Innovation of Spun Pile Manufacturing Method in Indonesia Using a Risk Approach and ISO 56002 Innovation Process to Increase Competitiveness

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INNOVATION OF SPUN PILE MANUFACTURING METHOD IN INDONESIA USING A RISK APPROACH AND ISO 56002 INNOVATION PROCESS TO INCREASE COMPETITIVENESS

Abstract. As of market for precast is thriving, some activities still need to be carried out optimally and efficiently for precast concrete products by taking into account competitors locally and abroad to encourage continuous improvement necessity of productivity performance in increasing the competitiveness of companies. Thus, developing innovative methods for making precast concrete products is necessary. Focuses on a product with the highest production capacity in Indonesia, precast concrete with the rotary method spun pile. The paper aims to explore Indonesia's current precast concrete production process activities, identify risk factors, and find high risk as the basis of innovation of spun pile manufacturing methods. This goal was achieved using qualitative research, combining and validating the results from experts on production process activities and risk factors, which were analyzed using the Delphi method and ISO 56002. The findings of this study are focused on the dominant risk, honeycomb concrete, from the spinning process activity. This study resulted in an innovation process of high-volume fly ash cementitious mixtures for cement grout injection on honeycomb concrete and additional preventive activities on spun pile workflow, generated from 66 risk factors to increase a company's competitiveness in facing market competition.
Keywords: Innovation, Manufacturing Methods, Precast Concrete, Risk, Competitiveness, ISO 56002

1. Introduction

With the construction industry increasingly turning to precast concrete, the demand for precast is thriving. The lack of literature studies discussing precast concrete productivity by exploring the activities carried out in making precast concrete has resulted in poor analysis to develop precast concrete manufacturing activities (production process activities) currently in Indonesia. Previous studies found that companies achieve competitive advantage through innovation, one of which is the production process. There is a positive relationship between activities in the production area and company competitiveness by optimizing production flows with the most sophisticated production processes through innovation [1]. Thereof identifying the current precast concrete production process activities in Indonesia is needed to increase the competitiveness of products, product attractiveness, product quality, and competitive prices [2]. The use of precast products, methods, and technology in the precast industry in Indonesia is expected to have a corporate strategy, namely, innovation in the activity method of the precast concrete production process for buildings and infrastructure. Work methods significantly influence quality changes with increasingly fierce competition between companies, encouraging each company to create products that improve product quality, estimate material availability, and determine production schedules so that it is completed according to demand [2].

Good activity planning will encourage the marketing strategy to have competitiveness. The long-term marketing strategy does not forget how the products and production technology, as well as the methods used to control the production process, are the company’s characteristics from competing companies. One of the competitive forms of modern marketing is the process of deploying innovative products with new services, new methods, new technologies, and new processes [3]. The traditional mass-production model is no longer suitable for today’s market competition. Companies must compete to find solutions to increase their competitiveness [4]. Thus it is necessary to explore and innovate in making precast concrete. Precast concrete products generally are made of non-rotary and rotary methods. This research focuses on a product with the highest production capacity in Indonesia, precast concrete with the rotary method spun pile [1]. Risk management provides a methodology that can be used to see and manage the future with a scientific, structured, and comprehensive approach. The risk identification process can be essential in developing implemented innovations. By correctly understanding that risk is not just downside risk in the form of threats, organizations naturally identify top risks that can support the creation of opportunities and ensure that these opportunities support innovation with a proper innovation process from ISO 56002 [5].

2. Materials and Methods

2.1 Spun Pile Manufacturing Product in Indonesia

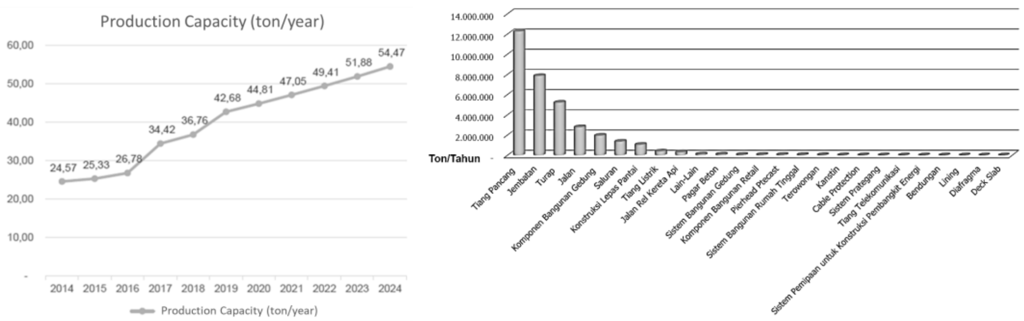

Figure 1 Existing Conditions, Precast Concrete Capacity Targets, and Product Availability Production Capacity

Source: AP3I, 2020 [6]

The trend of precast concrete production is increasing every year, except for the impact of the Covid-19 pandemic on the precast industry, requiring precast concrete production capacity to grow as well, as of market for precast is thriving. According to data from AP3I Members, Indonesia provided a production capacity of 24.6 million tonnes per year from a total of 57 factories. In 2015 it increased to 25.3 million tonnes per year from 58 factories. In 2016 it increased to 26.8 million tonnes per year from a total of 63 factories, and in 2017 it increased to 34 million tons per year from a total of 76 AP3I Member factories [1]. Figure 1 shows the production capacity of product availability in Indonesia, which AP3I reviewed in 2020, where the highest precast concrete product is spun pile [6].

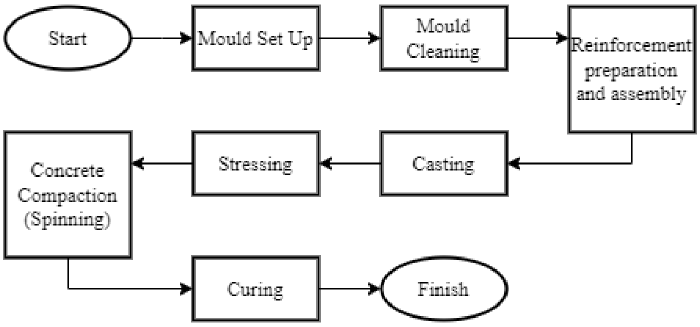

Figure 2 Spun Pile Production Process Diagram

Source: Satyadharma, 2022 [7]

In Figure 1, Indonesia's spun pile production begins with mould setup, mould cleaning, reinforcement preparation and assembly, casting, stressing, concrete compaction with spinning, and curing. One of the most important things in the spun pile production process pile is the production capacity of the pile itself. The optimum of each process stage determines production capacity [7].

From this spun pile process activity, research was carried out in more depth with interviews, observation, and expert validation to identify the goals and objectives of each activity to identify risks.

2.2 Company Competitiveness

Company competitiveness is part of a form of ability or advantage that is used as a strategic plan in creating part of the accumulated value of the company and is not carried out by competitors, and is difficult for competitors to imitate [8].
Competitiveness is the company's ability to compete with its competitors. Therefore, every company must have a competitive strategy and competitive advantage focused on dynamic processes [9].

The construct of company competitiveness, the Y variable in this research, is the superior ability of a company to provide more value to its products than its competitors through a dynamic process with cost, quality, and time [10].

2.3 Risk Management

According to PMBOK 6th edition [11], there are several stages in carrying out risk management. Namely, there are risk management plans, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, risk response implementation, and risk monitoring. The following is a discussion of risk management based on PMBOK 6th edition that is done in this study:

- Risk management planning is the process of defining how to carry out risk management activities.
- Identify Risks is the process of identifying overall risks and sources of risk and documenting their characteristics. The main benefit of this process is the documentation of existing risks and overall sources of risk [11]. Methods as tools and techniques that can be used vary, one of which is to make a checklist. This risk list can be developed based on information collected from the company.

- Perform qualitative risk analysis to improve the production performance of precast concrete manufacturing effectively, and this can be done by focusing on risks with the highest priority or high level. Qualitative risk analysis is used to test the priorities of the risk list that have been identified.
- Perform quantitative risk analysis is the process of numerically analyzing the combined effect of identified risks and other sources of uncertainty on the overall objective [11]. From the risk list, it can be determined the level of influence of the risks that have been identified. Data is collected through interviews and questionnaires given to experts (expert judgment).
- Plan risk response is carried out to increase opportunities and reduce threats to objectives. In that case, a risk response is developed, which becomes a recommendation for an innovative precast concrete method.
- Implement Risk Response is the process of implementing an agreed risk response plan. After the innovation recommendations for the manufacturing method pass the risk response plan, the innovation recommendations can be implemented according to the decision letter completed by the company.
- Monitor risk is the process of monitoring the implementation of agreed risk response plans, tracking identified risks, identifying and analyzing new risks, and evaluating the effectiveness of the risk process. Monitor the risk response or innovation recommendations that have been implemented so that the risk management performance that has been carried out can be identified.

2.4 *Manufacturing Method Innovation*

Innovation is a process of finding new ideas, methods, tools, or something that needs to be managed in innovation management to benefit human life. Process innovation is a change that affects how the output is produced, while product innovation has the opposite definition. Namely, product innovation is a change in the actual output of the goods and the service itself [12]. Innovation management provides a general framework for developing and deploying innovation capabilities, evaluating performance, and achieving desired results.

The Plan-Do-Check-Act (PDCA) [13] cycle can be used in innovation management to enable continuous improvement of innovation management. The PDCA cycle can be applied to an innovation management system or its parts.

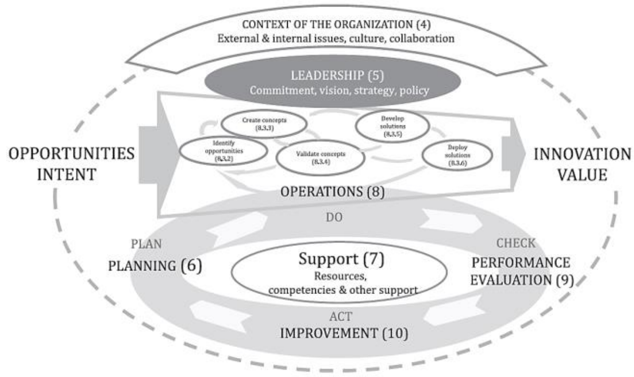

Figure 3 PDCA Guidelines for Innovation Management Systems

Source: ISO 56002 [13]

The innovation process is carried out in 5 stages: identifying opportunities, creating concepts, validating concepts, developing solutions, and deploying solutions. The following is a design implementation of the innovation process in this study.

Table 1 Manufacturing Method Innovation Process

Innovation Process	Description	Input	Process	Output
Identify opportuniti	Search GAP analysis and opportunities	Identification of production process activities	Archive analysis, interview, and observation	Precast Concrete manufacturing activities
Create concepts	Efforts to fill gaps and take advantage of opportunities	Opportunity identification output	Process innovation with a risk approach	The manufacturing method's risk factors, dominant risk, and additional preventive activities.
Validate concepts	Validate ideas and innovation concepts created	Create concepts output	Presentation and discussion of the design results of the FGD	Process innovation analysis regarding the validated production process activities
Develop solutions	Development of ideas from validated innovation concepts	Concept validation output	Refinement of the recommendations from the FGD discussions	Suggestions that have been corrected and adapted to the results of the FGD
Deploy solutions	Realization of the value of innovative ideas to be realized	Develop solutions output	Submission of making SOPs to carry out innovation recommendations	Implementation of innovation recommendations and monitoring of innovation implementation

The company achieves a competitive advantage through innovation, one of which is a new production process. There is a positive relationship between activities in the production area and the competitiveness of companies by optimizing production flows with the most sophisticated production processes through innovation [14].

2.5 Frameworks

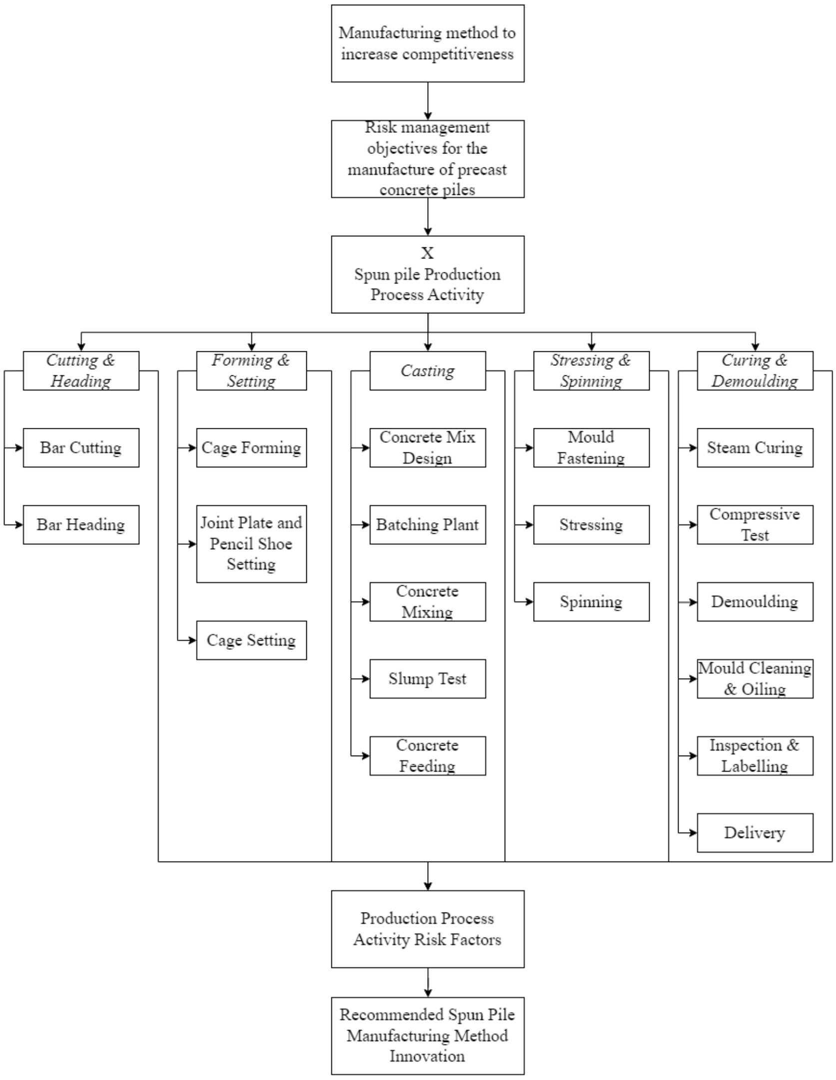

Figure 4 Research Framework

Carrying out an innovation process in developing innovative methods to reduce costs, improve quality, and timely completion of manufacturing method innovations using the most current and sophisticated production processes will increase a company's competitiveness in facing market competition. In this study, the innovation of the precast concrete method is based on the framework in figure 3, where the manufacturing method increases competitiveness by providing innovative recommendations for making precast concrete from the highest risk obtained from the objectives of each activity in the spun pile production process. The method concept emphasized the steps conducted in the production of an effective and efficient process [15].

3. Results and Discussions

3.1 Innovation Manufacturing Method Factors

Data was collected from literature studies, interviews, and observations. Interviews and observations were conducted by visiting a precast factory in Indonesia, then carried out qualitatively, combining and validating the results from experts on the variables and factors proposed and analyzed using the Delphi method. The spun pile production process is divided into cutting & heading, forming & setting, casting, stressing & spinning, and curing & demoulding activity. In Figure 4 are the activities contained therein.

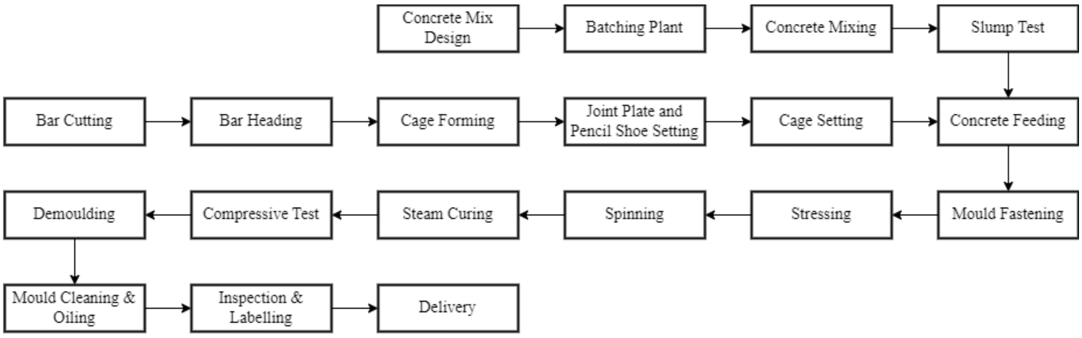

Figure 5 Current Manufacturing Methods for Spun Pile in Indonesia

3.2 *Manufacturing Method Risks*

Table 2 Main Activities and Variables Production Process Activities

Main Activities	Production Process Activity				
	Cutting & Heading	*Forming & Setting*	*Casting*	*Stressing & Spinning*	*Curing & Demoulding*
Variables	Bar Cutting^{X1} Bar Heading^{X2}	Cage Forming^{X3} Joint Plate and Pencil Shoe Setting^{X4} Cage Setting^{X5}	Concrete Mix Design^{X6} Batching Plant^{X7} Concrete Mixing^{X8} Slump Test^{X9} Concrete Feeding^{X10}	Mould Fastening^{X11} Stressing^{X12} Spinning^{X13}	Steam Curing^{X14} Compressive Test^{X15} Demoulding^{X16} Mould Cleaning & Oiling^{X17} Inspection & Labelling^{X18} Delivery^{X19}

Analyzing manufacturing methods risk is the stage of the create concept innovation process where this is a way to determine the high level or dominant risk. There are 18 variables from the activity process within 5 main activities that contain 66 identified risks from validated sub-activity production process activities, variable X of this study. Each risk is analyzed according to the 6th PMBOK Risk Management [11] by validating respondents, as the validate concept stage of the innovation process, from several companies in Indonesia regarding the frequency and impact of each risk to obtain risk level.

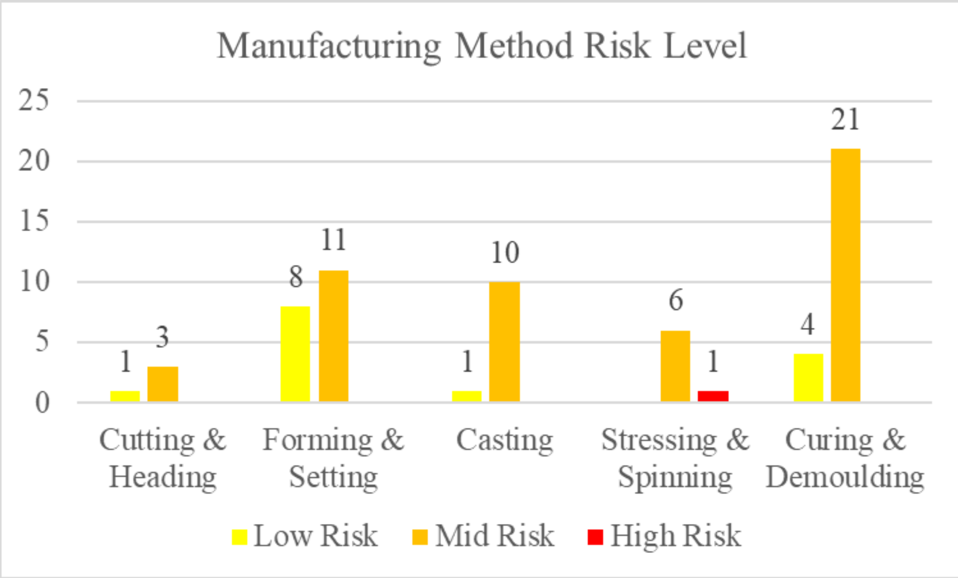

Figure 6 Manufacturing Method Risk Level

The graph in figure 6 results from an analysis of filling in the risk questionnaire by respondents from several precast companies in Indonesia. There were 14 risks included in the low risk level, 51 risks in the middle risk level, and 1 high risk, which became the dominant risk in this study. Dominant risks will be analyzed in the high risk analysis and other risks will underlie additional preventive activities in the spun pile manufacturing process.

3.3 High Risk Analysis

In this study, one high risk was found, which became the dominant risk, namely honeycomb concrete due to imperfect compaction risk, in the spinning process activity. The following is the development solutions stage in the innovation process by producing a risk analysis and providing suggestions that have been corrected and adapted to this risk.

Table 3 High Risk Analysis

High Risk: Spinning Process					
X13	Risk Description	Cause	Preventive action	Impact	Corrective Action
	Honeycomb concrete due to imperfect compaction	Dry ready mix due to late spinning process	Conditioning the slump value according to the spun pile cycle	Product defect	Grouting
		Loss of ready mix pasta (leaking) due to moulds that are not entirely closed	Carry out activities to ensure that the mould is completely closed (Eyebolts must be installed on both sides along the mould)		

		Unstable aggregate gradation	Sieve when pouring concrete into the mould		

One of the innovations in manufacturing methods for grouting can be done with high-volume fly ash cementitious mixtures for cement grout injection. According to prior research [16], it is advised to mix cement with additional cementitious materials (SCMs), such as fly ash, silica fume, ground granulated blast-furnace slag, or others, to improve Preplace Aggregate Concrete (PAC) grout. Fly ash was found to increase grout pump ability and lengthen its handling time. Moreover, it can be considered a sustainable SCM because fly ash reduces water demand and is made from waste. In addition, it was found that substituting 33% fly ash for portland cement greatly reduced the heat of hydration. Fly ash can enhance spread and decrease flow time, delaying the setting of lean grout mixtures. Fly ash particles only start to harden after cement hydration, producing calcium hydroxide. This delayed reaction caused by the high substitution of portland cement with fly ash can double the setting time compared to pure cement grout.

3.4 *Additional Activities on Spun Pile Workflow*

In addition to analyzing high risk, additional activities on spun pile workflow are generated from 66 risks identified, and preventive action is needed in the spun pile manufacturing process, which experts have validated. These preventive activities include operator inspection, tools and machine condition checks, cage checks before casting, and other activities, as shown in figure 7.

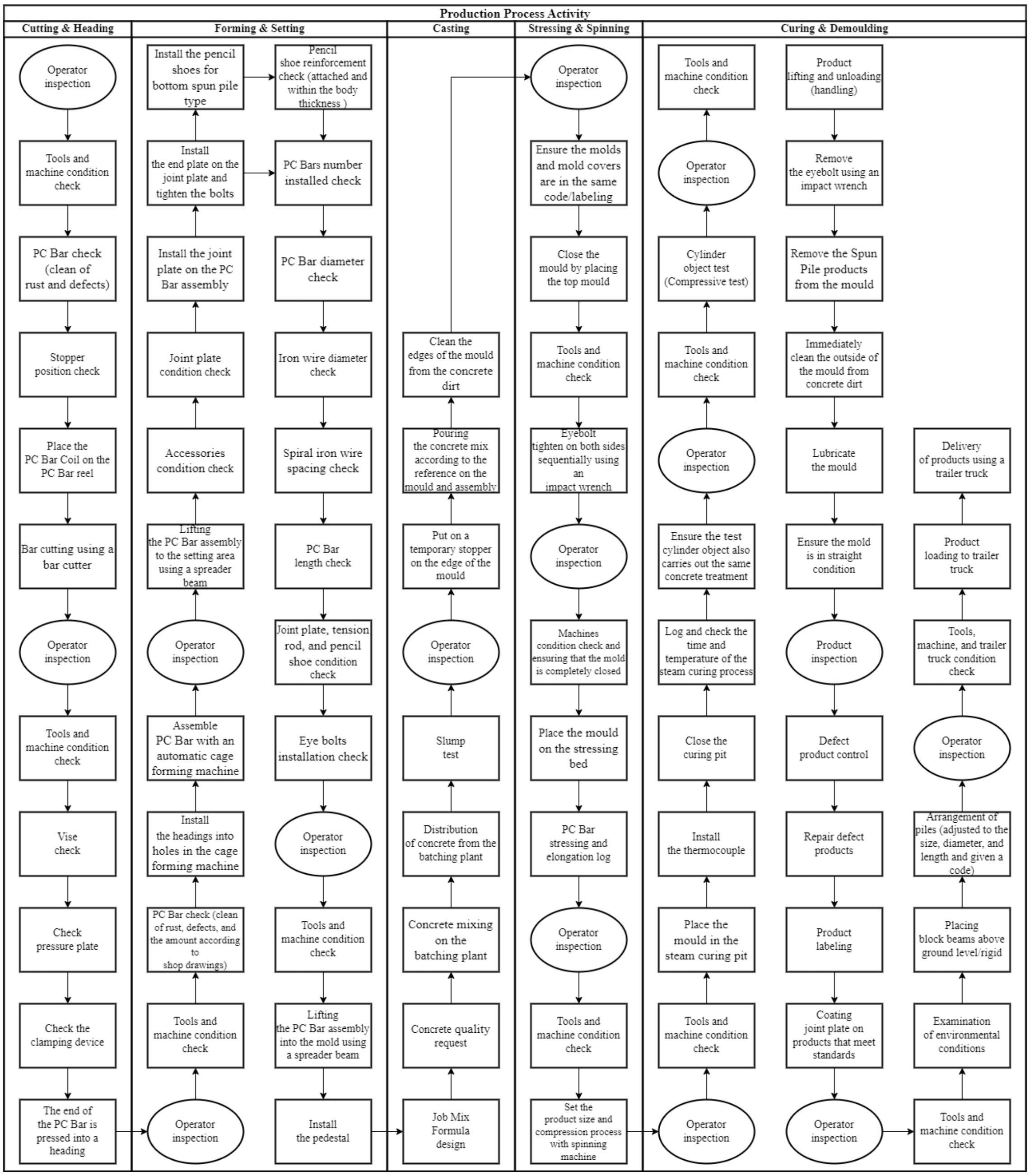

Figure 7 Additional Activities on Spun Pile Workflow

Spun pile workflow consists of five main work activities. Starting with cutting & heading, there are four preventive activities before the bar cutting activity and five preventive activities before the heading bar. In forming & setting, there are 16 additional preventive activities. Furthermore, in casting, there is one preventive activity. Then in the process of stressing & spinning there are seven preventive activities. And curing & demoulding process has 15 preventive activities.

The additional activities in the spun pile work flow are the sub-activities of variable X, which total 21. These activities include:

1. Bar Cutting
2. Bar Heading
3. Cage Forming
4. Joint Plate and Pencil Shoe Setting
5. Cage Check

6. Cage Setting
7. Concrete Mix Design
8. Batching Plant
9. Concrete Mixing
10. Slump Test
11. Concrete Feeding
12. Mould Fastening
13. Stressing
14. Spinning
15. Steam Curing
16. Compressive Test
17. Demoulding
18. Mould Cleaning & Oiling
19. Inspection & Labeling
20. Stock Yard/ Air Curing
21. Delivery

4. Conclusion

This study has identified current manufacturing methods for spun pile in Indonesia with five main work activities, including cutting & heading, forming & setting, casting, stressing & spinning, and curing & demoulding activity, conducted by Interviews and observations. Also, the study identified 66 risk factors from these activities, one dominant risk, which is honeycomb concrete due to imperfect compaction risk, in the spinning process activity. Additional preventive activities on spun pile workflow are generated from identified risk factors such as operator inspection, tools and machine condition checks, cage checks before casting, and other activities to achieve optimal and efficient spun pile manufacturing methods. With one dominant risk, the innovation of spun pile manufacturing method with honeycomb concrete can be done by high-volume fly ash cementitious mixtures for cement grout injection as corrective action.

For future study, research can be done with different types of object research by types of precast concrete products to recommend precast concrete innovation to increase a company's competitiveness in facing market competition.

5. Acknowledgement

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