

Disruptions Control on Precast Concrete Supply Chain in Construction Projects

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Abstract. *Agility amid uncertain circumstances is key to all-across sustainable industries. The construction industry depends heavily on projects as potent drivers to their operational activities regardless of projects' hardwired constraints—shipment, resistance to risks—to affect Key Performance Indicator (KPI). PT ABX, as one of the Indonesian precast-concrete manufactures, is the object of this research aiming to find precautionary strategies for controlling disruptions to the concrete supply chain in construction projects. It considers such supply-chain disruptions, and therefore, the two-layered House of Risk (HOR) model to subsume risks identification, and risks control is applicable for minimizing possible disruptions. It finds risk events, some of which are classified as critical risk events and preventive actions against risks. The findings contribute to a working framework for managers responsible for applying effective strategies for preventing such disruptions.*

Keywords: *house of risk; risks; disruptions, construction projects, supply chain.*

I. INTRODUCTION

Intense competition over product innovation, production, and performance in the precast concrete industry leaves the players bruised. The supply chain within management concept refers to the inseparable production process, distribution, and marketing as consumers are exposed to their-desired products available in markets. At the same time, producers are capable of producing products amounts, quality, proper-market location are subject to preliminary plan (Saptana et al., 2016). While working towards fulfilling consumers' expectations, projects should be quite agile in managing possible-yet-common risks to impact preliminary-planned aims (PMI, 2008). Projects apply risk management in order to unknown risks amid the ongoing projects, and therefore, cost and time efficiency, as well as

quality properness, are achievable (Nurlela and Suprpto, 2014).

Any activities inseparable from supply-chain management bound to risks as Handayani (2016) theorizes uncertainties (i.e., demand, capacities, time shipment, cutting-edge technology, market changes, intense competition, political upheaval, and government regulations) embedded in the supply chain are initial agents to spark risks. One risk agent commonly has domino effects of sparking other risks, and PT ABX precast supply chain is also exposed to domino-effect risks.

Marie et al. (2015) have conducted research of a model of disruptions control applied in processed bread makers and beef-sausages makers. That model anticipates and prevents any disruptions from supplying, demand, internal production system and varies in sub-models it has (i.e., preventive actions against disruptions, advanced policies of controlling disruptions, and inventory tolerance. The sub-model of preventive actions against disruptions recommends rule-based mechanisms to control disruptions; the sub-model of policies of controlling disruptions generates prevailing regulations against disruptions, and the sub-model of inventory tolerance by means of average disruptions produce safety stock value.

Each of the disruptions and preventions against them is recorded in a certain database whose names are input and locked with keywords. Should any disruptions occur, proper

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preventive actions for controlling that disruptions can be taken into effect by unlocking keywords. According to each of the processed food industries, the database on a periodical basis is subject to analysis to formulate new policies better. The sub-model of inventory tolerance update safety stocks to keep their adequate amount, and therefore, methods for determining safety stocks vary. Marie (2014) has proposed a safety stock, which is way more adaptive to periodical adjustment and production disruptions (i.e., supply, demand, internal production system).

Marie et al. (2017) has conducted research on a precautionary model against disruptions applied in automotive spare-parts manufacturers exposed to possible risks. The research finds a precautionary sub-model against disruptions (i.e., disruption risk levels, status to measure necessary management, measures for controlling disruptions, and safety stock calculation).

Disruptions to the production system in the heavy equipment makers have been mapped with respect to industrial volatility. Therefore, a proposal to determine dynamic safety inventories carefully considers the mapped disruptions (Marie et al., 2019).

Related to research for the management of supply chain disruptions conducted at an automotive battery company, by defining disruption as an event that hampers KPIs' achievement, a lean manufacturing approach is used. The research objective is to identify waste and cause of waste and propose an improvement to eliminate waste in the PT XYZ supply chain to reduce lead time and achieve the delivery target to improve company performance with the Lean Supply Chain approach. Based on Value Stream Mapping and analysis of waste, the researcher proposed improvements and decreased manufacturing lead time and the increased process cycle efficiency (Marie et al., 2017).

Companies to manage construction projects based on their supply chain uncertainty have the following characteristics (i.e., high level of volatility demand, high level of lead-time supply, moderate process uncertainty, high complexity). Thus, it is recommended that they adopt flexible strategies with low safety stock, high safety lead

time, low-capacity buffer, high supplier backup, moderate component commonality, high postponement, and high sub-contract outsourcing. (Angkiriwang et al., 2014).

PT ABX established in 2014, is a subsidiary of PT AK (Persero) Tbk and envisions to be the Indonesian third-largest precast concrete supplier. To ensure a smooth supply of precast concrete, it establishes two plants located in Sadang-Purwakarta and Mojokerto. These two plants supply precast concrete demands by PT AK Tbk (Group) and the domestic market.

The Company accredited with ISO 9001:2015 quality management system proves its performance of producing quality products and providing the best services to its customers. Figure 1 shows PT ABX's supply chain.

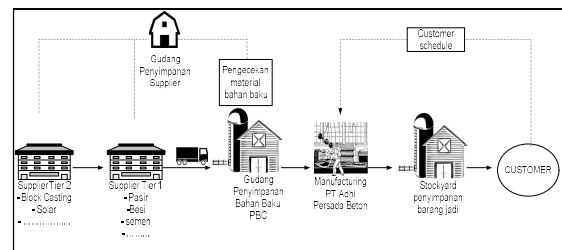


Figure 1. PT ABX's supply chain

The initial mapping of PT ABX's supply chain explains problems in precast concrete supplied for construction projects. Thus, to ensure an undisturbed supply chain, PT ABX, running its business, is equipped with two-typed plants: permanent and temporary. Its permanent plants supply generally-marketed precast concrete, while temporary plants whose locations are impermanent and near the ongoing projects specifically supply precast concrete for certain construction projects. The impermanent locations require properly-planned strategies for managing disruptions: uncertain supply, internal and operational issues to hamper the production system.

A proper precautionary system against possible disruptions is mandatory. For example, companies - PT ABX - by means of projects Key Performance Indicators (i.e., budget, schedule, and quality) can fulfill customers' expectancy.

Precise qualitative and quantitative risk measures are prerequisites and complementary. The qualitative method measures "analysis accuracy" in terms of risk descriptions, risk agents, plausible occurrence, impacts of risks on supply-chain performance. In contrast, the quantitative method calculates probable events and their impacts on supply-chain risks (Waters, 2007).

This research aims to find proposed strategies for controlling disruptions to the precast supply chain in construction projects, for it also considers disruptions as risks to such a supply chain. Thus, quantitative and qualitative methods are measurements applied to control supply-chain disruptions. The qualitative method measures risks level, while a qualitative method is necessary for in-depth analysis and provides recommended solutions for risks.

House of Risk (HOR) model is applicable for identifying and measuring supply-chain risks in construction companies as two widely-used tools—Failure Mode & Effect Analysis (FMEA) and House of Quality (HOQ) of Quality Function Deployment—are the basis for its developed framework (Millaty et al., 2014). Its developed framework generally is categorized into two phases: risk identification and risk management. Risk identification involves comprehensive identifications and measurement of risk events and risk agents, while risk management subsumes the first-phase measurement of managing and mitigating risk agents (Kristanto et al., 2014).

Several research pieces have applied the HOR model to identify and prevent possible risks, as Pujawan et al. (2009) developed HOR management risks of fertilizer companies' supply chain. Then, Cahyani et al. (2016) carried out HOR's implemented study in the heavy shipbuilding industry. Meanwhile, Kristanto et al. (2014) continued to apply HOR for risk mitigation in the leather-made shoe industry's supply chain. Ma et al. (2018) developed a fuzzy HOR assessment method based on severity and frequency level applied for supply-chain risks in Hong Kong-based electric equipment producers. Additionally, Dewi et al. (2015) used HOR to compared risks arising from 3 surrounding veil industries in order to develop new-designed veils.

Any research on risks or disruptions to the precast supply chain has never been conducted. Therefore, this research analyzes a model for controlling disruptions or risks to the precast supply chain applied in the construction project. This research applies HOR to identify varied risks and analyzes precautions, which also utilizes a lean manufacturing approach against possible risks.

II. RESEARCH METHOD

Flowchart diagram of research methodology is described in Figure 2. This research collects data provided by PT ABX as a precast supplier for construction projects and this research object. The collected data consists of corporate data, business process data, supply-chain network data (i.e., customers order, checking finished inventories, data storage, raw-material and supporting-material procurement process, manufacturing, finished precast concrete, delivery to customers complete with a schedule for each of activity), suppliers and customers' data.

Customer data varies from value, customer demands, managing-construction-project KPI to critical quality of precast concrete products. Meanwhile, manufacturing data varies from

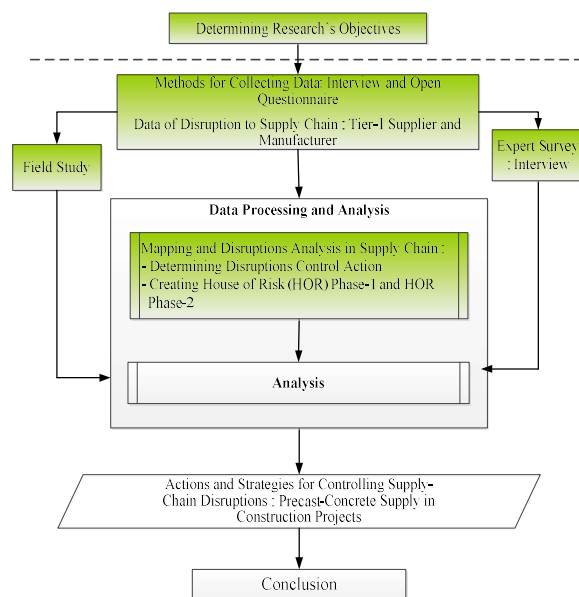


Figure 2. Flowchart of research methodology

production layout, working machinery used in production, production operator, production activities, production planning, managing, inventories, material handling, and material receiving and storage in warehouses. Another type of collected data is documentation of recorded risks and disruptions to supply-chain activities. All kinds of data are collected through structured interviews with experts working for vocal and I-tier companies and documentation of visiting precast-concrete producers and construction projects in the Jakarta greater area. This research applies a HOR model to process the collected data further so that disruptions and risks to the precast concrete supply chain are found.

Based on the results of filling out the questionnaire, which has been strengthened by the results of interviews with supply chain actors regarding the disruptions that occur in each supply chain, disruptions mapping and control actions for each disruption were carried out. This mapping will help supply chain actors identify disruptions control actions to anticipate the disruptions to reduce the impact of disruptions. Next, the results of disruptions mapping and analysis will be used in data processing for HOR creating. In HOR-1 data processing, the disruption becomes a risk agent, while disruption control action becomes a risk event. Next, we calculate the Aggregate Risk Potential (ARP) level by multiply the severity, occurrence, and

correlation between risk events and agents. The highest ARP level represents risk potential to have the most destructive impacts on companies, and therefore, be on top-managed priority. Furthermore, the HOR-2 data processing is carried out by utilizing the data from the HOR-1 calculation. HOR-2 determines the correlation value between risk prevention and risk agents as well as the calculation of Total Effectiveness (TEk), Degree of Difficulty (Dk), Effectiveness to Difficulty (ETDk) in order to figure out the priority of prevention action measures.

III. RESULTS AND DISCUSSION

Supply-Chain Activities

Owners of construction projects through the marketing division give orders to PT ABX. The marketing division will then process orders so that receipts of prices or product specifications will be resentful to the owners. After accomplishing the deal, a selling agreement contract is drafted as the marketing team coordinates with the production and engineering team to discuss orders from construction companies, then issues a license to produce precast concrete and calculate raw materials and time allocation for production. The raw-material preparation requires 14 days to subsume raw-material order to raw-material delivery to processing plants. The product processing requires a sample taken from 7 pcs of finished

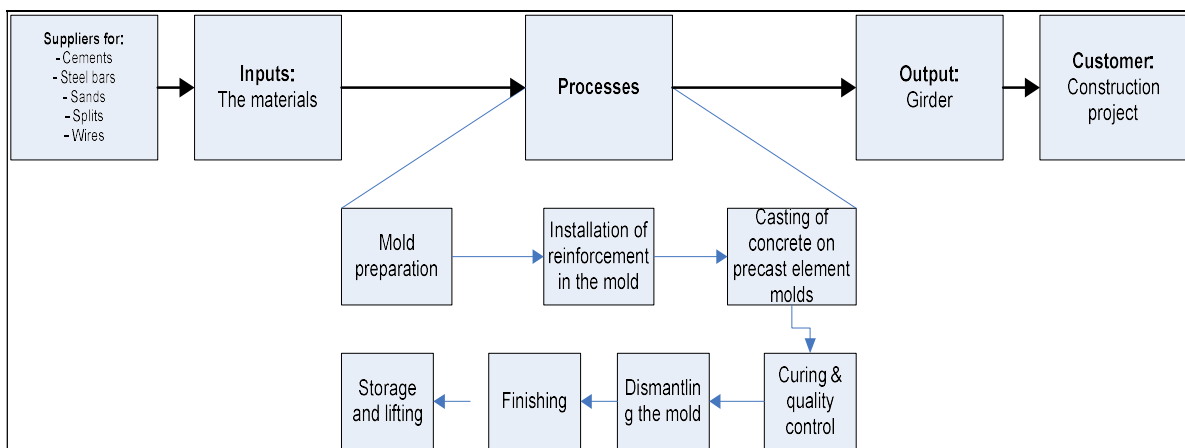


Figure 3. Precast concrete supply-chain activities

precast concrete to undergo 7 days, 14 days, and 28 days of a preliminary test to figure out their high tensile strength. The production team will update information relating to products, number of produced products, defective or perfect and finished products. Figure 3 describes precast concrete supply-chain activities carried out by PT ABX.

Preventive actions against Disruption

Interviewees with experience and knowledge of disruption and prevention reveal recorded documentation of precast concrete constraints for construction projects. Such supply chain is integrated with suppliers, precast, and construction projects, where Table 1, Table 2, and

Table 3 depict constraints in each chain.

Preventive actions are precautions against potential disruptions and provide appropriate control when disruptions hampered the supply chain. The mapping of disruptions and necessary control is recorded in a system to be corporate smartbooks.

House of Risk-1 (HOR-1)

HOR-1 identifies to-be-managed risks. The required data varies from risk event, risk trigger, severity, occurrence, and a correlation between risks and risks.

Risk event identifies potential risk event using supply-chain operation reference consisting of Plan, Source, Make, Deliver, Return (SCOR) to

Table 1. Precautionary Control on Disruption by Suppliers

Supply Chain	Disruptions	Keywords	Control on Disruptions
Suppliers of steel bars	Operators' incompetence to cause human error	Steel Bars' Operators	Routine Training for Operators
	non-standardized raw materials	Raw Material Quality of Steel Bars	More detailed check of incoming material
	Broken Machinery	Broken Machinery	Optimized machinery maintenance
	Defect overfill	Broken Machinery	Repair of machinery setting, more effective and detailed supervision
	Position shift in one of the pass rolls	Broken steel bars machinery	Creating a check sheet for machinery maintenance
	Power Outage	The energy supplied for steel bars.	Make use of alternative energy other than the energy supplied by state-owned electricity (PLN)

Table 2. Control on Disruptions in Precast Supply Chain

Supply Chain	Disruptions	Keyword	Precautionary Measures
Precast	Power Outage	Precast energy supply	Make use of diesel generators as alternative energy.
	Rain (unpredicted weather)	Natural disaster	High intensity of rainfall to undermine quality product (i.e., higher water content) and to temporarily discontinued construction
	Broken Machinery	Broken precast machinery	Routine inspection and repair
	Full stock capacity	Stock area	Smooth team coordination to deliver finished products

Table 3. Control on Supply-Chain Disruption in Construction Projects

Supply Chain	Disruptions	Keywords	Precautionary Control
Construction Project	Imperfect design	Construction Quality	Evaluation by related team
	Changes in design	Construction Quality	Next project to implement changes in design
	Broken heavy equipment	Broken Equipment	Routine checking and repair by mechanics
	Rain (unpredictable weather)	Natural disaster	Temporarily discontinued construction.
	Broken materials	Quality of raw materials for construction	Safer warehouse areas
	Lack of warehouse areas	Construction Facilities	Finding an alternative warehouse

Table 4. The Mapping of precast concrete supply chain

Plan	1. Production planning and controlling 2. Calculation of raw-material needs
Source	1. Purchase raw 2. Receive and store raw materials 3. Check received raw materials 4. Store raw materials in a warehouse area 5. Receive customers' orders
Make	1. Perform production process 2. Quality Control 3. Relocate finished products to stockyard area
Delivery	1. Information on product availability data 2. Product delivery to consumers
Return	1. Return materials to suppliers 2. Manage products returned by customers

classify varied risks occurred in supply-chain activities. This research finds 14 risk events in precast concrete supply-chain activities. Table 1 describes the mapping of the precast concrete supply chain using the SCOR model.

Severity displays the level of severity caused

by any risk event on companies. The severity assessment of risk events is performed by direct questions and answers with production supervisors. The severity level falls on a scale from 1 to 5, as 5 represents the extreme impacts. Table 2 describes the level of risk events.

Risk agent identifies a risk agent by means of direct questions and answers with production supervisors.

Occurrence elucidates the possible occurrence frequency of risk triggers. Measurement of an event caused by a risk agent is performed.

Correlation between risk events and agents. If risk agents cause plausible risks, it implies a strong correlation and is scored 9, while moderate and weak correlation is scored 3 and 1, respectively.

Aggregate Risk Potential (ARP) level functions to put priority over managed risks. ARP level comes from the multiplication of severity, occurrence, and a correlation between risk events and agents. ARP levels are put in order from the biggest to the smallest. The highest ARP level

Table 5. Severity Level of Risk Events

Risk Events	Code	Severity
Sudden changes in a production plan	E1	4
Incompatibility between system capacities and real condition	E2	3
Postponed delivery of primary materials by suppliers	E3	5
Discontinued production process due to unavailable raw materials	E4	5
Lack of suppliers in certain areas	E5	5
Raw Materials warehouse	E6	3
Incompatibility of quantity and quality of material order	E7	4
Raw materials are misplaced	E8	3
Broken, raw materials during storage	E9	3
Lose factors with respect to nature materials	E10	3
Immediate demands for new products	E11	4
Time-consuming administrative process	E12	3
Miscommunication among owners, marketing division, and purchasing division	E13	3
Precast molds in compliance with SOP	E14	4
Error in handling process	E15	4
Malfunctioning machinery	E16	5
Erroneous method for collecting a sample	E17	4
Products unmatched with specification	E18	4
Rough finishing results	E19	4
Erroneous handling process to cause defective products	E20	4
Incompatibility of product specification	E21	4
Misplaced the finished products	E22	3
Incompatibility between the number of product in the system and real condition	E23	4
Error in product delivery	E24	4
Late shipment	E25	4
Incident	E26	4
Natural Disasters	E27	3

Table 6. Occurrence Level of risk agent

Risk Agent	Code	Occurrence
Sudden product demand	A1	3
Lack of material supply	A2	4
Postponed material procurement	A3	3
Not-yet-updated data	A4	4
Suppliers incapable of fulfilling materials needed for production	A5	3
Postponed receipt of purchasing requisition (PR) sent to suppliers	A6	2
Quantity misestimate written in PR receipt sent by users	A7	3
Act of God during material delivery	A8	2
Suppliers' lack of raw material inventories to cause required material incompatible with PR	A9	3
Suppliers' incapability of fulfilling quality demand	A10	4
Limited warehouse capacities	A11	4
Stock-material recorded data incompatible with stock opname	A12	5
Delay in managing received materials	A13	3
Prolonged inventories	A14	4
Unapplied FIFO system	A15	2
Highly-varied products	A16	4
Incompatible stock-material recording	A17	4
Lack of material inventories	A18	3
Postponed PR release	A19	2
Ill-functioning hydraulic machinery	A20	3
Error in machinery setup and setting	A21	2
Disruptions to an electric supply	A22	3
Imperfect inspection process	A23	3
Improper method	A24	4
Human error	A25	4
Loose binding	A26	4
Error in taking product samples	A27	2
Human error	A28	4
New employees or trained employees	A29	4
Error in goods identification	A30	4
Label specification unmatched with materials' real specification	A31	4
Lack of transportation availability	A32	4
Error in data input	A33	3
Disrepair transportation facilities	A34	4
An incident during material delivery	A35	2
Unconductive weather	A36	3

represents risk potential to have the most destructive impacts on companies, and therefore, be on top-managed priority. Appendix 1 describes the table of ARP level.

Risk agent to have the biggest ARP level shown by Pareto diagram is on the top-mitigation priority and put in HOR-2. The following figure is the list of to-be-mitigated risk agents based on the Pareto diagram-ranked ARP level. Figure 4 portrays the Pareto diagram. The Pareto diagram shows the top-priority-managed-and-mitigated risk agents to determine the proper precautions.

House of Risk-2 (HOR-2).

HOR-2 finds effective precautionary measures in order to lessen plausible risk agents. HOR-2 determines the correlation value between risk prevention and risk agents as well as the calculation of Total Effectiveness (TEK), Degree of

Difficulty (Dk), Effectiveness to Difficulty (ETDk) in order to figure out the priority of prevention action measures. Prevention actions suggested are also based on the lean manufacturing approach and using lean tools. Figure 5 displays HOR-2. Table 7 shows each of the prevention action's priorities based on the value of the effectivity ratio.

Proposed prevention action is Poka-Yoke method applied in Quality Control process, availability of product specification data, QC SOP (inspection and rework) and smartbooks quickly access by production operator. Production or working activities hardwired with erroneous factors—human error, flaw materials, improper methods, misinformation—to cause defects, and the further and in-depth analysis of erroneous factor will lead to the fact that each of the defects

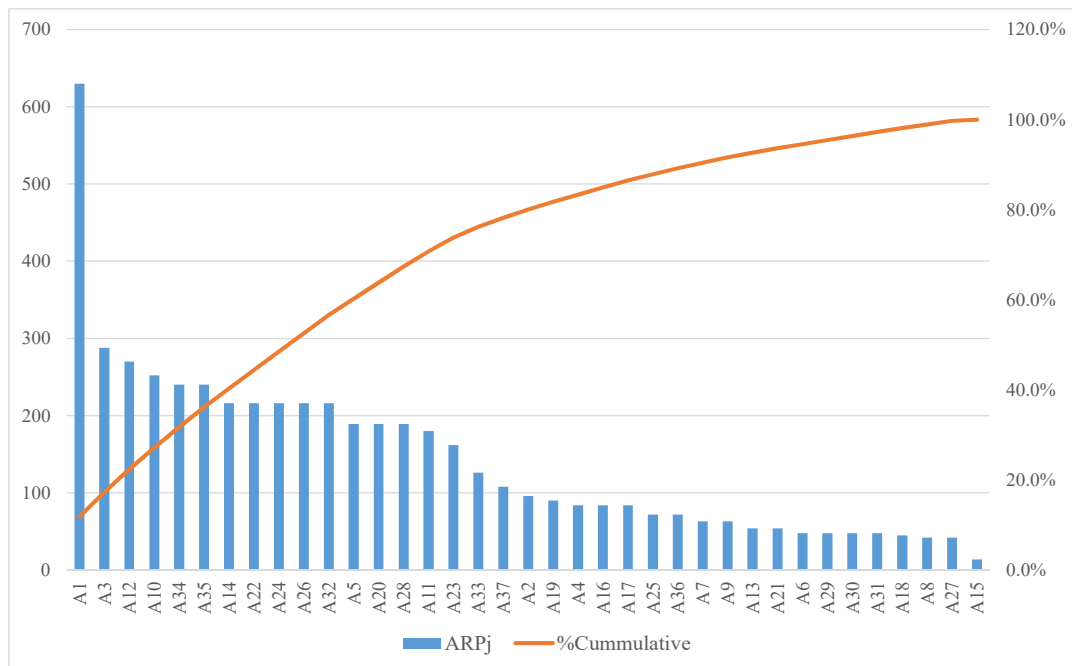


Figure 4. Pareto diagram of risk agent based on ARP Value

are made by humans (Syarifuddin and Sofyan, 2018). Poka-Yoke method is applied by creating supporting tools for controlling the working process so that checking and monitoring the quality control of precast concrete runs smoothly. These supporting tools must measure the suitability of dimensions and measure the visual condition of precast concrete from the surface to the inside. Company constraints in providing these supportive tools are in terms of cost. Companies must provide more budget, but if compared to the ease of the process and the results obtained, the provision of supporting tools for process control is still more effective and efficient.

Meanwhile, smartbooks mean applications to explain production and operators complete with their job descriptions comprehensively. It is expected that each of the operators using smartbooks can acquire information at hand so that coordination with related parties gets easier. The company itself can make this application; the features contained in the application can be tailored to the company's needs. Before running by all users, there must still be special training for

users to understand and not experience difficulties operating the application. The smartbook application can be ordered from the provider that provides this application for a broader scope.

The precast concrete industry's responsibility is not only in the production process but also includes product delivery. Therefore, adequate transportation facilities are needed and can guarantee that the product being moved remains safe. Precast concrete, which consists of several types, has a weight of around 25 tons. Transportation facilities used to deliver products are trucks, and the project's product delivery is carried out by road only. The company needs to calculate the optimal number of transportation suggestions that must be provided and adjust the provision of transportation facilities to the project that is being worked on.

Moreover, the MRP system is recommended to be complete with computerized safety stock; temporary suppliers are available to supply alternative materials, and safety stocks of rare material are adequate. MRP-computerized system initially was developed in the American

<i>To be treated risk agent Ai</i>	<i>Preventive Action</i>														<i>Aggregate risk potential</i>
	AP2	AP3	AP5	AP6	AP14	AP18	AP22	AP29	AP30	AP33	AP36	AP41	AP42	AP43	
A1													9		630
A2	9														96
A3	3														315
A4										9					84
A5								9							189
A6					9										54
A7					9										63
A8			3												42
A9	9														63
A10	3														252
A11							3								180
A12										3					270
A13											9				54
A14															216
A15							3								12
A16										9					72
A17										9					72
A18					9										45
A19					3										90
A20						9									216
A21						9									72
A22		9													216
A23												9	3		162
A24												9	9		252
A25													3		84
A26													9		252
A27												3	3		144
A28													3		180
A29												9	9		60
A30												9	3		60
A31												9	3		216
A32													9		240
A33									3						126
A34				3					3						240
A35				3					3						72
A36				3					3						108
<i>Total effectiveness of action k</i>	3132	1944	126	1260	1728	2592	576	1701	1638	2862	486	7182	5670	9774	
<i>Degree of difficulty performing action</i>	2	4	2	2	2	3	3	2	2	3	2	3	3	4	
<i>Effectiveness to difficulty ratio</i>	1566	486	63	630	864	864	192	851	819	954	243	2394	1890	2444	
<i>Rank of priority</i>	4	11	14	10	6	6	13	8	9	5	12	2	3	1	

Figure 5. House of Risk - 2

Production and Inventory System Society) APICS at the time of professional program development.

It gains popularity in industries applying computerized inventory design and management

Table 7. The priority of Prevention Action

No.	Prevention Action	Prev. Action Code	ETDk	Rank
1	POKA YOKE method for QC Process	AP43	7668	1
2	Product spec. data, QC SOP (inspection and rework), and smartbooks easily accessible by production operators.	AP41	4392	2
3	Design of transportation facilities and their alternative	AP30	2979	3
4	MRP System computerized with safety stock	AP42	2619	4
5	1. Availability of alternative substitute for rare materials 2. Availability of alternative interim suppliers 3. Sufficient inventories of rare materials	AP2	2295	5
6	ABC Item Classification; Q and P Implementation, and Recording and Updating data of material inventories	AP33	2079	6
7	Checking operational equipment and facilities	AP6	2048	7
8	Weekly PR Evaluation	AP14	1485	8
9	SOP for machinery use, updated records of machinery use, and scheduling preventive maintenance	AP18	1350	9
10	Keeping regular order for raw material in check; if companies' current suppliers are incapable of supplying required orders in less than a two-week notice, substitute for alternative suppliers shall be available	AP29	1094	10
11	An adequate alternative source of energy by a diesel generator	AP3	729	11
12	Coordinate with internal and external parties	AP36	607.5	12
13	Manage warehouse data and update inventories data	AP22	570	13
14	Update and monitor actual circumstances and natural conditions	AP5	108	14

as it identifies inventory items correlation so that more efficient inventory management determines precise and proper material needs (Yuliana and Octavia, 2001). MRP-computerized system whose operation is faster than the manual ones requires intensive operational training given to its operators to prove boon for the companies applying it. As business partners, suppliers play a crucial role in providing adequate material demand because they—in the supply chain concept—are significant for companies' sustainable production (Ramayanti & Ulum, 2017). Companies should have alternative suppliers to keep adequate inventories of rare materials in check. Another to having alternative suppliers, safety stock of rare materials is a precaution against possible project disruptions.

In addition, inventories review based on ABC classification, updated records of material stock data, evaluation of weekly PR, SOP for machinery use, updated records of machinery use, and routine preventive maintenance is also as significant as previously-elucidated prevention actions. Periodic monitoring of raw-material orders and alternative suppliers' availability to supply required material in less than two weeks

minimize any possible disruptions with respect to postponed material supply. In relation to risk agents in the form of technical troubles in plants to cause disruptions can be mitigated by routine checking of equipment and facilities used in operational activities, the availability of diesel generator, coordination with internal and external parties, management of warehouse stock data, updated record of inventories, and monitoring of factual and natural circumstances.

IV. CONCLUSION

The mapping of disruptions in precast supplied for construction projects reveals precautionary models for controlling disruptions are crucial in order to apply necessary control on disruption and maintain smooth operational activities in integrated parts of the supply chain. Key strategies for managing disruption to the precast concrete supply chain are Poka-Yoke method for QC process, availability of product specification data, QC SOP (inspection and rework), "smartbooks" accessible to production operators, MRP-computerized system integrated with safety stock, alternative interim suppliers, substitute for a rare material core to production.

The strategies should be useful to mitigate possible disruptions. Precautionary control on disruptions and HOR model prevent and minimize any possible disruptions; and therefore, KPI of the precast supply chain for construction projects and customers' values are successfully achievable.

ACKNOWLEDGMENT

A sincere thanks go to PT Adhi Persada Beton and the research institution of Trisakti University for making this research come into actualization.

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