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Analysis of Benefits of RFID Technology Implementation in Improving Precast Concrete Material Management Systems in Indonesian Construction

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Abstract. Material management is a crucial factor that needs to be considered in any construction project. Poor material management can significantly impact the construction's quality, time, and cost. In Indonesia, the implementation of technology in construction, particularly in the field of materials management, is still not developing rapidly. Therefore, this study aims to identify the issues with the precast material management system in Indonesia and the benefits of implementing RFID technology to improve it. The methods employed include quantitative surveys with expert validation, pilot surveys, questionnaire surveys, data testing, and the Relative Importance Index (RII) method. The quantitative survey involved 50 respondents, selected based on specific criteria. The primary issue arising from the absence of RFID technology in precast material management in Indonesia is the inconsistency between the quantity and quality of precast materials arriving at the construction site. The lack of an automated tracking and data collection system is a contributing factor to these issues. Meanwhile, the main benefit of implementing RFID technology in improving precast material management systems in Indonesia is the ability to maintain accurate and up-to-date inventory records of precast materials. RFID technology enables real-time storage of comprehensive information, thereby minimizing material data recording errors.

Introduction

In 2022, Indonesia is projected to experience a significant population growth of 1.17% compared to the previous year [1]. This growth will have an impact on the development of the construction industry in Indonesia. The availability of infrastructure will support community economic activities, ultimately affecting the level of community work productivity and economic development [2]. The success of a construction project relies on the effective utilization of manpower, machines, materials, methods, money, and time [3]. To avoid hindrances in construction projects, it is essential to implement efficient resource management.

In 2018, the Public Works and Spatial Planning Office of the Province of West Sumatra, Indonesia, handled 24 road infrastructure work packages. Out of these, 16 packages, or 66.7%, experienced delays in completing their tasks. [4]. Project delays have several adverse effects, including higher costs than initially anticipated, extended project completion times, a negative impact on the company's reputation, and reduced worker productivity and efficiency [5]. One of the primary causes of project delays is poor resource management, particularly in material management. Since materials contribute 40-60% to project costs, they play a crucial role in supporting project success [6]. Material management issues, such as material shortages and unfavorable material conditions, are significant factors leading to delays in construction projects in Indonesia [4]. Construction resources such as materials have a significant influence on the workers, thus the productivity of workers in material management becomes one of the factors causing project delays in Indonesian Construction [7]. In China, poor site management, especially regarding construction materials, is also identified as a contributing factor to project delays [8].

Material flow process management in construction is closely related to the delivery/distribution of construction materials [9]. Road conditions in the construction area will affect the material distribution process. DKI Jakarta and West Java are the provinces with the largest population density in 2021, with 15978 people/km^2 and 1379 people/km^2, respectively [10]. With high density, DKI Jakarta and West Java Provinces face many traffic congestion problems. This is supported by the number of motorized vehicles in each province in 2021, with DKI Jakarta having 21,034,054 units of motorized vehicles and West Java having 17,157,839 units of motorized vehicles [11].

In Indonesia, the precast industry is being developed to support Indonesian construction. The Ministry of Public Works and Public Housing (PUPR) continues to encourage the use of precast concrete technology, which has the advantage of being more standardized in quality and safe to use which guarantees speed and continuity in the concrete production process [12]. Based on data from the Directorate General of Construction, the capitalization of the precast concrete industry in 2014 accounted for around 16.61 percent of the total national concrete work [13]. This portion was projected to increase up to 30 percent by 2019 [13]. Based on data from the 2016 Indonesian Association of Precast and Prestressed Concrete (IAPPI), the total production capacity of 56 precast concrete factories throughout Indonesia is 25.4 million tons per year, with an average production of 454,499 tons per year for each factory [13]. Meanwhile, the demand continues to exceed the production capacity of the precast concrete industry by five times [13].

One of the problematic issues that occur in construction projects in Indonesia is the slow adoption of modern technology [14]. The National Contractor now requires each project to use BIM-based technology in the planning, implementation, and operational processes [15]. One of the modern technologies that facilitates real-time tracking and identification of materials based on a wireless non-contact system is Radio Frequency Identification (RFID) [9]. In the Public Housing Project located in Tuen Mun District, Hong Kong, paperwork in the production and logistics stages was reduced by 48.3% and 40%, respectively [16]. Production efficiency also increased, with the production life cycle and waiting time for delivery increasing by 40% and 25%, respectively, and assembly time increasing by 6.67% [16].

The implementation of RFID technology in construction material management can increase the precision of material planning, leading to significant cost savings and improved construction quality [17]. Therefore, this research is considered important as it aims to identify the issues in the construction precast material management systems in Indonesia and analyze the benefits of using RFID technology as an alternative to manual material management systems.

Literature Review

Materials Management. Project Resource Management is the process of identifying, obtaining, and managing the resources needed for the successful completion of a project [18]. There are six types of project resources, including man, material, equipment, method, money, and time. Of the six project resources, material is one of the resources that can affect project quality, cost, and time [19].

Materials management is a management system that aims to plan and control all the efforts required for construction materials [20]. Material planning is achieved by integrating and combining the functions of project planning, purchasing, transportation, field material control, and storage [21]. Inappropriate material planning and control can lead to insufficient statistics regarding material availability, a lack of funds for procurement, inadequate transportation capacity, prolonged waiting times, and uncertainty in the delivery of ordered materials [21]. According to Kasus et al. [22], the processes in material management are divided into material selection, material delivery, material receipt, material storage, and material expenditure.

Precast Concrete Materials. Precast material is a component of structural and non-structural concrete materials manufactured in a factory and transported as complete or semi-complete assemblies to the construction site where the structure will be placed [16]. Structural precast concrete is commonly used in various building and infrastructure elements, such as columns, beams, girders, driven piles, box girders, piers, and others [16]. Meanwhile, the use of facade materials as non-structural precast materials is an alternative choice that is often preferred due to their high aesthetic value and efficient installation process without altering the building's function [23]. Non-structural precast materials include precast walls (facades), precast culvert boxes, U-Ditch channels, and others [24]. Precast materials offer numerous advantages over non-precast materials. According to Tam et al. [25], there are seven benefits of precast materials: initial design for better prefabrication adoption, better supervision to improve the quality of prefabricated products, reduced overall construction costs, shortened construction time, improved environmental performance to minimize waste, design integrity and building construction, and aesthetic improvements in buildings. Off-site construction is becoming a prevailing trend in the construction industry due to the increasing pressure to reduce the environmental impact of construction projects [26].

Precast materials have four main phases: prefabrication, delivery, storage, and construction on-site [17]. In the prefabrication phase, the production of precast materials generally consists of mold making, mold assembly, reinforcement setting, casting, curing, mold release, and finishing/repair [26]. In this phase, it is essential to consider the details of the material components and the material component production schedule [17]. Additionally, the process of sending precast materials involves connecting construction sites with prefabricated factories. Transportation tracking serves to obtain location, status information, and the estimated time of arrival of precast materials [26]. Subsequently, the precast material is stored at the factory or construction site before being transported and assembled. In this phase, layout optimization, identification, tracking, and finding of precast materials are important considerations [26]. Finally, the precast materials assembled at the construction site can be controlled, and the construction progress can be monitored by summarizing the location information and the number of components [17].

Radio Frequency Identification (RFID) Technology System. Radio Frequency Identification (RFID) is an automation technology that uses radio waves with different frequencies to identify objects [27]. The main components of RFID consist of RFID tags, RFID readers, and host terminal [20]. RFID tags are used to identify objects. [28]. The RFID Readers are used to read objects that already have an identity that has been attached to an RFID tag [28]. Meanwhile, the host terminal functions as an integration system between RFID technology and other technologies [20]. RFID technology can be integrated with various other technologies, such as computer vision systems, positioning systems, and cloud systems, aiming to improve the accuracy of using RFID technology [29].

Fig 1. RFID Technology Components
Source : [20]

The RFID system consists of tags (transponders) attached to materials, with each tag containing product information such as name, category, price, serial number, location, or other data [30]. There are two components in the RFID Tag, such as the antenna and the silicon chip. The antenna is used to activate the tag by emitting radio waves so that the tag can receive information from the reader [28]. Meanwhile, the silicon chip contains data and information that allows for more data storage [28]. Additionally, RFID readers are equipped with antennas to read and access data from tags [30]. The resulting data is sent to the control computer for record-keeping. In this way, data collection is carried out automatically and correctly without human intervention [9]. There are four main functions of using RFID technology: planning, tracking, monitoring, and information systems. RFID technology can be used to gain real-time access to information related to precast materials, track and monitor precast material operations such as production, delivery, and use of precast materials [31].

Moreover, RFID technology can also reduce the time in the data transmission process, enabling quick and precise access by the involved stakeholders [16].

Methodology

Research Flow. The research method is a systematic approach used to achieve a specific goal by obtaining information about the activity [32]. The research thinking framework is a system of thought that illustrates the research workflow. The research flow is shown in figure 2. below,

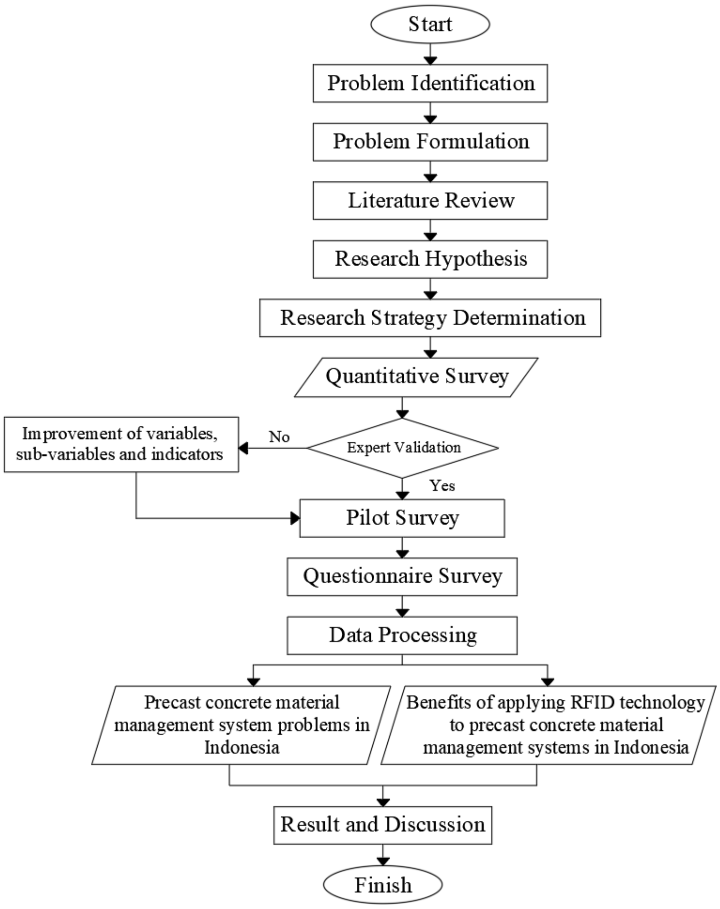


Fig 2. Research Flow Framework

Questionnaire Design. For the first and second research questions, the data collection method used was a questionnaire survey supported by expert validation and a pilot survey. Expert validation is carried out by recruiting 5 experts who have work experience of more than 10 years, experience in managing precast materials, and experience in using new technology in construction projects. Expert validation was conducted using the method of directly distributing validation questionnaires through face-to-face meetings or via Google Form and online meeting platforms. The majority of indicators were approved by the experts with some suggestions for improvements, making them suitable for data collection. The final validation is also conducted after the data has been collected and processed. The purpose of the final validation is to obtain feedback related to the research findings, which will be used as a basis for analysis. Next, a pilot survey was conducted to determine whether the indicators were easily understandable. The pilot survey involved 10 respondents, and it was found that all indicators were easily understood, making them suitable for the questionnaire survey. The questionnaire survey was conducted using a Likert scale of 1-5 with a total of 50 respondents for each research question. The respondents selected for the survey had at least two years of experience working with precast materials and were knowledgeable about new technologies used in construction projects. The following are the research variables used for the questionnaire survey,

Table 1. Issues of Precast Materials Management System in Indonesian Construction

Code	Sub Variable	Code	Indicator	References
X.1.1	Planning	X.1.1.1	Unbalanced production of precast materials between demand and storage	[33], [34]
		X.1.1.2	Lack of planning on the estimated delivery time	[20], [35], [34]
		X.1.1.3	Changes in design and specification of precast materials	[35], [16]
X.1.2	Tracking	X.1.2.1	Errors on specifications and precast material requirements	[35], [30]. [26]
		X.1.2.2	There's no tracking system during the delivery of precast materials	[26]
		X.1.2.3	Differences in the quantity and quality of precast materials that are delivered to the site	[8], [36], [35]
		X.1.2.4	Improper use of precast materials	[8], [35], [36]
X.1.3	Monitoring	X.1.3.1	Errors on specifications and precast material requirements	[35], [30], [26]
		X.1.3.2	Incorrect location of precast material storage	[37], [9], [34]
		X.1.3.3	Lack of on-site precast material storage	[35], [9], [34]
		X.1.3.4	Differences in the quantity and quality of precast materials at the site	[8], [35], [36]
X.1.4	Information Systems	X.1.4.1	Difficulties in accessing precast material request status and information between contractors and suppliers	[38], [35]
		X.1.4.2	Information gaps among stakeholders	[8], [30]
		X.1.4.3	Lack of agreement between the contractor and the owner regarding the requirements for seeking precast materials that are more urgently required in advance	[34], [38]
		X.1.4.4	Miscommunication related to the use of precast materials	[8], [35], [34]
		X.1.4.5	Loss of progress records of precast material assembly by workers	[36]

Table 2. Benefits of RFID Technology Implementation in Precast Concrete Material Management Systems in Indonesian Construction

Code	Sub Variable	Code	Indicator	References
X.2.1	Planning	X.2.1.1	Estimated lead time production for precast materials	[33]
		X.2.1.2	Accurate prediction of precast material delivery time	[39], [33]
		X.2.1.3	Real-time changes in precast material information	[16], [17], [40]
X.2.2	Tracking	X.2.2.1	Real-time tracking of precast material production process	[16], [41], [42], [17]
		X.2.2.2	Accurate tracking of precast material delivery location	[9], [26]
		X.2.2.3	Real-time tracking of precast material's condition during delivery	[16], [17]
		X.2.2.4	Tracking the history of precast material use from storage	[36], [42], [37], [43]
X.2.3	Monitoring	X.2.3.1	Real-time monitoring of precast material production information	[36], [44], [16]
		X.2.3.2	Checking the storage arrangement for precast materials	[42], [37]
		X.2.3.3	Accurate and up-to-date supply records of precast materials	[42], [36]
		X.2.3.4	Controlling the use of precast materials at the job site	[29] [41] [36] [39]
X.2.4	Information Systems	X.2.4.1	Ease of access to information by involved stakeholders	[40], [16], [30]
		X.2.4.2	Transparency of material information for involved stakeholders	[39], [17]
		X.2.4.3	Automatic repository of detailed information	[41], [26]
		X.2.4.4	Accurate and quick data transmission	[9] [16] [26]
		X.2.4.5	Increased data security	[45], [9]

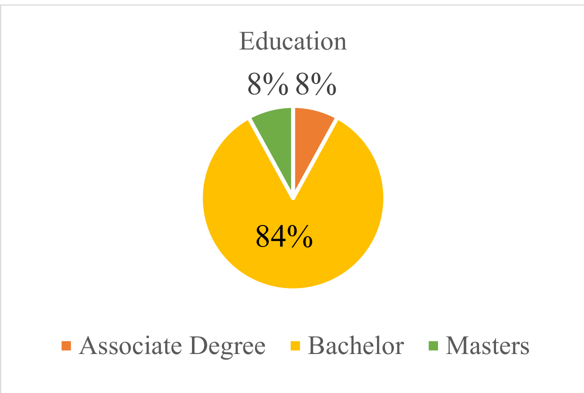
Data Processing Methods. The data analysis method used in this study was quantitative analysis for the first and second research questions. For the first and second research question, data analysis was performed using SPSS and Microsoft Excel software to test validity, reliability, homogeneity, hypothesis, and the Relative Importance Index (RII) method. The validity test serves to determine whether or not a variable is appropriate for use in this study [46]. The validity test is conducted by comparing the calculated R-value (Pearson correlation) with the critical R-value from the table for a two-tailed test with a significance level of 0.05. Nest, the reliability test was carried out to measure the consistency of a questionnaire for all indicators of variables [46]. The reliability test is conducted by comparing the Cronbach's alpha value with the chosen significance level used in the analysis. A homogeneity test is performed to determine whether the variances of two or more distributions are the same [47]. In the homogeneity test, data can be considered homogeneous if the obtained significance value is greater than 0.05. The data used in this homogeneity test is parametric in nature. This is because the type of data collected does not assume anything, and the data will be normally distributed. This will be verified through the homogeneity test. The unknown population data makes the normality test unnecessary. Lastly, hypothesis testing is carried out to determine whether the research hypothesis that has been made is appropriate or not [46]. Meanwhile, the RII method is used to see the ranking of the data that has been obtained. The following is the formula used for the RII method according to [36],

$$\mathrm{RII} = \frac{\sum \mathrm{W}}{\mathrm{A} \times \mathrm{N}} \tag{1}$$

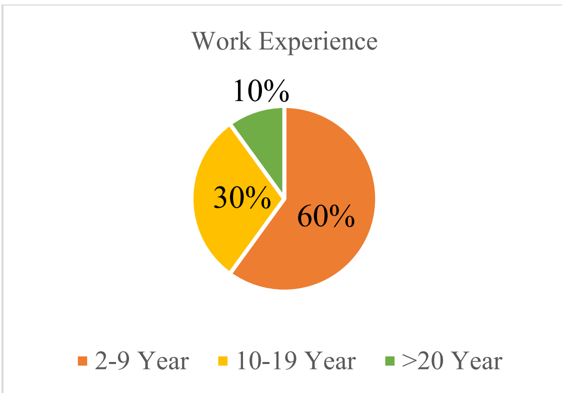
W : Weight on each factor given by respondents in the range 1-5
N : Number of Respondents
A : The largest scale weight (in this study is 5)

Discussion

Issues of Precast Concrete Materials Management System in Indonesian Construction. Out of the 50 respondents, the majority were state-owned contractors (56%), holding a bachelor's level of education (84%), with 2-9 years of work experience (60%), and occupying staff-level positions (56%). Geographically, most of the respondents worked in West Java (58%). The following is a summary of the respondent's profile on this research question,



(a)



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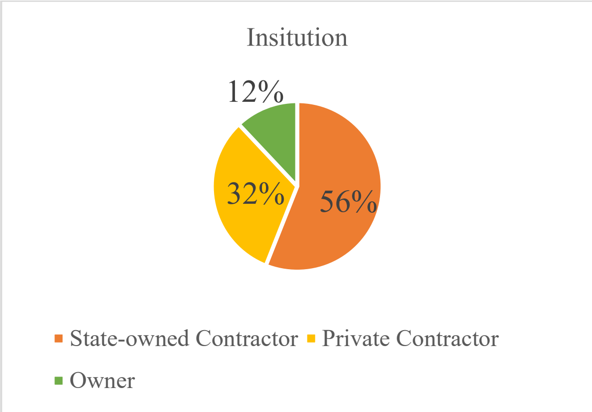

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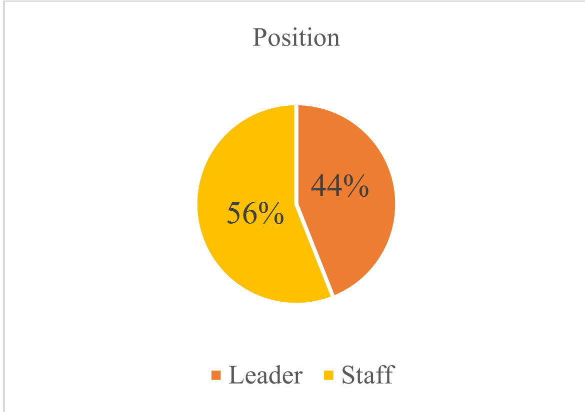

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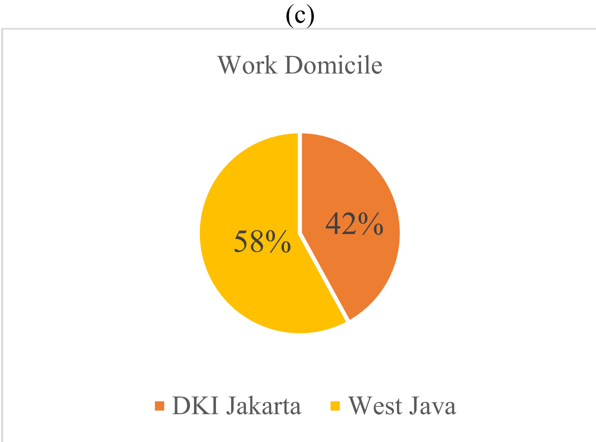

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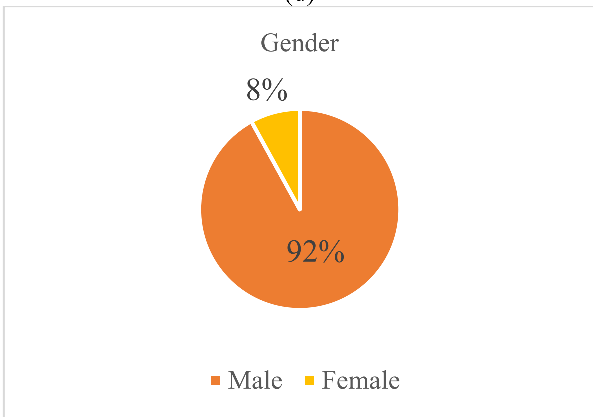

(f)

Fig 3. (a) Respondent's Education RQ 1, (b) Respondent's Work Experience RQ 1, (c) Respondent's Institution RQ 1, (d) Respondent's Position RQ 1, (e) Respondent's Work Domicile RQ 1, (f) Respondent's Gender RQ 1

For this research question, data testing was carried out on each indicator of issues with the precast concrete material management system in Indonesia. The following are the results of testing the validity, reliability, and hypothesis,

Table 3. Validity, Reliability, and Hypothesis Test Result for Research Question 1

Indicator	**Validity Test R-Statistic**	**Reliability Test *Cronbach's alpha***	**Hypothesis Test T-Statistic**
X.1.1.1	0.515	0.887	7.88
X.1.1.2	0.618	0.884	5.72
X.1.1.3	0.406	0.893	6.54
X.1.2.1	0.645	0.883	4.66
X.1.2.2	0.532	0.887	4.97
X.1.2.3	0.693	0.881	6.23
X.1.2.4	0.780	0.876	3.80
X.1.3.1	0.710	0.880	3.77
X.1.3.2	0.540	0.888	2.51
X.1.3.3	0.287	0.896	3.84
X.1.3.4	0.533	0.887	7.40
X.1.4.1	0.582	0.885	4.16
X.1.4.2	0.710	0.880	2.77
X.1.4.3	0.787	0.876	1.94
X.1.4.4	0.778	0.877	4.38
X.1.4.5	0.673	0.882	1.98

The test results show that all indicators can be considered valid and consistent because both the R-Statistic and Cronbach's Alpha values are greater than the R-Table for a population of 50 respondents, specifically 0.279. According to the hypothesis test, each indicator has a greater T-Statistic value than the T-Table, specifically 1.677. This indicates that each problem indicator in this research question has a significant impact on the precast material management system. Additionally, the homogeneity test shows that the data comes from a homogeneous variance or the same population because the significance value obtained is greater than 0.05. Below are the results of the homogeneity test for this research question,

Table 4. Homogeneity Test Result for Research Question 1

	Education	Institution	Position	Work Experience	Work Domicile
Sig.	0.153	0.183	0.436	0.121	0.489

According to the results of the questionnaire survey, the precast material management system can cause many issues that significantly affect the execution of construction projects. The following is a precast material management system problem based on the sub-variable RII value in this research question,

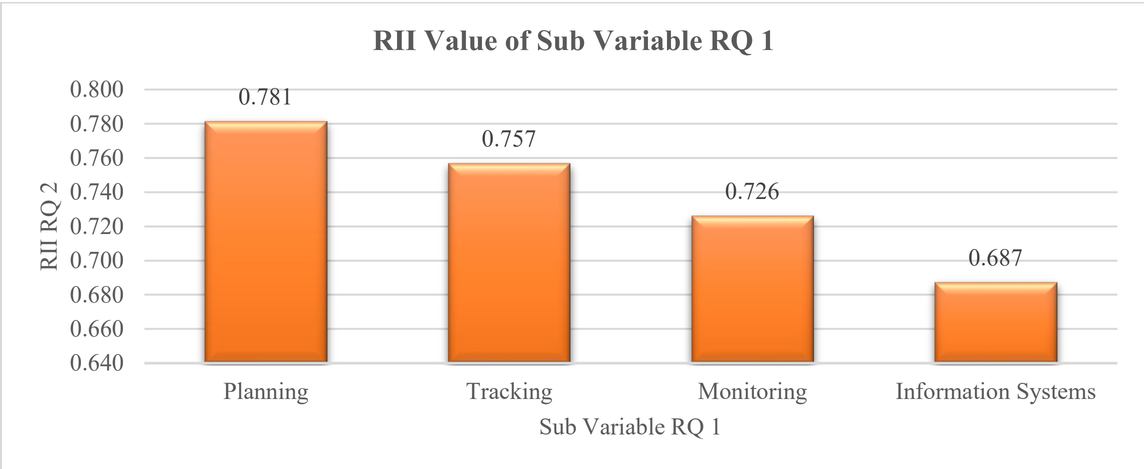

Fig 4. RII Value of Sub Variable RQ 1

The largest RII value indicates that the planning function is the most significant aspect of the precast concrete material management system issues in Indonesian construction. This can be attributed to the fact that the planning function plays a crucial role in determining the project schedule. The existence of miscommunication regarding production, delivery, and material tracking will cause changes in the project cycle so that more resources are needed to re-plan the precast management system. On the other hand, the information system function is the least significant issue that occurs in the precast material management system in Indonesian construction. This is because communication between stakeholders is still considered lacking urgency in the precast material management system.

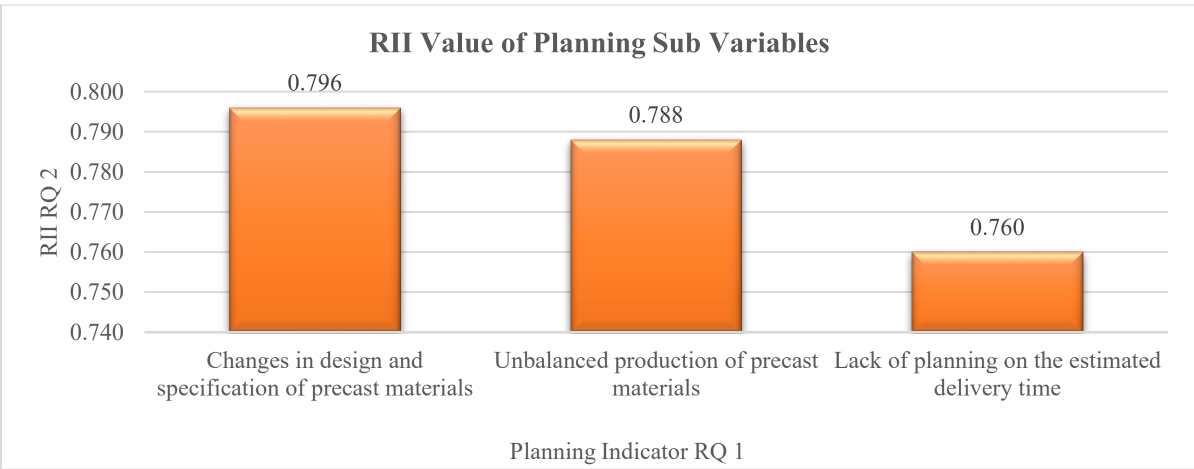

Fig 5. RII Value of Planning Sub Variables RQ 1

Changes in material design and specifications are the primary indicators of problems in the precast material management system, particularly in the planning function [35]. Changes in design and material specifications often occur due to changes in precast material requirements, which can be affected by project conditions during the project [16]. Changes in the design and specification of precast materials can have a serious impact on the project because it will take time and cost in the process of reproducing precast materials. Moreover, discrepancies in design and material specifications between the planning phase and on-site materials may result in disputes among the involved stakeholders.

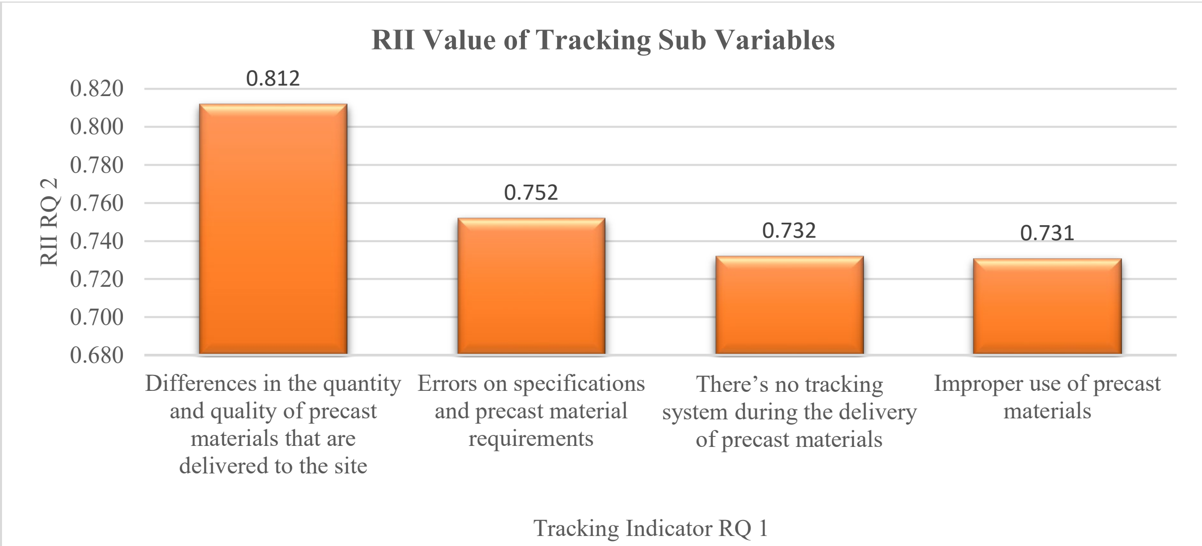

Fig 6. RII Value of Tracking Sub Variables RQ 1

The tracking function identifies the differences in quantity and quality of precast materials delivered to the site as the primary issue with the precast material management system [36]. This can be caused by checking the precast material manually, so massive precast material production will cause errors in data collection from the quantity and specifications of precast material [9]. One of the factors contributing to data collection errors is the large size of precast materials, which requires workers to check the material in several storage zones during data collection. Differences in the quantity and quality of precast materials will lead to additional construction time and costs because the work will be hampered.

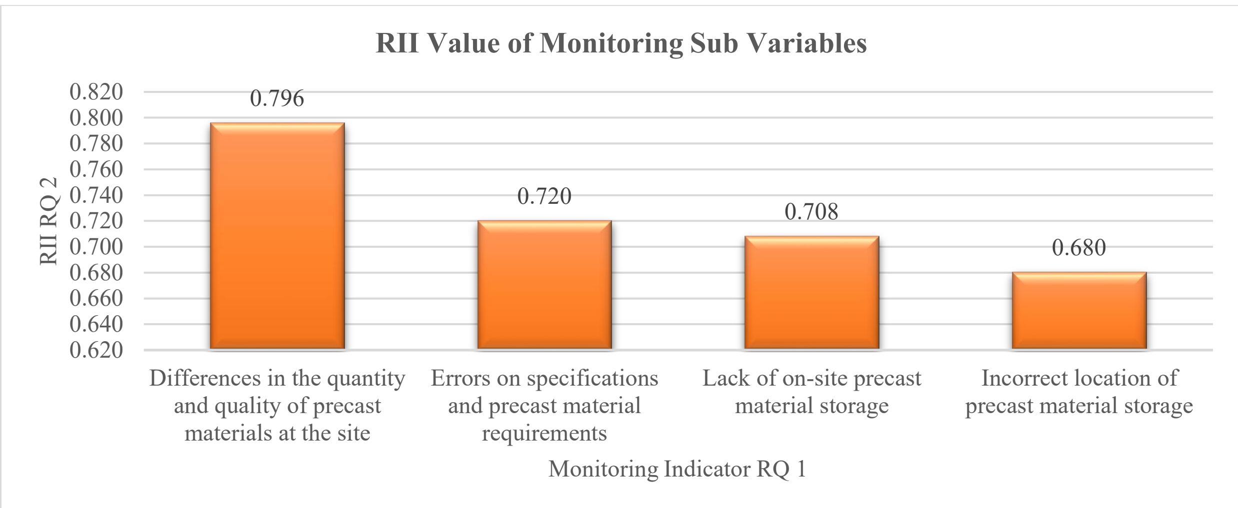

Fig 7. RII Value of Monitoring Sub Variables RQ 1

The differences between the quantity and quality of precast material in the project field and factory are the key issues in the precast material management system, particularly in the monitoring function [36]. Projects that store precast materials at the work site or factory need regular monitoring for both quantity and quality. This is because planning for material storage is a complex process [9]. Precast materials cannot be placed randomly, as improper placement can cause cracks in the precast material.

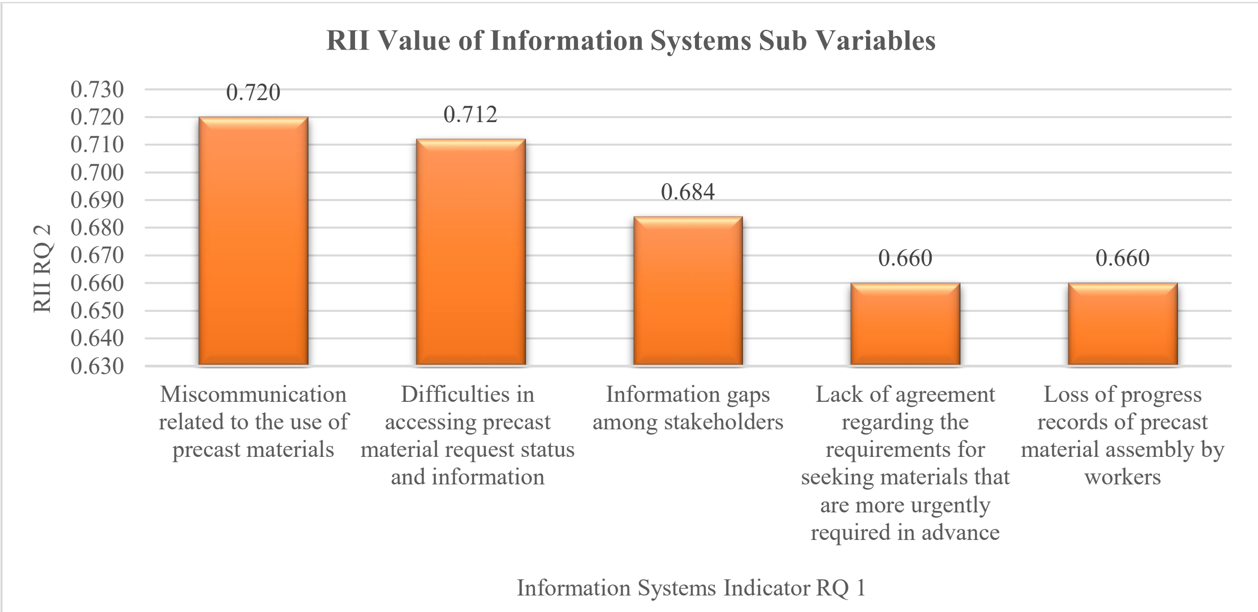

Fig 8. RII Value of Information Systems Sub Variables RQ 1

In the information system function, the main problem in the precast material management system is miscommunication related to material use [35]. Precast materials have codes that indicate their type and intended use. These codes are usually written on or affixed to the precast materials. The large number of variations in the use of precast materials can lead to a high level of discrepancy in their intended use. When precast materials are not installed in the appropriate locations, it can result in improper fitting and create gaps in the installation.

From the overall value of RII (Relative Importance Index), the main issue in the precast construction material management system in Indonesia is the inconsistency of the quantity and quality of precast materials arriving at the site due to the lack of implementation of an automated tracking system, specifically using integrated RFID technology. Previous research results have shown that issues in material management systems, particularly in Egypt, are related to tracking material functions, such as changes in material types and specifications during construction, material damages in the storage, and low quality of construction materials leading to damages and shortages of materials. [35]. The lack of automated tracking and data collection system is one of the contributing factors to the occurrence of issues. Additionally, changes in design and material specifications often occur during the prefabrication phase. According to Zhong et al [16], sudden changes in design and material specifications can lead to significant losses. This is because there is no capability to respond to design changes and work plans in real-time.

Benefits of RFID Technology Implementation in Precast Concrete Material Management Systems in Indonesian Construction. There are several respondents who are different from the previous research question because this research question requires knowledge related to new technology in construction projects. Out of the 50 respondents, the majority were state-owned contractors (56%), holding a bachelor's level of education (84%), with 2-9 years of work experience (58%), and occupying staff-level positions (54%). Geographically, most of the respondents worked in West Java (56%). The following is a summary of the respondent's profile on this research question,

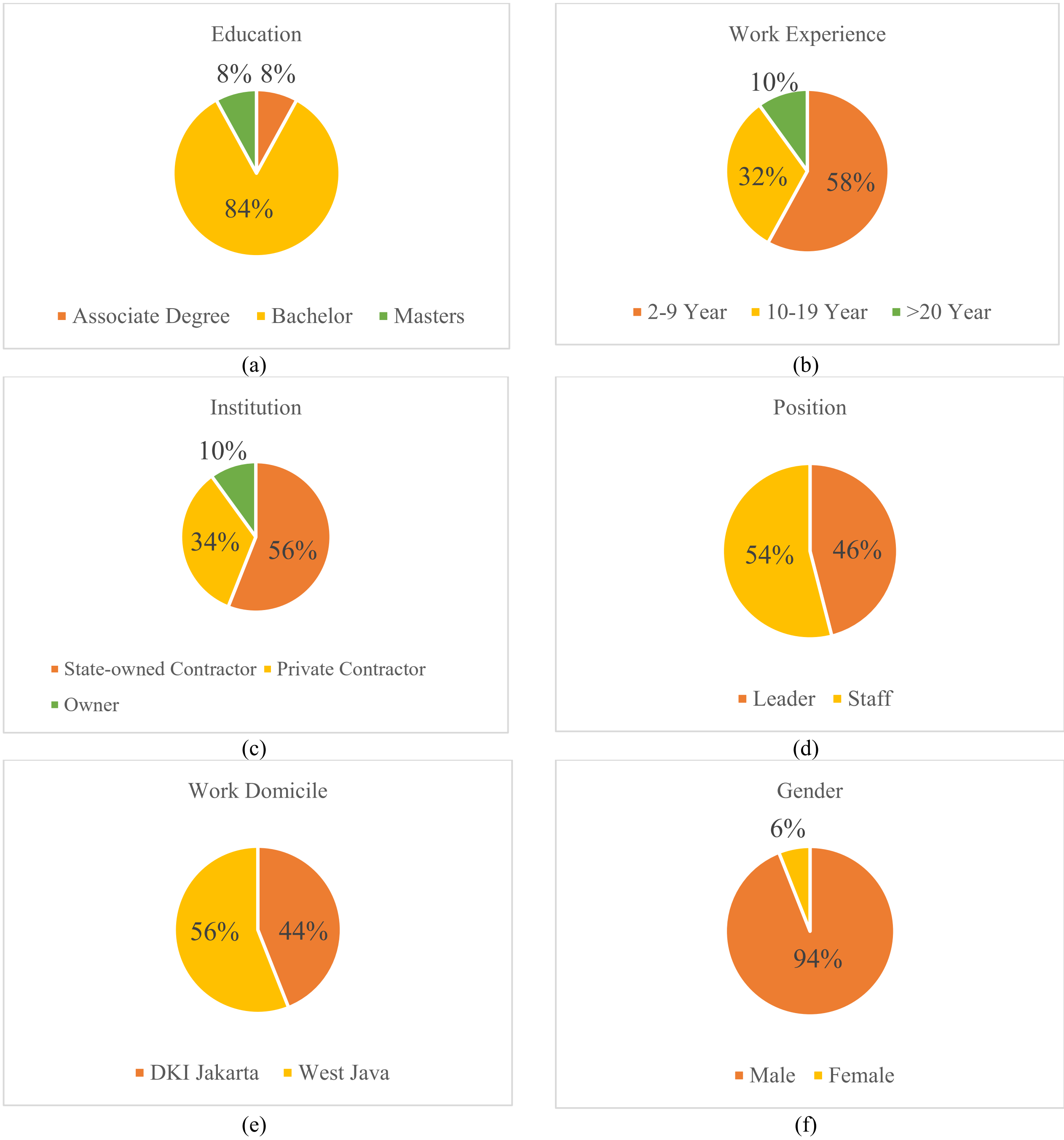

Fig 9. (a) Respondent's Education RQ 2, (b) Respondent's Work Experience RQ 2, (c) Respondent's Institution RQ 2, (d) Respondent's Position RQ 2, (e) Respondent's Work Domicile RQ 2, (f) Respondent's Gender RQ 2

For this research question, data testing was carried out on each indicator of the benefits of implementing RFID technology in precast material management systems in Indonesia. The following are the results of testing the validity, reliability, and hypothesis testing,

Table 5. Validity, Reliability, and Hypothesis Test Result for Research Question 2

Indicator	Validity Test R-Statistic	Reliability Test *Cronbach's alpha*	Hypothesis Test T-Statistic
X.2.1.1	0.459	0.830	14.00
X.2.1.2	0.646	0.819	10.25
X.2.1.3	0.723	0.813	8.63
X.2.2.1	0.499	0.829	9.86
X.2.2.2	0.671	0.818	6.62
X.2.2.3	0.547	0.827	7.85
X.2.2.4	0.309	0.841	10.92
X.2.3.1	0.695	0.817	11.48
X.2.3.2	0.641	0.820	6.82
X.2.3.3	0.374	0.834	20.61
X.2.3.4	0.427	0.834	10.30
X.2.4.1	0.424	0.833	9.34
X.2.4.2	0.439	0.832	9.71
X.2.4.3	0.510	0.828	10.53
X.2.4.4	0.485	0.829	11.48
X.2.4.5	0.685	0.817	6.29

The test results show that all indicators can be considered valid and consistent because both the R-Statistic and Cronbach's Alpha values are greater than the R-Table for a population of 50 respondents, specifically 0.279. According to the hypothesis test, each indicator has a greater T-Statistic value than the T-Table, specifically 1.677. This indicates that each indicator of the implementation of RFID technology brings significant benefits to the precast material management system. Additionally, the homogeneity test shows that the data comes from a homogeneous variance or the same population because the significance value obtained is greater than 0.05. Below are the results of the homogeneity test for this research question,

Table 6. Homogeneity Test Result for Research Question 2

	Education	Institution	Position	Work Experience	Work Domicile
Sig.	0.120	0.052	0.173	0.193	0.578

From this research question, it can be seen that the most useful implementation of RFID technology in precast material management systems is through the RII value. The following is the RII sub-variable value in this research question,

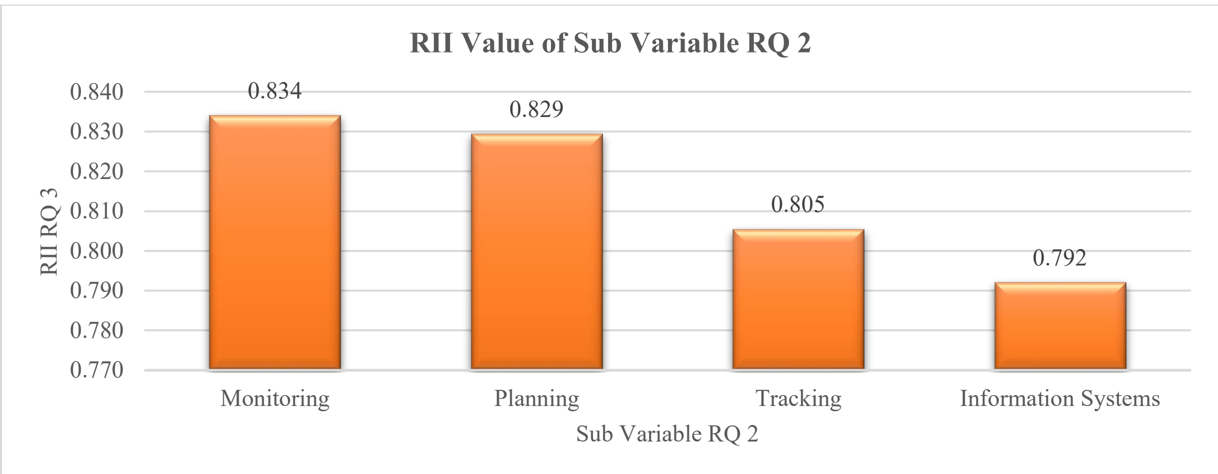

Fig 10. RII Value of Sub Variable RQ 2

Monitoring and planning functions are the most beneficial functions in the implementation of RFID technology in improving precast material management systems in Indonesia. This may be attributed to the monitoring function's ability to reduce error rates in time planning and facilitate adjustments between work conditions in the field and production in the factory. RFID technology, when integrated into monitoring and planning functions, proves useful for real-time monitoring of precast material production information [36], monitoring precast material storage layouts [42], recording accurate and up-to-date material inventories [42], controlling material usage in job locations [41], estimated lead time production for precast materials [33], accurate prediction of material delivery time [39], and real-time changes in material information requirements [16]. On the other hand, the information system function's implementation of RFID technology is deemed less useful in improving the precast material management system in Indonesia. This is because real-time communication between stakeholders is still considered to lack urgency in the precast material management system.

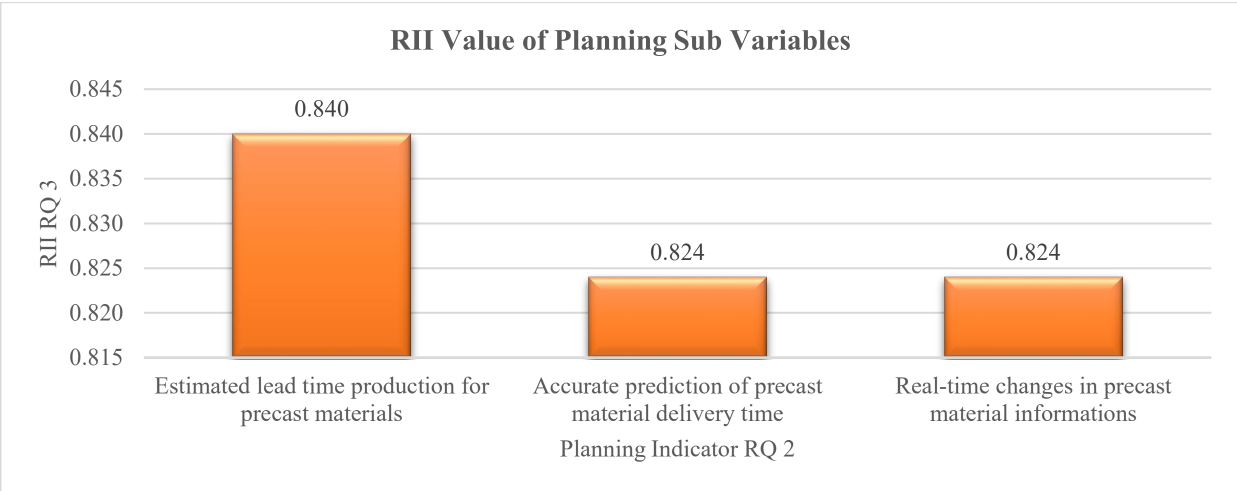

Fig 11. RII Value of Planning Sub Variables RQ 2

The ability to predict the lead time for precast material production is one of the key advantages of integrating RFID technology into a precast material management system for the planning function [33]. Production data generated from the RFID system can be used to calculate productive processing time and capture real-time snapshots of production so it can produces an optimal production schedule [33].

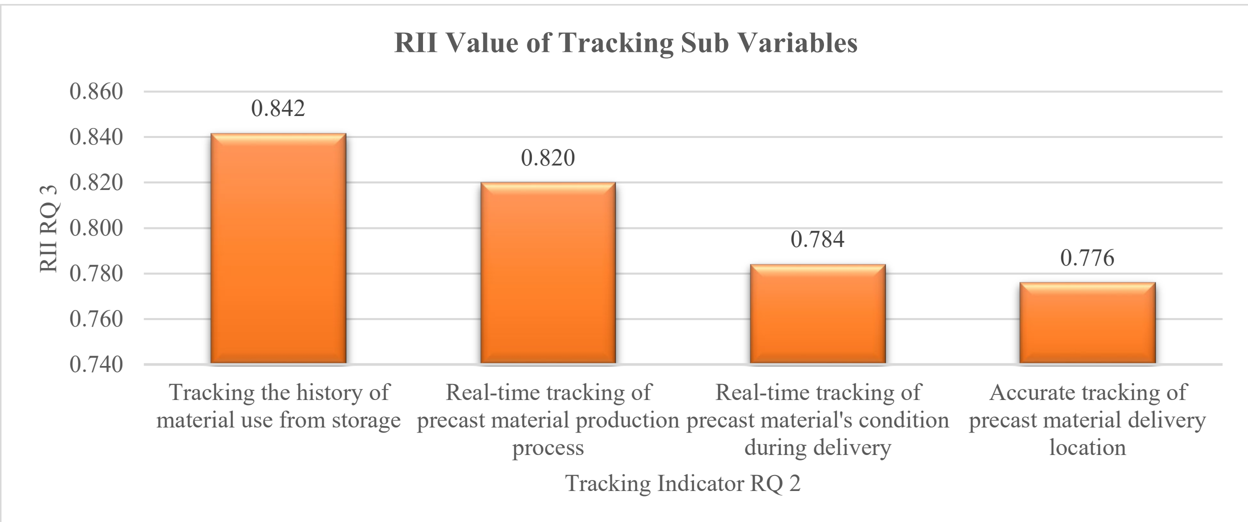

Fig 12. RII Value of Tracking Sub Variables RQ 2

Tracking the history of material used from storage is the key advantage of integrating RFID technology into the precast material management system for the tracking function [36]. Tracking the history of precast material usage from storage using RFID allows for the retrieval of comprehensive information on precast materials, including their intended uses, specifications, and the locations of their respective production factories [9]. This data collection is highly helpful for reducing mistakes made when using precast materials in the field and for planning the procurement of additional precast materials. In addition, identification using RFID can prevent disputes between the project and the factory.

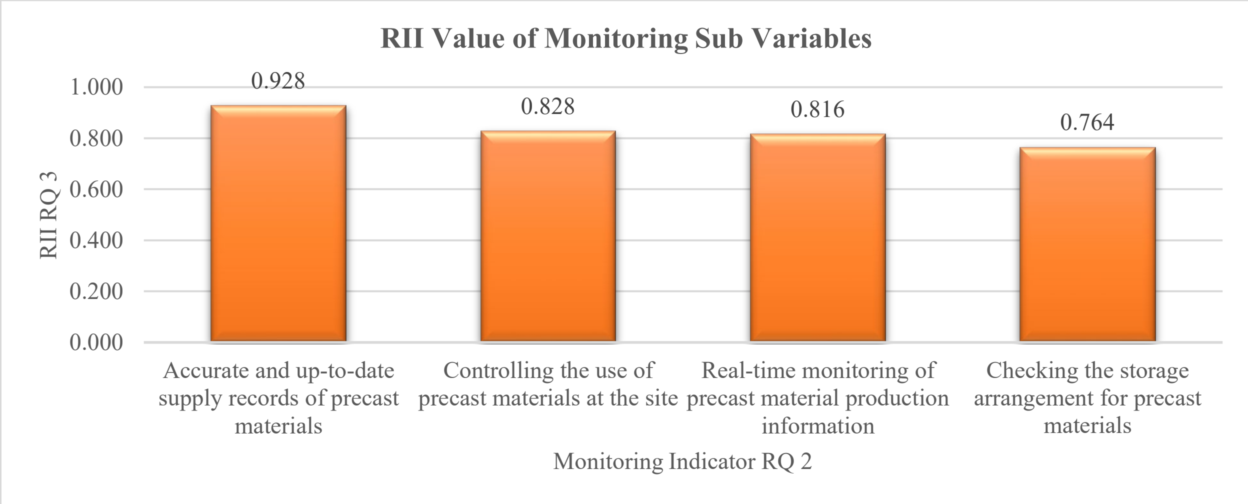

Fig 13. RII Value of Monitoring Sub Variables RQ 2

The precast material inventory is recorded accurately and up-to-date, which is the fundamental benefit of integrating RFID technology into the precast material management system in the monitoring function [42]. Recording precast material inventory can be time-consuming, especially in large storage facilities. RFID technology provides a solution by efficiently identifying stored precast materials and retrieving essential information, such as quantity, specifications, and storage location of each precast material [26].

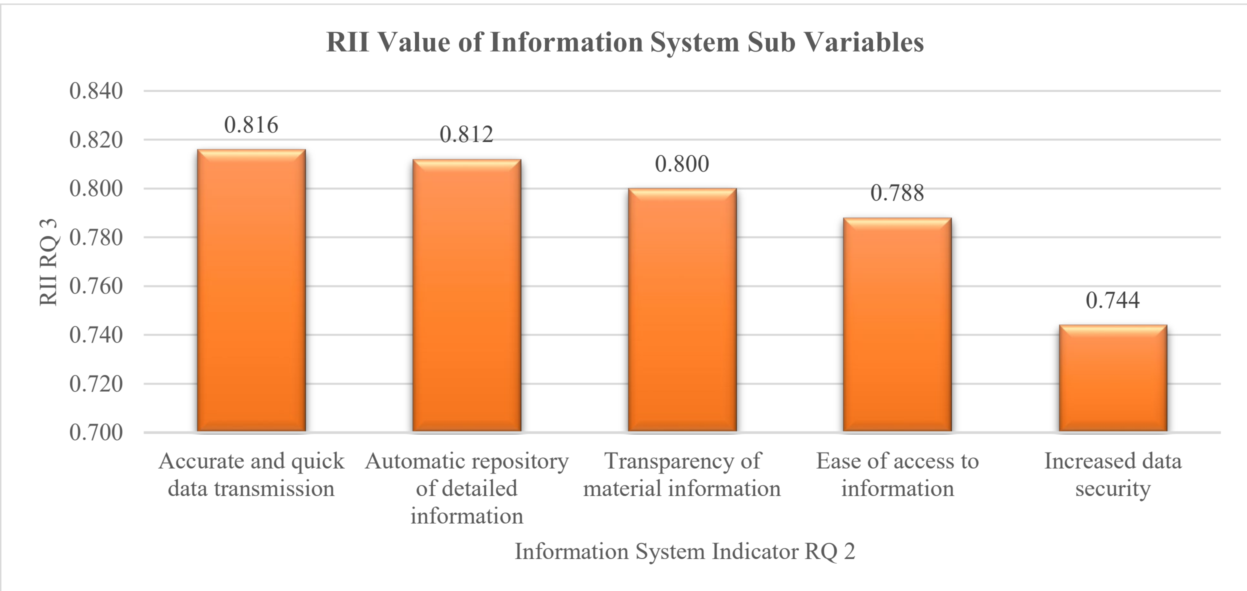

Fig 14. RII Value of Information System Sub Variables RQ 2

The accurate and quick data transmission is the primary benefit of integrating RFID technology into the precast material management system from an information system perspective [9]. RFID technology can transfer precast material information precisely and quickly so that it can minimize precast material data collection errors and other stakeholders can view information quickly and precisely.

From the overall value of RII (Relative Importance Index), The main benefits of implementing RFID technology in improving the precast construction material management system in Indonesia are accurate and up-to-date recording of precast material inventory. Previous research findings indicate that RFID technology plays a crucial role in the material management system, specifically in data recording of precast material, including quantity, specifications, and location [9]. This aligns with the benefits obtained from this research, which are related to accurate recording of precast material inventory and tracking the usage history of materials from storage locations. RFID technology can store complete information in real-time, thereby minimizing material data recording errors [30].

Conclusion

The conclusion that can be drawn from this study regarding the RFID technology benefits analysis in developing precast concrete materials management systems in Indonesia as follows,

1. The main issue in the precast material management system in Indonesian construction is in the precast material planning function.
2. The issue that has the biggest impact on the precast material management system due to the lack of an automated tracking system using integrated RFID technology is the difference between the quantity and quality of precast materials arriving at the location.
3. The main benefit of implementing integrated RFID technology in improving precast material management systems in Indonesia is in the precast material monitoring and planning functions.
4. Accurate and up-to-date inventory recording of precast materials is the most useful function of RFID technology in improving precast material management systems in Indonesia

This research has several limitations so that this research can still be developed. With the object used in the form of precast concrete material, research can be developed using other objects such as human resources, heavy equipment, and non-precast materials in the implementation of integrated RFID technology to support a wider scope of resource management. With the method taken in the form of a questionnaire survey, the implementation of an integrated RFID technology system can also be developed for further research by conducting system development and experiment testing of RFID technology systems on precast material management systems in Indonesia.

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