progress in various sectors of the economy, including the construction industry. Criticisms of the slow pace of innovation in the construction industry may not always be accurate, given the characteristics of the industry structure and the nature of the construction industry itself (Davis et al., 2016). With increased globalization marking 21st-century trends such as personalization and commoditization of technology, product design has become an integral part of product development for engineering professionals and manufacturers. This is associated with shifting industry terminology including crowdsourcing, cloud-based design and manufacturing, mass collaboration, and the concept of Open Innovation (Forbes and Schaefer, 2017). Open Innovation describes an emerging innovation model where companies utilize research and development that may not originate from within the organization, For example, the use of open source software and itself (Keil and Salmenkaita, 2023). The conventional product design process and the design results produced by the designer are still subject to evaluation and optimization for the next process, mainly in terms of the manufacturing process and the assembly process by the production department. During this process, it may be necessary to make design adjustments that require consultation with the designer to improve efficiency. This is related to the three aspects of the product, mainly quality, cost, and production time (Fathurrachman Batara Sulo et al., 2023). If the context involves products in the construction business industry, therefore it is also related to six things that influence the production industry, mainly: (1) client and producer aspects; (2) production structure; (3) relationships between individuals and firms within the industry and between the industry and external parties; (4) procurement systems; (5) regulations/standards; and (6) the nature and quality of organizational resources. Awareness and emphasis on these factors by business decision-makers and public policymakers will be a key component of effective innovation strategies and policies (Blayse and Manley, 2004). Considering the factors above, this study will focus on the 5th aspect relating to regulations and standards to achieve company competitiveness.

2.3. Implementation of internal company innovation

A company's innovation policy is a system of regulatory measures for the organization including management and conditions conducive to the process of creation, implementation, and realization of successful innovations. It must be structured following a sequence of activities in planning, organizing, developing, and introducing novelties using administrative and economic influences to maintain the potential for a positive internal environment for innovation (Bichurova and Yordanova-Dinova, 2018). There is general agreement that innovation is driven by those who are at the heart of a company's innovation enterprises. However, people innovate in specific institutional environments that must comply with rules, and there may be regulations that support or inhibit innovation. The open innovation paradigm requires companies to be more involved in the external relationships of the company to achieve innovation. Nevertheless, companies often overlook true internal employee transparency, which is crucial before collaborating with external partners (Kratzer et al., 2017). Companies must develop an innovation strategy that outlines how they seek out and solve problems at the organizational level by synthesizing ideas, concepts, and designs into their business strategy (Schmuck and Benke, 2020). Innovation performance in Indonesia, especially construction, is relatively low due to lack of knowledge and poor quality of internal management (Theodora and Latief, 2020).

Measurable steps to be implemented by assessing the impact of external and internal factors on the operating organization at the company level will be identified. The need to implement strategic management of innovation processes at the company level must be implemented and the structural interaction of external and internal factors in the company's operating organization will be determined. Subsequently, the classification of external and internal environmental factors in the context of strategic management of innovation processes at the company level should be compiled (Shatilo, 2019). Establishing and executing an effective eco-innovation strategy in the company must adapt to changes and a dynamic environment so that it can contribute to a competitive advantage. In this case, internal factors have a greater influence in shaping the most suitable and effective business model. Nevertheless, there are also internal factors that can only be modified to enhance the efficiency of responding to changes in the business environment. Circumstances like this are the reason why the company's internal capabilities need to be explored in depth and then developed comprehensively (Salim et al., 2019). Competitive companies, especially in Indonesia, are closely connected to innovation, whose main purpose involves the creation of ideas that are different from those of their competitors in the same industry. This implies that during a company's product innovation, they require a unique advantage or specific market specification. These conditions necessitate analytical contributions, regarding methods to enhance product competitiveness and marketing strategies for precast organizations (Hidayawanti, 2023).

The spun pile production process is in accordance with the interviews and survey observations in this study. It was conducted at a precast manufacturer in Indonesia and then data collection was conducted which was processed quantitatively and qualitatively. The extraction of facts and processes, as well as the validation of the results by experts on the variables and factors proposed as material for preparing the questionnaires, were analyzed using the Delphi method. The spun pile production process is divided into cutting & heading, forming & setting, casting, stressing & spinning, and curing & demolding activities (Andika, 2023; Satyadharma, 2022), as shown in **Figure 2**.

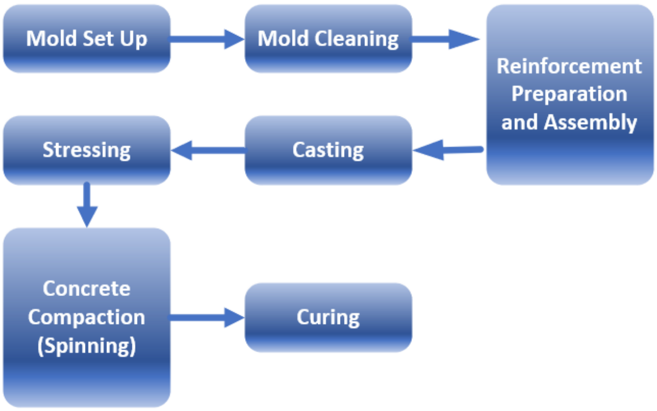

Figure 2. Spun pile manufacturing process.

In **Figure 2**, the production of spun piles begins with mold preparation, mold cleaning, reinforcement preparation and assembly, casting, stressing, concrete compaction by spinning process, and curing. One of the most crucial factors in the production of spun piles is the pile's production capacity. Optimization of each stage of the process determines the production capacity.

2.4. Innovation, intellectual property rights, and corporate competitiveness

Various theories and research in the field of economics indicate that there are many factors that determine a nation's competitive economic position. Apart from classic factors such as having natural resources, technology, and capital (including human capital), other elements include openness and readiness to generate and apply innovations obtained. In this regard, an important role is played by the country's institutional and legal system, which provides economic freedom, free competition, and protection against monopoly, corruption, and crime. According to some research, intellectual property issues (and more precisely, industrial property) also play an important role (Poszewiecki, 2019). In the field of Economics with an International background, intellectual property rights competition has become a new area of competition to achieve competitive value for companies. The development of intellectual property competitiveness has come to be an important goal of corporate strategy (T. Zhang and Dai, 2011).

Companies must have and evaluate their intellectual property rights and the quality of their patent documents to develop innovative products as well as be able to identify and discover the latest technology trends. The product technology covered by a patent claim is protected by law, and the quality of the patent guarantees against infringement by competitors, while also enhancing the value of the invention. Thus, patent quality analysis is needed as a means by which companies can determine whether to adjust and produce innovative products or not. This is because patents provide significant financial protection for businesses, and the number of patent applications is increasing rapidly. Companies that cannot process patent information or fail to protect their innovations by filing patents will inevitably lose market competitiveness (Trappey et al., 2012). Referring to existing research, there is no direct quantitative relationship between a company's competitive value and the amount of intellectual property it owns. However, a company's innovation value is usually measured by the valuation of its intellectual property assets.

The practical implication of innovation encountered in companies is in industrial design, which is currently the most efficient IPR for SMEs to protect their intellectual property in terms of open innovation collaboration. It also depends on the size of the company, where the use of different IPRs is recommended. In addition, companies should strive to improve the efficiency of open innovation and the use of IPRs (Brem et al., 2017). In this study, IPR recommendations in the form of Patents and Copyrights will be proposed.

According to DJKI (Kemenkumham) (2020), a patent is the inventor's exclusive right over an invention in the field of technology for a certain period of time to carry out or grant approval to another party to carry out the invention. Copyright is the exclusive right of the creator that arises automatically based on the declarative principle after a creation is manifested in a tangible form without prejudice to the limitations in accordance with statutory provisions.

Ownership of IPRs will increase the number of company assets because IPRs can also be categorized as intangible assets (Ardhanti, 2022).

Of course, the registration and formulation of claims for the company's intellectual property ownership must be carried out through a verification process by experts in that field.

2.5. Risk management

According to the 6th edition of the PMBOK, there are several important stages in risk management. First, the risk management plan helps formulate risk management activities. Then, risk identification involves recognizing and documenting risks and their sources. Qualitative risk analysis is carried out to improve the efficiency of precast concrete production with a focus on key risks. Quantitative risk analysis involves a numerical evaluation of the combined impact of risks on overall objectives through expert interviews and questionnaires. The risk response plan is designed to mitigate threats and increase opportunities, especially in terms of innovation in precast concrete methods. Implementation of risk response is the application of recommended innovations after approval, while risk monitoring includes tracking the implementation of response plans, identifying new risks, and evaluating the effectiveness of risk management that has been carried out (ASV, 2021).

Decisions regarding the procurement of goods and contracts in civil engineering projects have a broad effect on the development and implementation of innovation. Trends regarding integrated contracts are beginning to increase the construction industry's ability to stimulate innovation. However, to implement radical innovation, the allocation of innovation risk tends to be avoided because most of the associated innovation risks are difficult to assess, predict, and manage due to high uncertainty (Lenderink et al., 2022).

Regarding the mentioned difficulties, the risks in each sub-process in the spun pile production line will be calculated and identified and then they will be integrated with the innovation process that will result in innovation recommendations to management.

3. Respondent demographics and risk calculation

In this research, the criteria for filling out the questionnaire are divided into three, namely recent education, work experience, and position. The tested criteria must have the same level of homogeneity, which is to show whether two or more sample data groups are taken from populations with the same variance and to determine whether there is a difference in perception between respondents based on certain criteria.

The null hypothesis (Ho) is accepted if the *p*-value is in the *Asymp column. Sig* ≥ *Level of Significance* of 0.05.

The null hypothesis (Ho) is rejected if the *p*-value is in the *Asymp column. Sig* < *Level of Significance* of 0.05.

Figure 3 shows 30 respondents who have filled out the questionnaire, in the position category consisting of 3 categories and work experience and education divided into 4 categories. Based on the results of the homogeneity test on these 3 criteria, there is no difference in perception between respondents with different backgrounds.

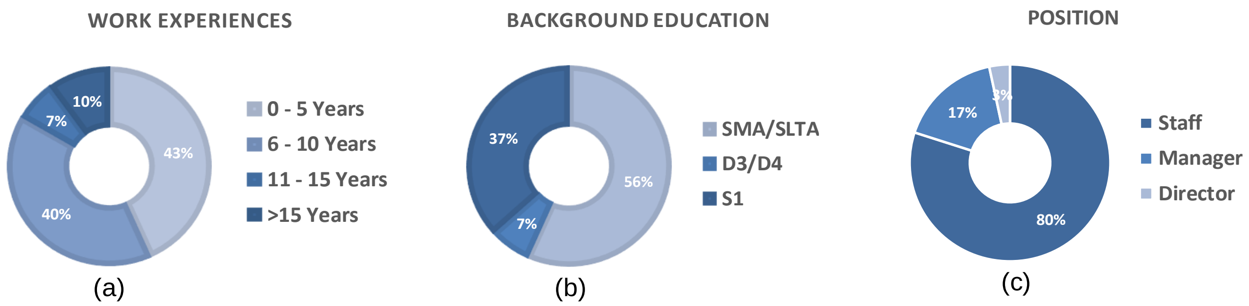

Figure 3. Respondents who filled out the questionnaire. **(a)** Work Experieces (%); **(b)** Background Education (%); **(c)** Position (%).

The final impact score value is calculated based on the average value of the impact value survey results referring to the equation.

$$Impact_{average} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) \quad (1)$$

where;

n = respondents,

x_i = respondent's answer.

The risk score value is the average frequency of risk multiplied by the average impact of the risk that occurs.

$$Frequency_{average} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) \quad (2)$$

where;

n = respondents,

x_i = respondent's answer.

$$Score_{risk} = Impact_{average} \times Frequency_{average} \quad (3)$$

Risk classification will be divided into 3 (three) classes, namely: High Risk, Medium Risk, and Low Risk.

$$Score_{risk} \rightarrow Classification = \begin{cases} High\ Risk \\ Medium\ Risk \\ Low\ Risk \end{cases} \quad (4)$$

The proportion of risk value if calculated against the failure and success of spun pile products from every 100 rods follows the calculation:

$$High\ Risk_{Prop} = \frac{High\ Risk_{Total}}{High\ Risk_{Total} + Medium\ Risk_{Total} + Low\ Risk_{Total}} \times 100 \quad (5)$$

$$Medium\ Risk_{Prop} = \frac{Medium\ Risk_{Total}}{High\ Risk_{Total} + Medium\ Risk_{Total} + Low\ Risk_{Total}} \times 100 \quad (6)$$

$$Low\ Risk_{Prop} = \frac{Low\ Risk_{Total}}{High\ Risk_{Total} + Medium\ Risk_{Total} + Low\ Risk_{Total}} \times 100 \quad (7)$$

4. Methodology

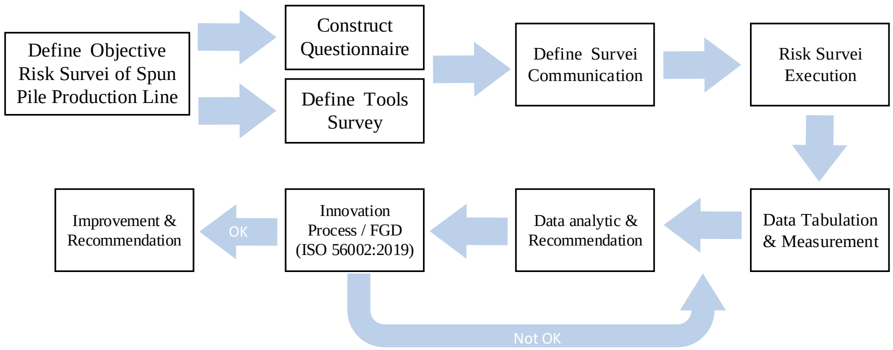

Figure 4. Methodology diagrams.

Determining the objectives of risk survey activities on the spun production line in **Figure 4** is by defining respondent, namely all personnel involved in the scope of spun pile production from every level of the organizational structure. Prepare questions and media or questionnaire tools in the form of google forms, statistical methods and questionnaire sheets that will be distributed. Draft Survey communications with management approval. Carry out planned risk survey activities. Tabulate, classify risk data from survey results and carry out measurement using statistical tools. Analize the results of measurement tabulation and make recommendations based on statistical analysis. Carrying out innovation process activities according to standard ISO 56002:2019 by conducting FGDs with experts and management for innovation decisions to be implemented. The results of the innovation process carried out can be implementation can be postponed with re-analysis to make it more acceptable.

5. Result and discussion

5.1. Risk identification

Based on the results of the survey questionnaire distributed, it was identified that there were 66 activities that had risks from the Spun Pile production method in manufacturing. The details show there were 4 risks at the cutting and heading stage, 19 risks at the forming and setting stage, 11 risks at the casting stage, 7 risks at the stressing and spinning stage, and 25 risks at the final stage, namely curing and demolding. The risk value and risk impact will be classified into three risk categories. The categories are Low Risk, Medium Risk, and High Risk.

It can be identified that there are 5 dimensions which are sub-processes of the spun pile production line. There are a total of 19 indicators from the existing dimensions consisting of 2 indicators for cutting and heading, 3 indicators for forming and setting, 5 indicators for casting, 3 indicators for stressing and spinning, and 6 indicators for curing and demolding. From a total of 19 indicators based on field observations, 66 activities were identified. This is illustrated in **Figure 5**.

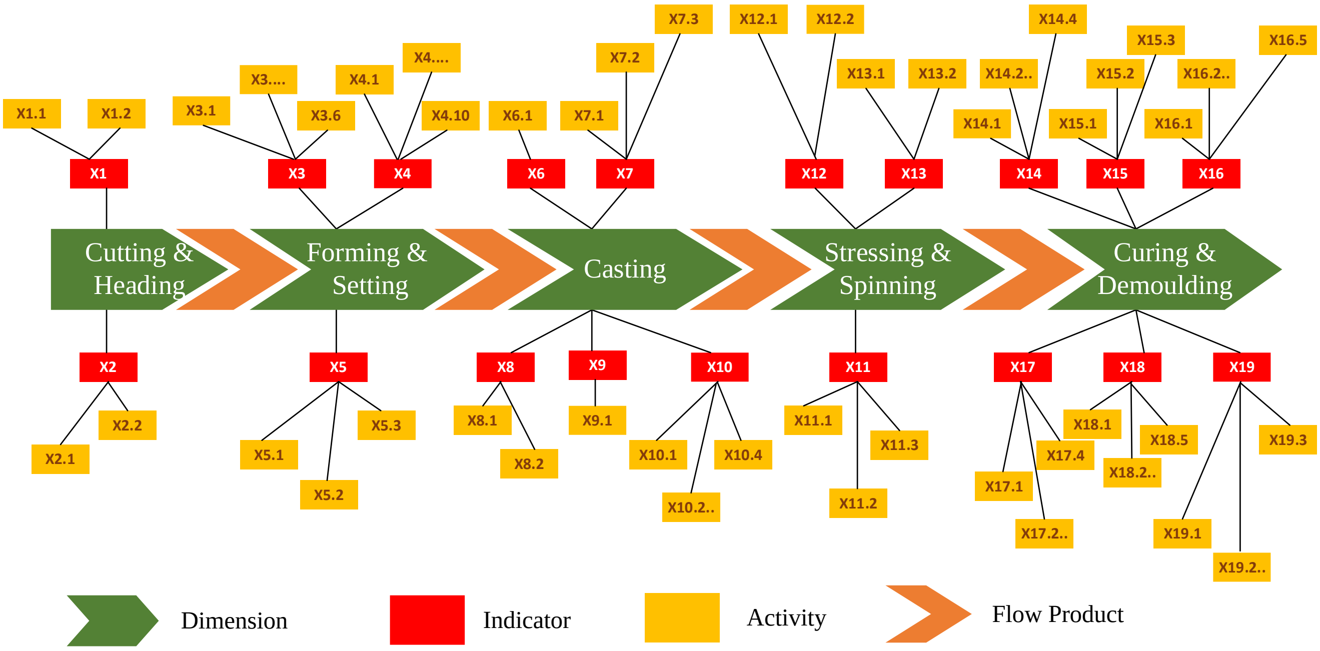

Figure 5. Detailed mapping of spun pile manufacturing method.

Identification of risks from each activity as seen in **Figure 5** will be calculated using Equations (1)–(7).

Based on this spun pile manufacturing method, more in-depth research was conducted through interviews, observations, and validation from experts to identify the objectives of each activity in order to identify risks. The processed risk survey results were then ranked according to the risk level for each activity for each dimension, as shown in **Figure 6**.

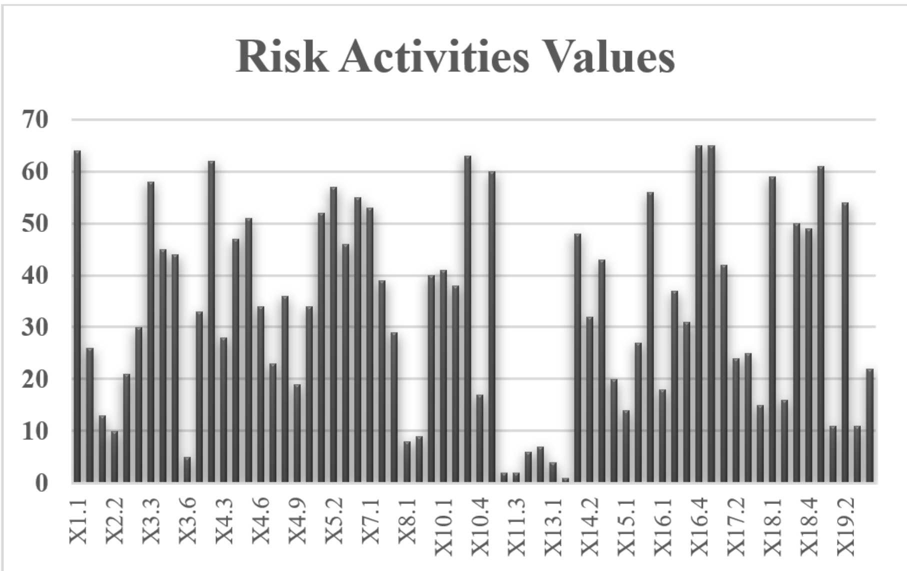

Figure 6. Values of risk activities.

Figure 6 above shows the results of an analysis of filling out risk questionnaires by respondents from several precast companies in Indonesia. There are 5 high risks, 16 medium risks, and 45 low risks. The dominant risks will be analyzed in the high-risk analysis which will underlie the method innovation with preventive and corrective actions in the spun pile manufacturing process.

Based on the survey data Risk Level classification, from the low, medium to high-risk categorization aspect, the results are shown in **Table 1**.

Table 1. Results of risk assessment of spun pile manufacturing method.

Risk Level	Dimension				
	Cutting & Heading	Forming & Setting	Casting	Stressing & Spinning	Curing & Demolding
Low Risk	2	16	8	1	18
Medium Risk	1	2	3	3	7
High Risk	1	1	0	3	0

The table above illustrates the results of an analysis of filling out risk questionnaires by respondents from several precast companies in Indonesia. There are 5 high risks, 16 medium risks, and 45 low risks. The dominant risks (high risk) will be analyzed from each dimension, and this will form the basis for the method innovation recommendations in the form of preventive and corrective actions in the spun pile manufacturing process. Thus, from the 5 high risks as shown in **Table 1**, the dominant risks are risks 41, 10, 4, 37, and 36. The high-risk values are then marked and analyzed by considering the production process on the indicators and production method activities, as shown in **Table 2**.

Table 2. High risk factors.

Main Activity	Sub Variable	Rank Risk	Risk ID	Risk Factor
Stressing & Spinning	Compaction (Spinning)	1	R41	The diameter of the spinning machine wheel is flattened and there is a sound
Forming & Setting	Making Rebar Arrangement	2	R10	Spalling or product breaks when the pile head is driven
Cutting & Heading	Making PC Bar Heads	3	R4	PC bars are not of the same length in one diameter
Stressing & Spinning	Mould Closing	4	R37	Loss of cement paste during the spinning process
Stressing & Spinning	Mould Closing	5	R36	Eye bolt flies out during the spinning process

According to the results of the research conducted for the risk survey, if based on the indicators, the order of the largest accumulated value is first Curing & Demolding and Stressing & Spinning at 29% each, casting at 14%, Forming & Setting at 14% and finally Cutting & Heading at 14%. Measurement and analysis Survey results based on **Tables 1** and **2** show that spun pile production lines in companies, especially in Indonesia, indicate that the riskiest production handling is in the Stressing and Spinning. The implications must influence the organization’s policy to carry out appropriate improvement innovations based on the greatest risk value.

If based on activities, then the first rank is Curing & Demolding and Stressing & Spinning at 30% each, the second is Casting and Forming & Setting at 15% each, and the third is Cutting & Heading at 10%. The method aspect is one of the aspects that must be carried out in the innovation process activities in this study. There are many other aspects both internal and external to the organization that have not been measured. This can be carried out in further research and this is a limitation in the discussion of this study.

5.2. Innovation identification result

Based on the risk categories shown in **Table 1**, the urgency of the innovation carried out must be in accordance with the value category of each risk.

The innovation process is carried out in 5 stages (**Figure 1**), namely identifying opportunities, creating concepts, validating concepts, developing solutions, and deploying solutions. The following is the implementation of the innovation process design on the spun pile manufacturing method in this study. Integrating the assessed risks into the innovation process has been carried out as shown in **Table 3** below.

Table 3. The innovation process of method based on ISO 56002:2019.

Innovation Process					
Identify Opportunities		**Create Concepts**	**Validate Concepts**	**Develop Solutions**	**Deploy Solutions**
Explanation	Search for GAP analysis and opportunities	Concepts or ideas for improvement/filling gaps and options to take advantage of opportunities	Validation of ideas and innovation concept designs	Development by collecting valid innovation ideas and concepts	Realization of the value of innovative ideas to be realized in a tangible form
Input	Observation of spun pile manufacturing method	Existing Spun Pile production method	Implementation plan for the method according to the dominant risk and additional preventive activities	Implementation recommendations from the analysis of the validated manufacturing method innovation	Discussion review of the recommendations that have been improved and adjusted to the FGD results
Process	Analysis of relevant documents (literature study), interviews and observations	Risk-based process innovation concepts	Presentation and discussion of the FGD implementation plan for the method and preventive activities	Refinement is carried out from the recommendations of the FGD results	Proposing the issuance of a decree and the implementation of SOPs
Output	Existing Spun Pile manufacturing method	Implementation design of risk-based method and additional preventive activities	Recommendations for the implementation of validated innovations regarding the manufacturing method	Review the complete recommendations (ideas) that have been adjusted to the FGD recommendations	• Decree on implementation of recommendation • Monitoring & Evaluation, as well as periodic control of innovation recommendations

5.3. Innovation recommendations

Based on **Table 3**, the details of the preventive and corrective improvement recommendations for the spun pile manufacturing method innovation based on the 5 high risks obtained are shown in **Table 4** below.

For risk 4, which is related to PC Bar length discrepancies within one diameter, it is recommended to calibrate the forming machine to ensure consistent lengths. For risk 37 related to less neat and chipped finishing, it is recommended to implement an online quality monitoring system. Also, it is suggested to implement an online quality monitoring system innovation for the risk related to the eye bolt flying out (risk 36), which can cause loss of cement paste during the spinning process and surfaces that do not meet standards.

Table 4. Preventive and corrective actions for high-risk method innovations.

No	Risk Factor	Cause	Impact	Preventive Action	Corrective action
1 R4	PC Bars are not of the same length in one diameter	Bar Cutter is no longer suitable or damaged The stopper position does not match the cutting length of the iron	The tensile force is not evenly distributed (concentrated on the longer PC Bar) during the stressing process	Equipment condition inspection Checking the stopper position and machine calibration	Rework by carrying out reprocessing activities from cutting PC Bars and creating product sorting or reject reports
2 R10	Spalling or product breaks when the pile head is driven	The iron wire spacing is not uniform or does not comply with standards The iron wire is not attached properly due to the PC Bar not being clean	Rejected product	Checking the distance of the spiral iron wire in the additional activity of checking the rebar arrangement (after installing accessories) Calibrate forming machine Checking that the PC Bar is free from rust and defects and that the number matches the shop drawing	Product non-conformance reporting
3 R36	Eye bolt flies out during the spinning process	Operator negligence The eye bolt is not installed securely The eye bolt is in damaged condition so it cannot be tightened	Loss of cement paste during the spinning process	Inspection of machine operators Check the eye bolt installation Calibrating the impact wrench, especially the pump Regularly sorting the feasibility of eye bolts	Carrying out additional finishing activities by polishing parts of the Precast concrete surface that have lost cement paste so that the surface becomes flat and smooth
4 R37	Loss of cement paste during the spinning process	The impact wrench pump is not working optimally There are eye bolts that are not installed (The number of eye bolts installed does not match the length of the mold)	The product surface performance is not dense and neat	Regularly checking the condition of the impact wrench tool and creating tool maintenance data records Tightening the eye bolts on both sides simultaneously and sequentially using an impact wrench tool	Carrying out additional finishing activities by polishing parts of the Precast concrete surface that have lost cement paste so that the surface becomes flat and smooth
5 R41	The diameter of the spinning machine wheel is flattened and there is a sound	The spinning RPM speed and time do not comply with the standards due to the deformation of the spinning wheel	The time and quality of the outer curve of the spun pile do not meet the standards	Checking machine condition and creating spinning machine maintenance data records	Ensure the condition of machines and equipment before each machine operation is carried out

For risk number 41 which is related to rejected products, it is recommended to utilize these rejected products by converting them into concrete barriers. The implementation of these innovation recommendations is expected to improve product quality and production efficiency, and reduce risks associated with the spun pile manufacturing workflow. Each action as shown in **Tables 3** and **4** is a form of recommendation to company management. The Focus Group Discussion (FGD) mechanism was carried out by bringing all the results of the risk assessment survey, details of operations, and real facts on the spun pile production line. The FGD process involves company management and experts to achieve recommendations.

The results of recommendations for improvement are shown in **Table 5** below.

Table 5. Recommendations for method innovation.

Process Activity	Innovation	
Stressing & Spinning	Online Quality Monitoring System	A visual monitoring system with stereo-vision technique. This technique is configured to enable sequential data acquisition and online data transfer, which estimates the pose of the spun pile product relative to the design status in real-time and is used to detect product defects in visual form in real-time during the spun pile production process so that the physical characteristics of the spun pile can be identified, such as dimensions, surface conditions, and others. Increase production efficiency through a real-time defect detection quality check method as an initial.
Inspection	Utilization of spun pile paste waste as a paving block manufacturing material	In the spinning process activity, there is waste material, namely pasta waste. The remaining paste or waste produced from the spun pile making process can be used as a component of the mixture in making paving blocks. In this context, the paste waste can be considered as an additional material mixed with the main raw materials such as sand, cement, and other aggregates. Utilize the existing waste into added value, as waste management, and reduce waste disposal costs.
	Concrete barrier from rejected spun pile products	Spun pile waste material that cannot be reused from rejected products can be utilized by making product reject chunks as raw material for concrete barriers that meet the required technical requirements. Utilize rejected products to have added value that reduces losses

In addition to the method recommendations shown in **Table 5**, based on the analysis in **Table 4**, recommendations for potential Intellectual Property Rights can be identified from each improvement activity carried out.

The recommended types of IPR in Indonesia are Patents and Copyrights. Patents have a commercial protection period of 10 to 20 years. Copyrights have varying ownership protection periods. Some are for 20 years, 50 years or for the lifetime of the creator, or more than 70 years. This depends on the type of work required.

Table 6. Recommendations for intellectual property rights.

Main Activities	Sub Variable	Risk ID	Action	Form	Potential IPR
Stressing & Spinning	Compaction (Spinning)	R41	Preventive	SOPs/Manuals	Copyright
			Corrective	SOPs/Manuals	Copyright
Forming & Setting	Iron Making Series	R10	Preventive	Model	Patents
			Corrective	Manuals	Copyright
Cutting & Heading	Manufacturing of PC Bar Heads	R4	Preventive	SOPs/Manuals	Copyright
			Corrective	SOPs/Manuals	Copyright
Stressing & Spinning	Mold Closing	R37	Preventive	SOPs/Technology	Copyright/Patent
			Corrective	SOPs/Manuals	Copyright
Stressing & Spinning	Mold Closing	R36	Preventive	SOPs/Technology	Copyright/Patent
			Corrective	SOPs/Manuals	Copyright

In addition to the proposed potential IPR recommendations as shown in **Table 6**, 2 (two) more Patent registrations can also be proposed for the waste handling model and waste products. As seen in **Table 4**, in the inspection process activity column, this is related to the processing of waste material into paving blocks and concrete barriers with special material characteristics means producing new innovative products.

6. Conclusion and future research

Based on the risk assessment of the spun pile production line at a manufacturing company in Indonesia, it appears that the highest potential risk is in the 4th process, which is the Stressing & Spinning sub-process with 3 risks, namely R36, R37, and R41. Cutting & Heading has 1 risk (R4) and Forming & Setting has 1 risk (R10). The focus of the innovation process carried out is to reduce the risk value in high-risk category activities in the spun pile production method process. Improvement recommendations are made by defining preventive and corrective actions for each aspect of the spun pile production method activities. Monitoring and measurement of results are also carried out on the results of preventive and corrective actions. This is to assess how much the risk value can be reduced while the product quality and production line can be improved. Innovation recommendations are also proposed to monitor production activities in real time utilizing existing information and communication technologies. Handling of spun pile waste material must also be carried out using certain methods and produce value-added products for the company. To increase the company's competitiveness by increasing assets, it is recommended to increase the company's intangible assets. The company's intangible assets are in the form of IPR ownership which is the result of the company's innovation. **Table 6** shows recommendations for the company's potential IPR which can be in the form of Patents and Copyrights. The commercial value of the acquired IPR has the potential to benefit the company in the future.

The assessment and analysis of the innovation process for product and production company competitiveness of spun piles is not only influenced by variables of the spun pile manufacturing method and risk-based variables. There are still other variables such as planning, technology, products, and others, even external company variables also have an influence such as competitors, prices, regulations, and others. These are recommendations for future research activities.

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