INNOVATION MANUFACTURING METHOD OF PRECAST CONCRETE FOR SPUN PILE PRODUCTS AT PRECAST CONSTRUCTION COMPANY IN INDONESIA WITH A RISK APPROACH AND ISO 56002 INNOVATION PROCESS TO INCREASE COMPETITIVENESS

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Abstract. With the construction industry increasingly turning to the precast concrete method because of its ability to reduce costs, improve quality and be on time in production, the market for precast is thriving. In Indonesia, according to data from the Ministry of Public Works and Public Housing, the use of precast concrete increases every year from 24 million tons in 2014 to 41.82 million tons in 2019. Activities that still need to be carried out optimally and efficiently for precast concrete products by taking into account competitors locally and abroad encourage continuous improvement necessity of productivity performance in increasing the competitiveness of companies. Thus, it is necessary to develop innovative methods for making precast concrete products by identifying the risks that hinder the process of making precast concrete. Precast concrete products generally are made of non-rotary and rotary methods. Focuses on a product with the highest production capacity in Indonesia, precast concrete with the rotary method spun pile. The paper aims to explore the current precast concrete production process activities in Indonesia and identifies risk factors for company competitiveness in precast concrete 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. Using ISO 56002, additional activities on spun pile workflow are generated from 66 risk factors and innovation processes. Innovation in high-risk spun pile manufacturing methods through causes, preventive actions, impacts, and corrective actions will be obtained from the dominant risk from spinning process activities to increase a company's competitiveness in facing market competition.
Keywords: Innovation, Manufacturing Methods, Precast Concrete, Risk, Competitiveness

1. Introduction

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. In 2014 AP3I Members 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, according to the AP3I data profile [1]. Several local companies have produced various precast products. Still, there is no consistency in size or quality because the producers make different precast constructions based only on orders, without considering the minimal design loads the duct system can carry. Hence, it is inefficient [2]. Apart from that, according to Sundari [2], in the production and mixing of materials (mix design), they pay less attention to the materials used, so the results are also inadequate, and production decreases. So to increase the competitiveness of local products, product attractiveness, product quality, and competitive prices are needed. 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 lead to product quality improvement through materials for production, estimating material availability, and determining production schedules so that it is completed according to demand [3].

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. 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 innovate in the method of making precast concrete. 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 [5].

2. Materials and Methods

2.1 Current Methods for Making Precast Concrete in Indonesia

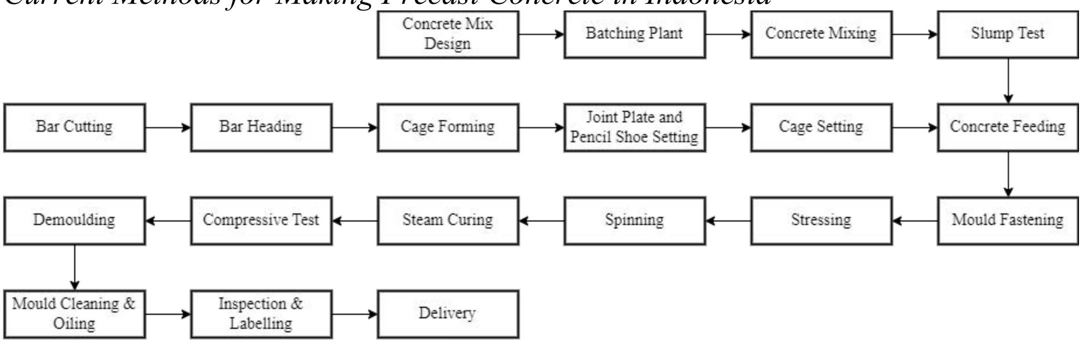

Figure 1 Current Methods for Making Precast Concrete in Indonesia

The spun pile production process is divided into cutting & heading, forming & setting, casting, stressing & spinning, and curing & demoulding activities. In Figure 1 are the activities contained therein.

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 [6].

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 [7].

The company's competitiveness aimed at in this study 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.

2.3 Risk Management

According to PMBOK 6th edition [8], 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:

- Risk management planning is the process of defining how to carry out risk management activities. The key benefit of this process is ensuring that risk management level, type, and visibility are commensurate with the risks and importance to the company and other stakeholders.
- 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 [8]. 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 list of risks 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. The main benefit of this process is that it measures overall risk exposure and can also provide additional quantitative risk information to support risk response planning [8]. From the list of risks created, it can be determined the level of influence of the risks that have been identified. Data collection is done through interviews and questionnaires given to experts (expert judgment).
- Plan risk response is carried out to increase opportunities and reduce threats to objectives. It is necessary to assume what factors can lead to inefficient precast concrete production. Suppose these factors are known based on the assumptions that have been determined in the list of risks. 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 method of making the precast concrete pass the risk response plan, the innovation recommendations can be implemented according to the decision letter made 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 both the goods and the service itself [9]. Innovation management provides a general framework for developing and deploying innovation capabilities, evaluating performance, and achieving desired results.

The Plan-Do-Check-Act (PDCA) [10] 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 as a whole or its parts by:

- Plan is the stage for setting goals and determining actions to address opportunities and risks.
- Do, carry out as planned in terms of support and operations.
- Check, monitors and (where possible) measures results against objectives.
- Act, is done by taking action to improve the innovation management system's performance continuously.

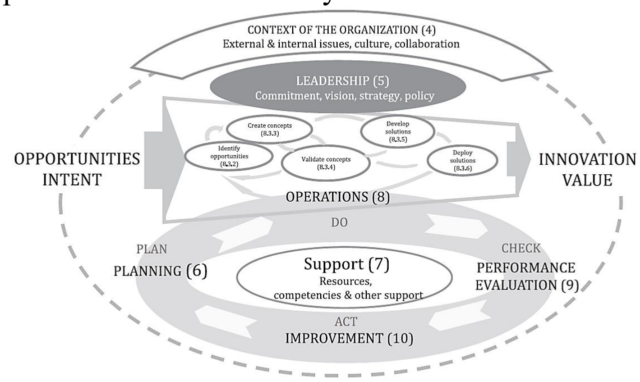

Figure 2 PDCA Guidelines for Innovation Management Systems

Reference: ISO 56002 [10]

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

MANUFACTURING METHOD	Description	Input	Process	Output
Identify opportunities	Search GAP analysis and opportunities	Identification of Precast Concrete production process activities	Archive Analysis	Precast Concrete manufacturing activities
		Identification of variables and risk factors in the method of making Precast Concrete that affects the competitiveness		Factors in the method of making Precast Concrete that affects the competitiveness
Create concepts	Efforts to fill gaps and take advantage of opportunities	Opportunity identification output	Process innovation system orientation through the implementation of a manufacturing innovation management system with a risk approach	The design of production process activity factors that affect company competitiveness and innovation in methods of making precast concrete through high risk
Validate concepts	Validate ideas and innovation concepts created	Create concepts output	Presentation and discussion of the design results of the FGD	The results of the process innovation analysis regarding the validated production process activities

MANUFACTURING METHOD	Description	Input	Process	Output
Develop solutions	Development of ideas from validated innovation concepts	Concept validation output	Refinement and completion 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.

2.5 Frameworks

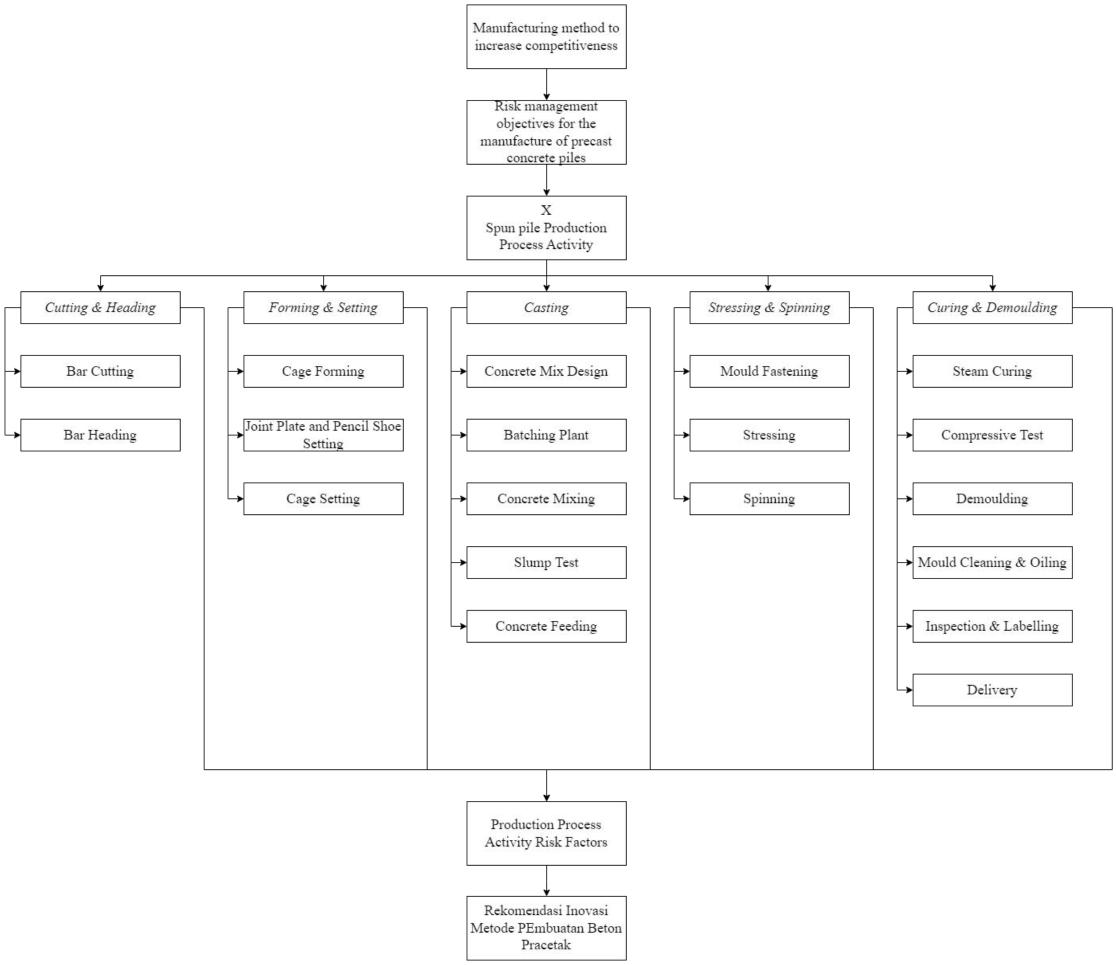

Figure 3 Research Framework

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 method of making precast concrete is based on the framework above, 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.

3. Results and Discussions

3.1 Innovation Manufacturing Method Factors

Data collection was carried out from the results of literature studies, interviews, and observations. Interviews and observations were carried out 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 following is a production process activity, variable X of this study, and validated by experts, which is the output of the innovation process of the identify opportunities stage.

Table 2 Innovation Manufacturing Method Factors

Var No.	Production Process Activity	
	Variable	**Sub Variabel**
Cutting & Heading		
X1	*Bar Cutting*	Place the PC Bar Coil on the PC Bar reel
		Make PC Bar cuts using a bar cutter
X2	*Bar Heading*	The emphasis on the PC Bar ends as the Heading Bar on the heading machine
Forming & Setting		
X3	*Cage Forming*	PC Bars that have been subjected to the heading process are installed in the holes in the cage forming machine
		Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar Settings, Iron Wire, and welding current conductor distance)
X4	*Joint Plate and Pencil Shoe Setting*	Lifting the PC Bar assembly to the setting area using a spreader beam
		Installing the joint plate on the iron assembly
		Installing the end plate on the joint plate and tightening the nuts and bolts on the end plate
		Installation of pencil shoes
X5	*Cage Setting*	Lifting the PC Bar assembly that has accessories installed on the mould using a spreader beam
		Installing the pedestal iron
Casting		
X6	*Concrete Mix Design*	Designing the Job Mix Formula
X7	*Batching Plant*	Request for concrete quality
		Distribution of concrete from the batching plant
X8	*Concrete Mixing*	Making concrete mix on the batching plant
X9	*Slump Test*	Performing slump tests
X10	*Concrete Feeding*	Put on a temporary stopper on the edge of the mould
		Pouring the concrete mix according to the reference on the mould and assembly
		Clean the edges of the mould from the remains of the concrete
Stressing & Spinning		
X11	*Mould Fastening*	Close the mould by placing the top mould
		Eyebolt tightening on both sides simultaneously and sequentially using an impact wrench
X12	*Stressing*	Placing the mould on the stressing bed
		PC Bar withdrawal, recording, and checking elongation

Var No.	Production Process Activity	
	Variable	**Sub Variabel**
X13	*Spinning*	Set the product size on the spinning machine
		Mould rotation using a spinning tool
Curing & Demoulding		
X14	*Steam Curing*	Placing the mould in the steam curing pit
		Installing the thermocouple
		Close the curing pit
		Log on and check the time and temperature of the steam curing process
X15	*Compressive Test*	Cylinder object test
X16	*Demoulding*	Product lifting and unloading (handling)
		Remove the eyebolt using an impact wrench
		Removing Spun Pile products from the mould
X17	*Mould Cleaning & Oiling*	Immediately clean the outside of the mould from concrete dirt
		Lubricate the mould
X18	*Inspection & Labeling*	Product inspections
		Defect product control
		Repair defect products
		Product labeling
		Coating joint plate on products that meet standards
X19	*Delivery*	Product loading to trailer truck
		Delivery of products using a trailer truck

3.2 *Innovation Manufacturing Method Risks*

Analyzing innovation 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 66 identified risks from validated production process activities. Each risk is analyzed according to the 6th PMBOK Risk Management [8] 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 a risk ranking.

In cutting & heading, there are 4 risks

Table 3 Cutting & Heading Risks

Cutting & Heading				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variabel	**Sub Variable**		
X1	Bar Cutting	Make PC Bar cuts using a bar cutter	2	The length of the PC Bar is not by the standard

Cutting & Heading				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variabel	**Sub Variable**		
X2	Bar Heading	The emphasis on the PC Bar ends as the Heading Bar on the heading machine	6	PC Bars are not the same length in one diameter, so the tensile force is not spread evenly (concentrated on the PC Bar which is longer) during the stressing process
X2	Bar Heading	The emphasis on the PC Bar ends as the Heading Bar on the heading machine	16	The form of the heading that is made does not meet the standard
X1	Bar Cutting	Place the PC Bar Coil on the PC Bar reel	65	PC Bar coiled

Then forming & setting there are 19 risks

Table 4 Forming & Setting Risks

Forming & Setting				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X3	Cage Forming	Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar Settings, Iron Wire, and welding current conductor distance)	3	Spalling or product breakage when the pile head is driven because the iron wire is not up to standard
X5	*Cage Setting*	Installing the pedestal iron	8	Loose support iron inhibits the stressing process
X4	Joint Plate and Pencil Shoe Setting	Installation of pencil shoes	10	Anchor reinforcement out of the surface of the spun pile (not in the spun pile concrete)

Forming & Setting				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X3	Cage Forming	PC Bars that have been subjected to the heading process are installed in the holes in the cage forming machine	18	PC Bar breaks during the stressing process because the tensile force is not evenly distributed
X4	Joint Plate and Pencil Shoe Setting	Installing the joint plate on the iron assembly	30	The product is porous and bends in the area where the joint plate meets
X3	Cage Forming	Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar Settings, Iron Wire, and welding current conductor distance)	33	The iron wire coming out of the concrete surface (the inside part)
X3	Cage Forming	Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar Settings, Iron Wire, and welding current conductor distance)	36	Reinforcement data does not match the product being made
X4	Joint Plate and Pencil Shoe Setting	Installation of pencil shoes	41	The finishing pencil is not neat, and there are shrinkage cracks

Forming & Setting				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X4	Joint Plate and Pencil Shoe Setting	Installation of pencil shoes	46	The Pencil Shoe is asymmetrical
X4	Joint Plate and Pencil Shoe Setting	Installing the end plate on the joint plate and tightening the nuts and bolts on the end plate	47	The joint plate is not installed correctly so that the PC Bar comes out of the surface of the joint plate
X3	Cage Forming	Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar Settings, Iron Wire, and welding current conductor distance)	50	Slanted iron series, not according to product standards
X4	Joint Plate and Pencil Shoe Setting	Installing the end plate on the joint plate and tightening the nuts and bolts on the end plate	54	Random material is also cast in the concrete product
X3	Cage Forming	Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar Settings, Iron Wire, and welding current conductor distance)	57	Welding is detached from the surface of the PC Bar

Forming & Setting				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X4	Joint Plate and Pencil Shoe Setting	Installing the joint plate on the iron assembly	57	Product head spalling (chipped), broken
X4	Joint Plate and Pencil Shoe Setting	Installation of pencil shoes	59	The pencil shoe is detached from the main body spun pile
X4	Joint Plate and Pencil Shoe Setting	Lifting the PC Bar assembly to the setting area using a spreader beam	61	The assembly fell from a great height while lifting it to the setting area
X5	*Cage Setting*	Lifting the PC Bar assembly that has accessories installed on the mould using a spreader beam	62	The spreader beam is damaged while lifting the PC Bar assembly to the mould
X4	Joint Plate and Pencil Shoe Setting	Lifting the PC Bar assembly to the setting area using a spreader beam	63	The spreader beam was damaged during lifting to the setting area
X5	*Cage Setting*	Lifting the PC Bar assembly that has accessories installed on the mould using a spreader beam	66	The assembly falls from a height during lifting onto the mould

Then in casting, there are 11 risks

Table 5 Casting

Casting				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X10	Concrete Feeding	Clean the edges of the mould from the remains of the concrete	6	The mould is deformed
X9	Slump Test	Performing slump tests	13	The ready mix does not meet the requirements and is rejected
X8	*Concrete Mixing*	Making concrete mix on the batching plant	15	Poor aggregate gradation

Casting				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X7	Batching Plant	Distribution of concrete from the batching plant	17	Spun piles lack concrete mix halfway through feeding concrete
X10	Concrete Feeding	Put on a temporary stopper on the edge of the mould	20	Concrete spilled or scattered during the pouring
X8	*Concrete Mixing*	Making concrete mix on the batching plant	21	Concrete segregation
X10	Concrete Feeding	Pouring the concrete mix according to the reference on the mould and assembly	21	The thickness of the spun pile is less than the plan
X6	Concrete Mix Design	Designing the Job Mix Formula	25	Failure of design mix formula
X7	Batching Plant	Request for concrete quality	50	The quality of the ready mix that was ordered was wrong
X10	Concrete Feeding	Clean the edges of the mould from the remains of the concrete	50	Mould cannot be closed properly
X7	Batching Plant	Distribution of concrete from the batching plant	59	Wrong quality of the ready mix sent

Stressing & spinning have 7 risks

Table 6 Stressing & Spinning Risk

Stressing & Spinning				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X13	*Spinning*	Spinning process	1	Honeycomb concrete due to imperfect compaction
X11	Mould Fastening	Eyebolt tightening on both sides simultaneously and sequentially using an impact wrench	4	Loss of cement paste during the spinning process so that the product surface performance is not solid and neat

Stressing & Spinning				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X11	Mould Fastening	Eyebolt tightening on both sides simultaneously and sequentially using an impact wrench	5	Eyebolt ejected during the spinning process
X12	S*tressing*	Placing the mould on the bed stressing	8	PC Bar broke due to stressing failure (inappropriate positioning)
X12	S*tressing*	PC Bar withdrawal, recording, and checking elongation	14	Elongation exceeds the tolerance limit of ±5%
X11	Mould Fastening	Close the mould by placing the top mould	18	Mould cannot be closed completely
X13	*Spinning*	Set the product size on the spinning machine	47	Rotation speed - rpm and time are not up to standard

Last, Curing & Demoulding has 25 risks

Table 7 Curing & Demoulding Risks

Curing & Demoulding				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X19	*Delivery*	Delivery of products using a trailer truck	11	Cracked product
X14	*Steam Curing*	Close the curing pit	12	A lot of steam is wasted due to the pit not being tightly closed
X18	Inspection & Labeling	Repair defect product	21	Defective products cannot be saved
X18	Inspection & Labeling	Defect product control	24	Defective products are mixed up and difficult to detect
X16	*Demoulding*	Remove the eyebolt using an impact wrench	26	The impact wrench pump is damaged, so it cannot work optimally
X16	*Demoulding*	Remove the eyebolt using an impact wrench	27	The eyebolt ejects/ thrown when released

Curing & Demoulding				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X18	Inspection & Labeling	Product labeling	28	The product has no identity
X14	*Steam Curing*	Placing the mould in the steam curing pit	29	The amount of product that fits the curing pit is not optimal
X16	*Demoulding*	Remove Spun Pile products from the mould	31	Curved products due to non-straight moulding (improper)
X17	Mould Cleaning & Oiling	Immediately clean the outside of the mould from concrete dirt	32	Deformation mould
X17	Mould Cleaning & Oiling	Lubricate the mould	33	Untidy concrete surface
X14	*Steam Curing*	Installing the thermocouple	35	Broken thermocouple
X19	*Delivery*	Delivery of products using a trailer truck	36	The product crushes alternating chains to hinder the transfer of the product
X15	Compressive Test	Cylinder object test	38	Creep on concrete
X15	Compressive Test	Cylinder object test	39	Concrete bonds and prestress are not optimal
X19	*Delivery*	Product loading to trailer truck	40	The product lineup is collapsing
X16	*Demoulding*	Remove Spun Pile products from the mould	42	The spun pile product rolled against another object until it cracked
X17	Mould Cleaning & Oiling	Lubricate the mould	43	Oil puddle
X18	Inspection & Labeling	Product inspection	44	There are defective products that pass QC
X15	Compressive Test	Cylinder test object test	45	Inadequate cross-section capacity
X19	*Delivery*	Product loading to trailer truck	49	The chain sling is crushed by the product, thereby hindering the movement of the product

Curing & Demoulding				
Var No.	**Production Process Activity**		**Rank**	**Risk Description**
	Variable	**Sub Variable**		
X17	Mould Cleaning & Oiling	Immediately clean the outside of the mould from concrete dirt	53	The spinning process disturbed due to concrete dirt that sticks
X14	*Steam Curing*	Log on and checking the time and temperature of the steam curing process	55	The steam curing process is not carried out according to the rules (time standard)
X16	*Demoulding*	Product lifting and unloading (handling)	56	Twisted chain slings
X18	Inspection & Labeling	Coating joint plate on products that meet standards	64	The color of the joint plate coating does not match the company's identity

3.3 High Risk Analysis

In this study, 1 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 8 High Risk Analysis

High Risk: Spinning Process					
Var No.	**Risk Description**	**Cause**	**Preventive action**	**Impact**	**Corrective Action**
X13	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)		

High Risk: Spinning Process					
Var No.	**Risk Description**	**Cause**	**Preventive action**	**Impact**	**Corrective Action**
		Unstable aggregate gradation	Sieve when pouring concrete into the mould		

3.4 Additional Activities on Spun Pile Workflow

In addition to analyzing high risk, additional activities on spun pile workflow are generated from 66 risk factors in the form of preventive actions in the following table, which are gray.

Table 9 Additional Activities on Spun Pile Workflow

Var No.	Production Process Activity	
	Variable	**Sub Variabel**
Cutting & Heading		
X1	Bar Cutting	Operator inspection
		Tools and machine condition check
		Checking the PC Bar is clean from rust and defects
		Check the position of the stopper
		Place the PC Bar Coil on the PC Bar reel
		Make PC Bar cuts using a bar cutter
X2	Bar Heading	Operator inspection
		Tools and machine condition check
		Vise check
		Check pressure plate
		Check the clamping device
		The emphasis on the PC Bar ends as the Heading Bar on the heading machine
Forming & Setting		
X3	Cage Forming	Operator inspection
		Tools and machine condition check
		Checking PC Bar clean of rust, defects, and the amount according to shop drawings
		PC Bars that have been subjected to the heading process are installed in the holes in the cage forming machine
		Assembling PC Bar with an automatic cage forming machine with: -Setting reinforcement data on the monitor screen -Mechanical settings on the driving machine (PC Bar

Var No.	Production Process Activity	
	Variable	**Sub Variabel**
		Settings, Iron Wire, and welding current conductor distance)
X4	Joint Plate and Pencil Shoe Setting	Operator inspection
		Lifting the PC Bar assembly to the setting area using a spreader beam
		Check the condition of accessories
		Check the condition of the joint plate
		Installing the joint plate on the iron assembly
		Installing the end plate on the joint plate and tightening the nuts and bolts on the end plate
		Installation of pencil shoes
		Checking the reinforcement attached to the PC Bar or iron wire and is in the thickness of the Spun Pile product concrete
X5	Cage Check	Check the number of PC Bars installed
		Checking the diameter of the PC Bar
		Check the diameter of the iron wire
		Check the spacing of the spiral iron wire
		Check the PC Bar length
		Check the condition of the joint plate, tension rod, pencil shoe
		Check the installation of eye bolts
X6	Cage Setting	Operator inspection
		Tools and machine condition check
		Lifting the PC Bar assembly that has accessories installed on the mould using a spreader beam
		Installing the pedestal iron
Casting		
X7	Concrete Mix Design	Designing the Job Mix Formula
X8	Batching Plant	Request for concrete quality
		Distribution of concrete from the batching plant
X9	Concrete Mixing	Making concrete mix on the batching plant
X10	Slump Test	Performing slump tests
X11	Concrete Feeding	Operator inspection
		Put on a temporary stopper on the edge of the mould
		Pouring the concrete mix according to the reference on the mould and assembly

Var No.	Production Process Activity	
	Variable	**Sub Variabel**
		Clean the edges of the mould from the remains of the concrete
Stressing & Spinning		
X12	Mould Fastening	Operator inspection
		Ensuring molds and mold covers are in the same code/labeling
		Close the mould by placing the top mould
		Tools and machine condition check
		Eyebolt tightening on both sides simultaneously and sequentially using an impact wrench
X13	Stressing	Operator inspection
		Checking the condition of tools and machines and ensuring that the mold is completely closed
		Placing the mould on the stressing bed
		PC Bar withdrawal, recording, and checking elongation
X14	Spinning	Operator inspection
		Tools and machine condition check
		Set the product size on the spinning machine
		Mould rotation using a spinning tool
Curing & Demoulding		
X15	Steam Curing	Operator inspection
		Tools and machine condition check
		Placing the mould in the steam curing pit
		Installing the thermocouple
		Close the curing pit
		Log on and check the time and temperature of the steam curing process
		Checking the test sample also carries out the same concrete treatment as the Spun Pile product batch
X16	Compressive Test	Operator inspection
		Tools and machine condition check
		Cylinder object test
X17	Demoulding	Operator inspection
		Tools and machine condition check
		Product lifting and unloading (handling)
		Remove the eyebolt using an impact wrench
		Removing Spun Pile products from the mould
X18	Mould Cleaning &	Immediately clean the outside of the mould from concrete dirt

Var No.	Production Process Activity	
	Variable	**Sub Variabel**
	Oiling	Lubricate the mould
		Make sure the mold is in straight condition
X19	Inspection & Labeling	Product inspections
		Defect product control
		Repair defect products
		Product labeling
		Coating joint plate on products that meet standards
X20	Stock Yard/ Air Curing	Operator inspection
		Tools and machine condition check
		Examination of environmental conditions
		Placing block beams above ground level/rigid
		Carry out the placement of the arrangement of beams adjusted to the size, diameter, and length and given a code
X21	Delivery	Operator inspection
		Tools, machine, and trailer truck condition check
		Product loading to trailer truck
		Delivery of products using a trailer truck

4. Conclusion

This research resulted in the current spun pile production process activities in Indonesia, risk identification based on each production process activity, which resulted in recommendations for additional activities on spun pile workflow in the form of preventive actions. Using the risk approach and ISO 56002 process innovation process stages, 66 risks were analyzed. And resulted with 1 high risk, namely honeycomb concrete, due to imperfect compaction risk in the spinning process. This risk was then analyzed to increase a company's competitiveness in facing market competition.

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The second International Conference on Scientific Research and Innovation (2ICSRI 2023)

Organized by

Oakland Publishing and Quality Conferences

Ohio Publishing and Academic Services

Cincinnati, OH, United States, May 3-4, 2023

Acceptance Letter

Date: 07/03/2023

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

Manuscript ID: 2ICSRI- 4235

Dear Amanda Yohanna Pasaribu, Yusuf Latief, Ranti Hidatawanti, Rossy Armyn Machfudiyanto and Leni Sagita Riantini,

We are pleased to inform you that the manuscript with the above title has been accepted for oral presentation in the **Second International Conference on Scientific Research & Innovation (2ICSRI 2023)**, organized by ***Oakland Publishing and Quality Conferences***, and ***Ohio Publishing and Academic Services***, which will be held in **Cincinnati, OH, United States, May 3-4, 2023**, and the publication will be in **AIP Conference Proceedings (E-ISSN:1551-7616).** The concept note and draft agenda will be sent to you at a later time.

We look forward to your attendance.

Thank you very much for your participation.

Prof. Dr. Justin Link
Scientific Chairman

Assoc. Prof. Dr. Haider Raad
Publication Chairman

Dr. Thaer Al-Jadir
Organizing Chairman

The second International Conference on Scientific Research and Innovation (2ICSRI 2023)

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Scientific Chairman	Publication Chairman	Organizing Chairman

Google

Amanda Yohanna Pasaribu <amanda.yohanna11@ui.ac.id>

2ICSRI 2023 submission 4235

2 pesan

2ICSRI 2023 <2icsri2023@easychair.org> 20 Februari 2023 pukul 00.35
Kepada: Amanda Yohanna Pasaribu <amanda.yohanna11@ui.ac.id>

Dear authors,

we have the following question about your submission
to 2ICSRI 2023 entitled

Innovation Manufacturing Method of Precast Concrete for Spun Pile Products at Precast Construction Company in Indonesia with a Risk Approach and ISO 56002 Innovation Process to Increase Competitiveness.

Please follow the revewers comments carefully within THREE days or the paper maybe rejected.

Revewer 1:

- I think at least two sources should be added to increase the scientific value.
- The author needs more clarification in the conclusion section and this paper in its current condition is almost like a review study. It's required to rewrite the methodology and refer to tables in text.
- In abstract section : Author did not clearly state his findings (Results).required to write the the results briefly in last of abstraction.
- Source of Figure (1)should be mentioned
- Source of table (2) ?

===

Revewer 2:

- The title of this work is very long;

- The abstract of this work is very long (The conference abstract should contain between 100 and 200 words).

- Please add the (ISO 56002) in the keywords;

- References are not used strictly by the author.

Objectives
- The excessive length of the article made the objectives unclear, even though it was very important research.

-Data should be added to the results obtained because the article lacks this.

-The maximum number of pages required is 12, including references. But this paper contains 23 pages.

-The paper should not be less than 3000 words and not more than 6000 words. The submitted article contains more than 30,000 words.

- Why didn't the author explain the results he obtained with graphs?

-Research is always based on illustrative results, with graphs and they are missing in this article.

Best regards,
Mohammed Muayad Ta.

Amanda Yohanna Pasaribu <amanda.yohanna11@ui.ac.id> 22 Februari 2023 pukul 22.57
Kepada: 2ICSRI 2023 <2icsri2023@easychair.org>

Thank you for the review, insights, and the opportunity, I would like to answer the questions in the following
Question Reviewer 1:
- I think at least two sources should be added to increase the scientific value.
Answer: References have been added

- The author needs more clarification in the conclusion section and this paper in its current condition is almost like a review study. It’s required to rewrite the methodology and refer to tables in text.
Answer: The additional activities on spun pile workflow has been rewriten in the form of a workflow in Figure 7
- In abstract section : Author did not clearly state his findings (Results).required to write the the results briefly in last of abstraction.
Answer: Research findings have been added to the abstract
- Source of Figure (1)should be mentioned
Answer: Figure 1 is processed by the author, and in the file update, figure (1) has been moved to the results section
- Source of table (2) ?
Answer: Table (2) is also from the author observations and interviews conducted in this study
===

Question Revewer 2:

- The title of this work is very long;
Answer: The title has been changed from “Innovation Manufacturing Method of Precast Concrete for Spun Pile Products at Precast Construction Company in Indonesia with a Risk Approach and ISO 56002 Innovation Process to Increase Competitiveness” to “Innovation of Spun Pile Manufacturing Method in Indonesia Using a Risk Approach and ISO 56002 Innovation Process to Increase Competitiveness” in the updated file

- The abstract of this work is very long (The conference abstract should contain between 100 and 200 words).
Answer: The abstract has been written down to 194 words in an updated file

- Please add the (ISO 56002) in the keywords;
Answer: ISO 56002 keywords have been added

- References are not used strictly by the author.
Answer: Reference has been fixed
===
Objectives
- The excessive length of the article made the objectives unclear, even though it was very important research.
Answer: The article has been made more comprehensive and hopefully not unclear anymore
-Data should be added to the results obtained because the article lacks this.
Answer: Data has been added to the results obtained.
-The maximum number of pages required is 12, including references. But this paper contains 23 pages.
Answer: Sorry for the inconvenience, I don’t see any page limit on the guidelines. However, the updated file has been made into 12 pages.
-The paper should not be less than 3000 words and not more than 6000 words. The submitted article contains more than 30,000 words.
Answer: There are less than 6000 words and 34,325 characters in the previous file. And in the updated file, there are 12 pages with words between 3000 and 6000.

- Why didn’t the author explain the results he obtained with graphs? Research is always based on illustrative results, with graphs and they are missing in this article.
Answer: The 66 risks obtained have been made into a risk level graph in figure 6

Hopefully this research can be considered and accepted at this conference. Let me know if you have any more questions.

Amanda Yohanna
Undergraduate Student of Civil Engineer, University of Indonesia
+6281310375946 | yohanna.pasaribu@gmail.com
Jakarta, Indonesia

[Kutipan teks disembunyikan]

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2ICSRI 2023 submission 4235 REVIEW

Question	Answer
Reviewer 1	
I think at least two sources should be added to increase the scientific value.	References have been added.
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Source of table (2) ?	Table (2) is also from the author observations and interviews conducted in this study
Reviewer 2	
The title of this work is very long.	The title has been changed from "Innovation Manufacturing Method of Precast Concrete for Spun Pile Products at Precast Construction Company in Indonesia with a Risk Approach and ISO 56002 Innovation Process to Increase Competitiveness" to "Innovation of Spun Pile Manufacturing Method in Indonesia Using a Risk Approach and ISO 56002 Innovation Process to Increase Competitiveness" in the updated file
The abstract of this work is very long (The conference abstract should contain between 100 and 200 words).	The abstract has been written down to 194 words in an updated file.
Please add the (ISO 56002) in the keywords.	ISO 56002 keywords have been added
References are not used strictly by the author.	Reference has been fixed
Objectives	
The excessive length of the article made the objectives unclear, even though it was very important research.	The article has been made more comprehensive and hopefully not unclear anymore.

Question	Answer
Data should be added to the results obtained because the article lacks this.	Data has been added to the results obtained.
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Why didn’t the author explain the results he obtained with graphs? Research is always based on illustrative results, with graphs and they are missing in this article.	The 66 risks obtained have been made into a risk level graph in figure 6

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

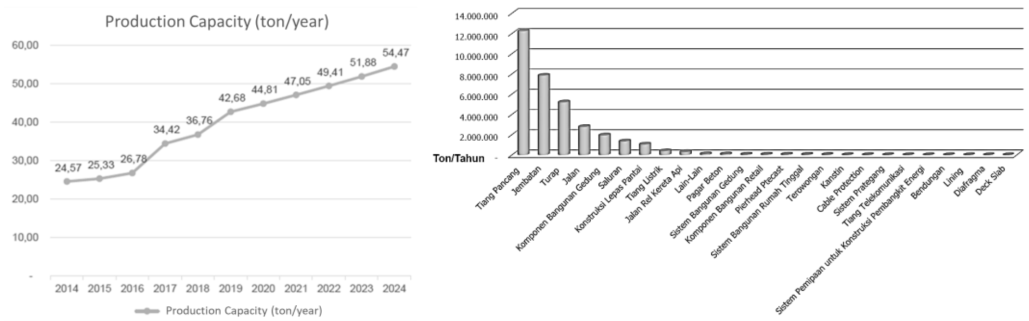

Figure 1 Existing Conditions, Precast Concrete Capacity Targets, and Product Availability Production Capacity

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].

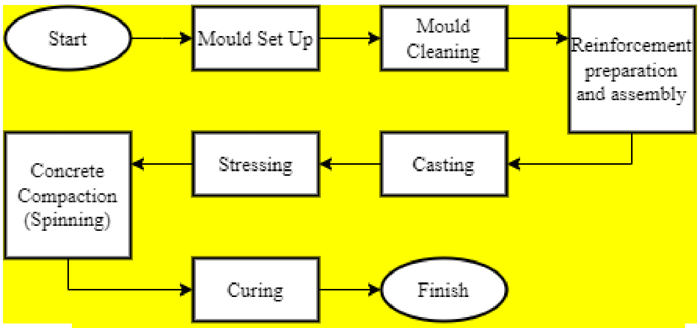

Figure 2 Spun Pile Production Process Diagram

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.

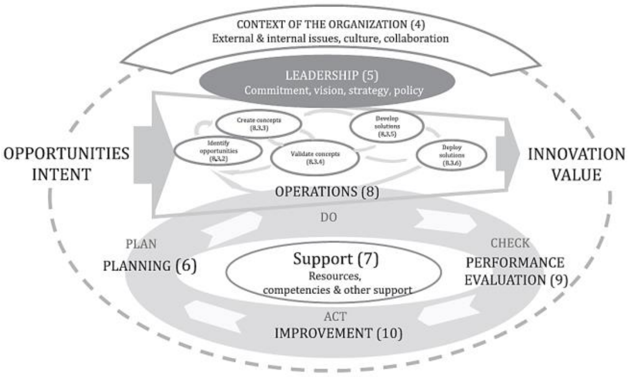

Figure 3 PDCA Guidelines for Innovation Management Systems

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

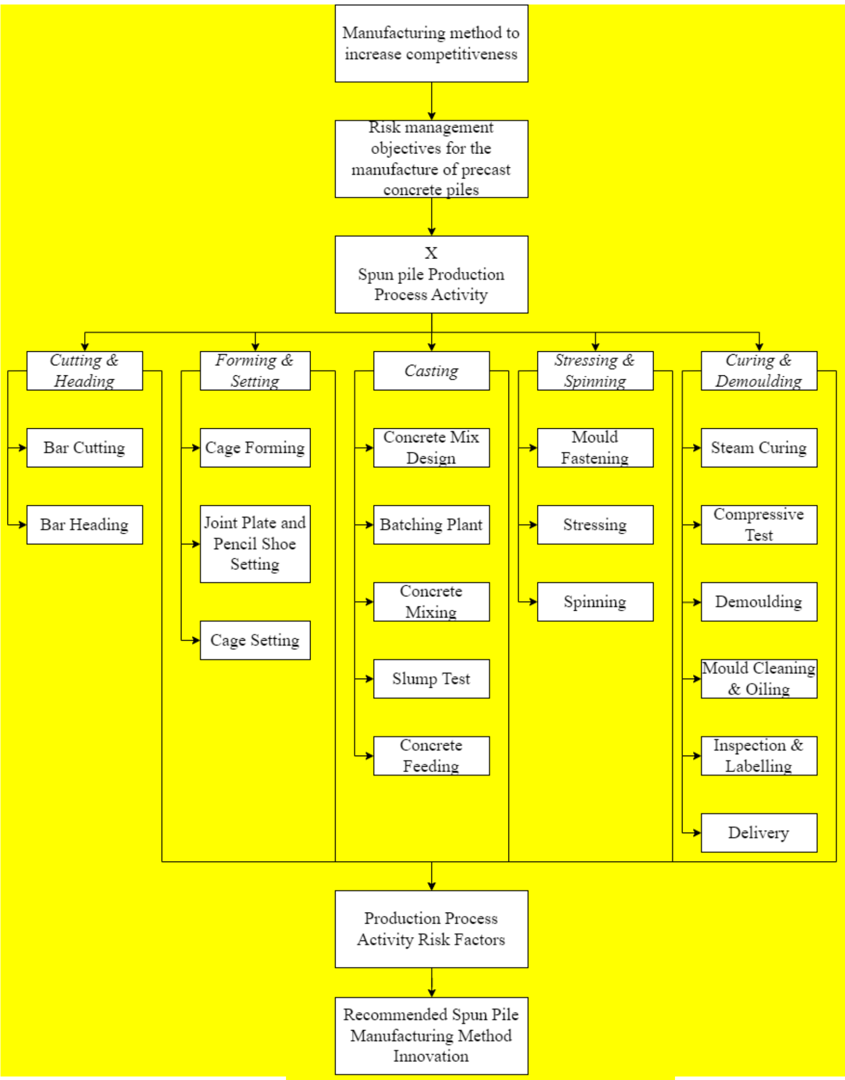

Figure 4 Research Framework

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.

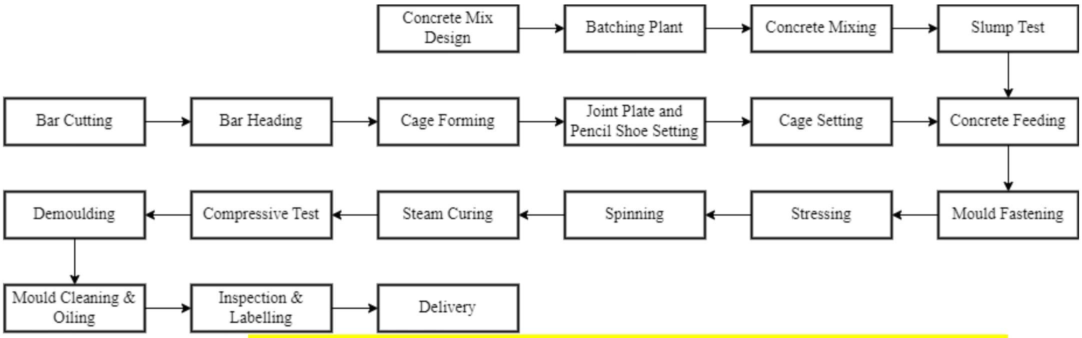

Figure 5 Current Manufacturing Methods for Spun Pile in Indonesia

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.

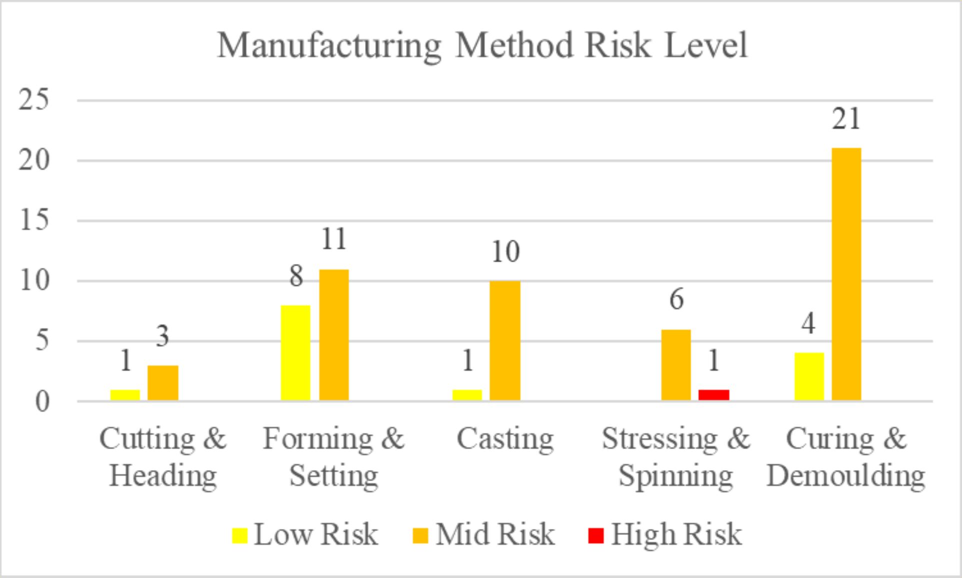

Figure 6 Manufacturing Method Risk Level

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.

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

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September 24, 2023

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

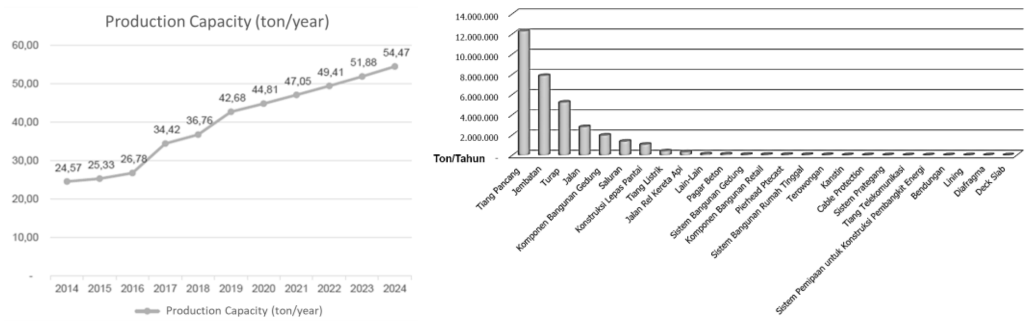

Figure 1 Existing Conditions, Precast Concrete Capacity Targets, and Product Availability Production Capacity

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].

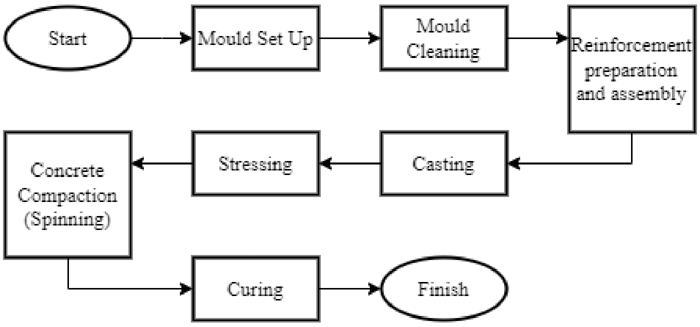

Figure 2 Spun Pile Production Process Diagram

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.

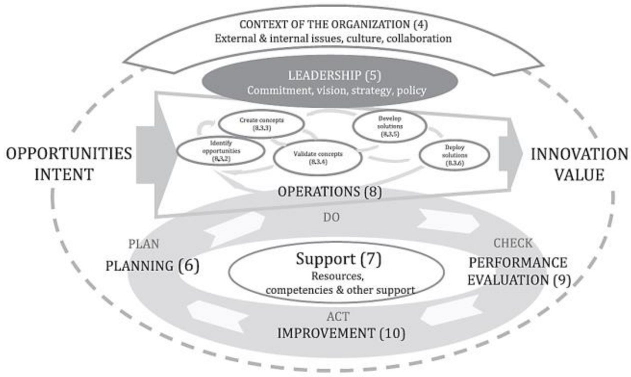

Figure 3 PDCA Guidelines for Innovation Management Systems

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

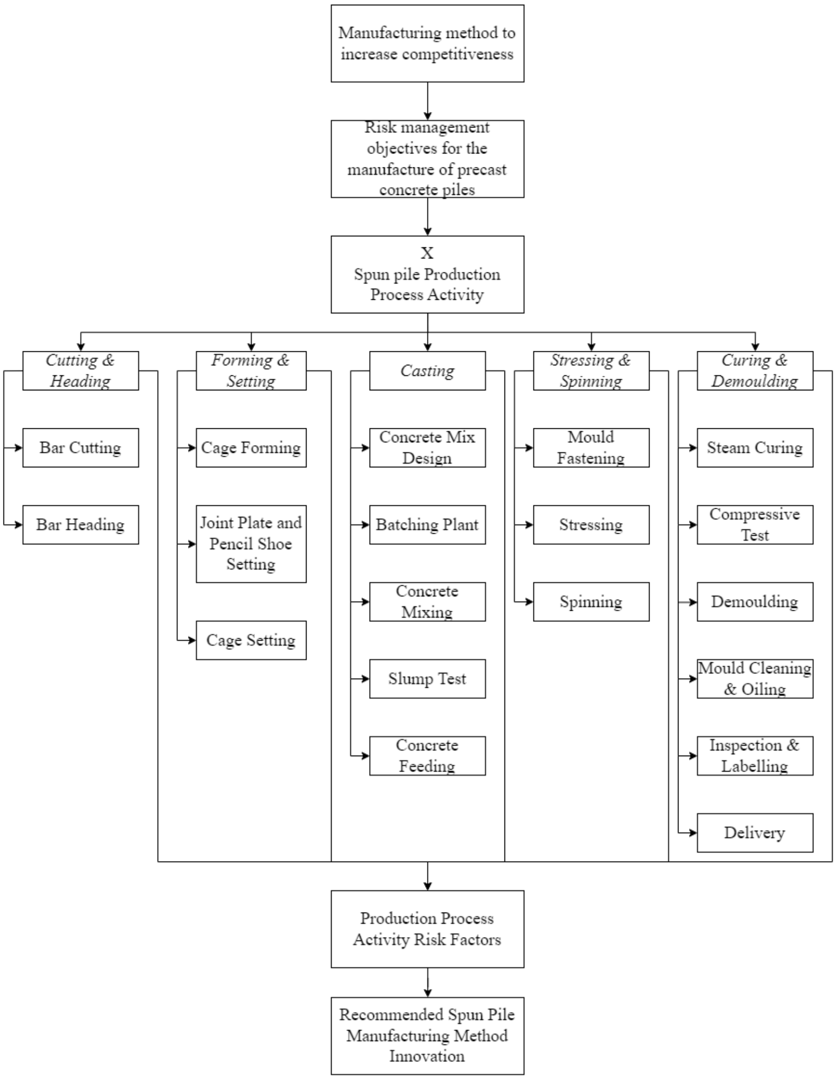

Figure 4 Research Framework

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.

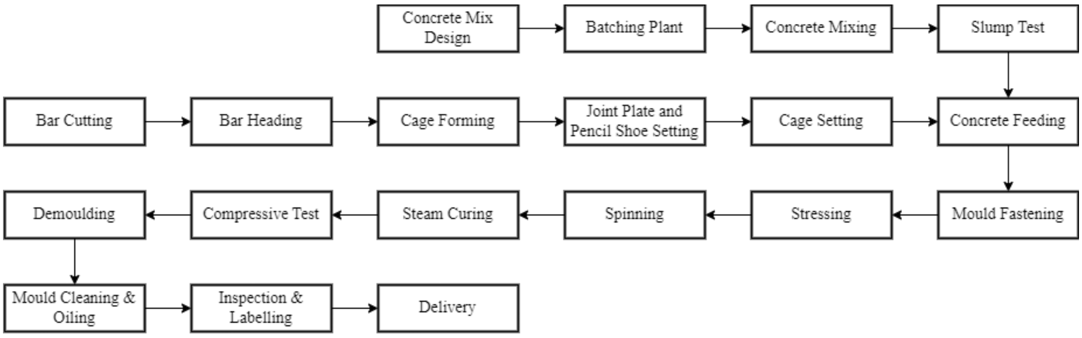

Figure 5 Current Manufacturing Methods for Spun Pile in Indonesia

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.

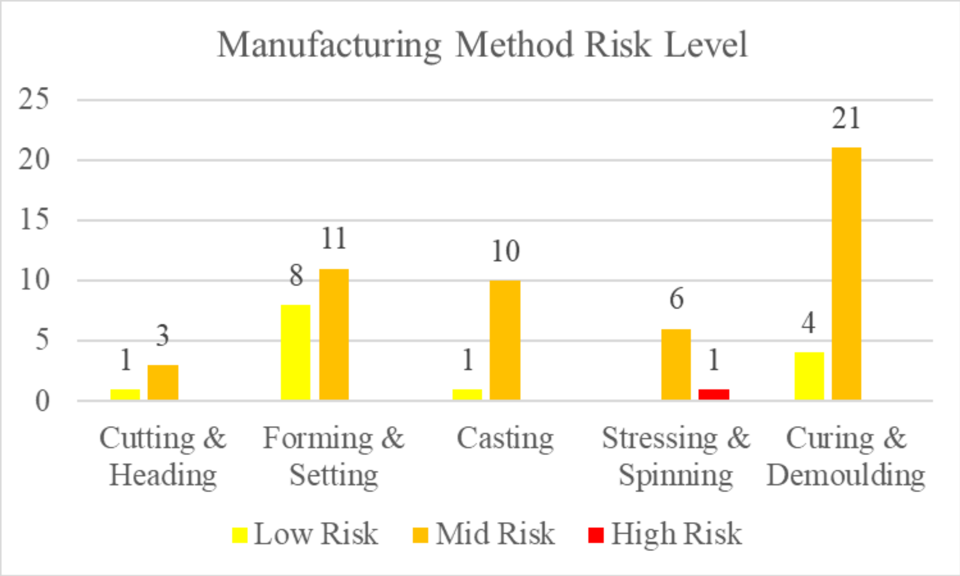

Figure 6 Manufacturing Method Risk Level

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					
	Risk Description	Cause	Preventive action	Impact	Corrective Action
X13	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.

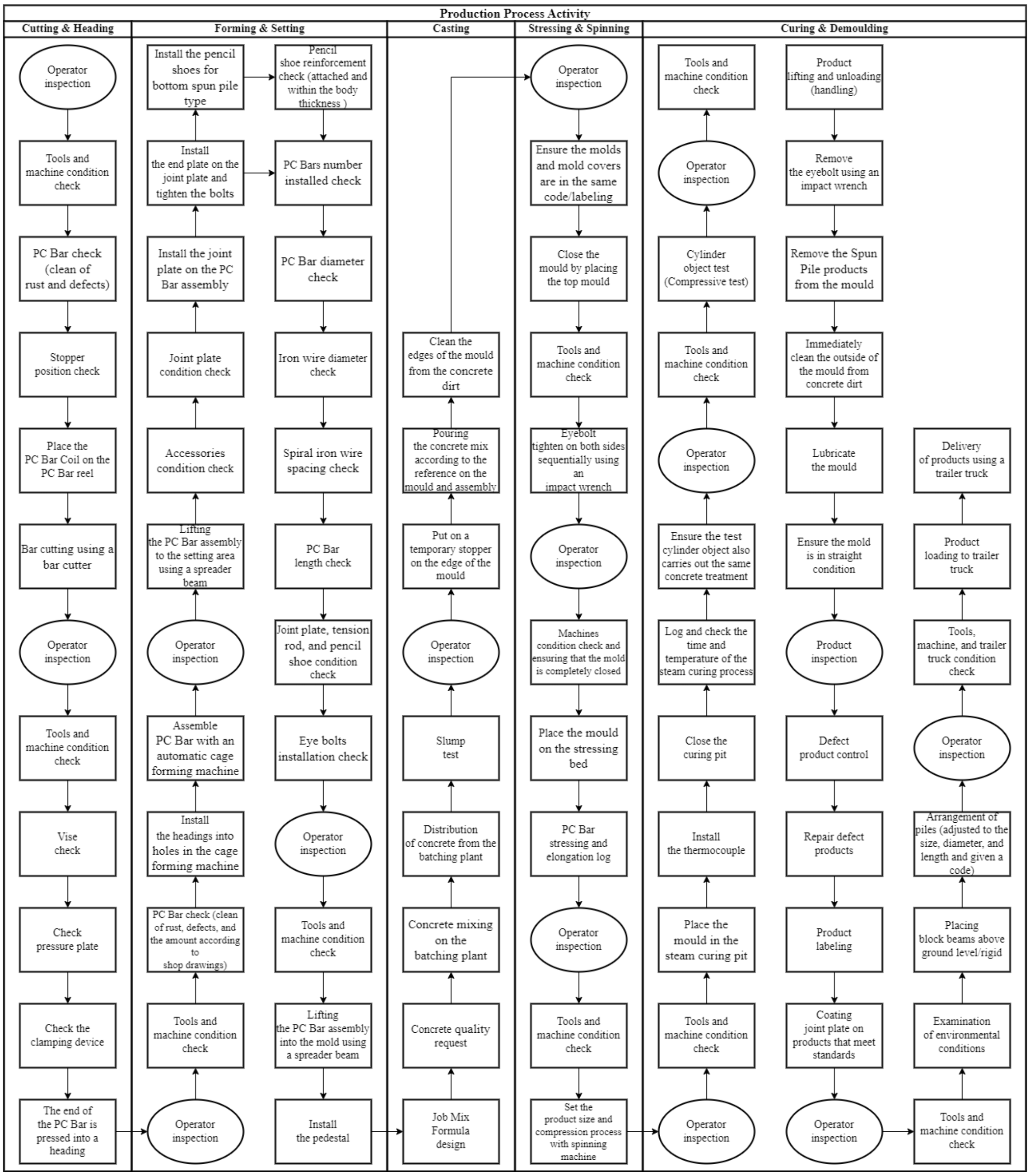

Figure 7 Additional Activities on Spun Pile Workflow

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.

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