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Research Article

Just-in-time application on readymix concrete production

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Abstract
The construction industry often faces problems occurring during construction projects such as delays in the delivery of raw materials and inadequate quality of raw materials. One of the raw materials needed for construction activities is readymix concrete (RMC). Therefore, a system that is capable of ensuring the quality and delivery of raw materials needs to be implemented. This study aims to investigate the application of a just-in-time (JIT) production system during the readymix production process. Moreover, this study also determines the effectiveness of the production process concrete batching plant implemented by the RMC supply company. The results showed that the concept of JIT has not yet been fully applied in RMC production. This is due to several obstacles that occur as since readymix production is a semi-manufacturing industry. The application of JIT requires some adaptation so that it can be applied to the production of RMC to maximixe the production productivity.

Keywords
Readymix concrete (RMC), Production management, Just-in-time (JIT), Productivity.

1.Introduction
The construction industry, one of the major global industries, faces significant challenges in improving its productivity due to its complex nature and unique requirements for achieving sustainable construction practices [1]. With increased demand stemming from infrastructure growth, there is great need to advance project performance and productivity [2]. Some problems which the construction industry faces are lack of productivity and skilled labor, technology adoption, project complexity, sustainability issues, and project performance [1]. In order to implement a project, the construction company has a very important role in creating the quality of infrastructure that will benefit the interests of the wider community [3]. To achieve high quality results, project implementation of course requires high quality materials. In addition, a project development has a tight completion time within its contract. However, a construction project often encounters obstacles, such as delays in the delivery of material, which will impede the project work process [4]. Along with the booming of construction projects, the demand for readymix concrete (RMC) is increasing.

For instance, the RMC sector in India is expanding quickly, at a rate of 15-20 percent yearly, while in developed nations, RMC accounts for about 80% of the market [5]. RMC is ready-to-use concrete produced in a batching plant as a special factory for the process of mixing concrete materials consisting of cement, sand, water, and split in large volumes or doses [6, 7]. RMC is considered more profitable than manual cast concrete, as RMC has advantages in the accuracy of the concrete mix and saves more time on project work [8]. RMC is sent to the project site using a truck mixer who performs the function of transporting RMC from the batching plant to the foundry location. Dry materials for the manufacture of RMC are mixed with water and stirred in a mixer truck during transportation to the foundry location. To maintain the stability of the concrete viscosity in the mixer truck, an agitation process or drum rotation process is carried out during the trip to the project site. RMC has been widely used in construction projects as one of the practical building materials [9].

Tommelein and Li [10] stated that RMC is a typical illustration of JIT construction processes. In order to increase efficiency and productivity, a construction company requires a decent managerial system. Just-in-Time (JIT) system is a managerial system producing only limited needs or requests from

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customers and has a flexible workforce that can perform multiple tasks, aiming to increase productivity and reduce waste in the form of inventory or activity costs not needed by the production process [11, 12]. The JIT system aims to meet a limited range of customer demands in a timely manner with quality products and at the lowest possible total cost [11]. Furthermore, the main objective of the JIT system is to increase profits through cost reductions and improve company productivity [13, 11]. This can be achieved by eliminating wastes such as large inventory and labor.

While JIT application is mostly applied in manufacturing companies [14], there is an urgency to adopt this concept in construction areas to better improve project performance. Moreover, studies on exploring JIT practices for RMC production are still lacking especially in Indonesia. There is also little attention given to the investigation of JIT practices in RMC production companies. Therefore, this research aims to investigate the application of a JIT production system at the concrete batching plant and to examine its effectiveness. The finding is expected to provide guidance and benefit to the application of JIT for RMC production. The rest of this paper is organized as follows. Section 2 presents a review of extant literature, while section 3 provides the rationalization of the research method. This is then followed by the results in section 4 and discussions in section 5. At the end, conclusions and future works are presented in section 6.

2.Literature review

Since the early 1970s, the JIT system has been developed and used by manufacturing companies in Japan [10, 15]. Taiichi Ohno was the one who first developed the JIT system at the Toyota car assembly plant. The development of this system was intended to obtain better production methods, especially in manufacturing production [16, 10, 17]. The JIT system developed by Japan is based on the idea of carrying out production according to needs and when needed. All resources that do not provide and add value to the product are classified as waste. Such waste must be minimized or even eliminated.

JIT is defined as a system inventory and production control where raw materials are purchased, and units are produced, based on the needs of the customer [11, 12]. It is intended to reduce waste and to increase company productivity [18]. JIT aims to meet customer demands in a timely manner with quality products and to increase profits through cost reduction as well as improve company productivity [19, 20]. According to Jinturkar and Mundada [21], JIT is defined as a production strategy that helps organizations or companies to achieve and increase profits by reducing inventory or material inventory. JIT is also defined as a logistics philosophy applied by many manufacturing companies with the aim of reducing inefficiency and unproductive time in the production process [22−24].

JIT production aims to eliminate non-value-added activities so as to reduce costs and improve product quality [22]. The increase in product quality can be seen from the number of product defects. If the level of product damage is small, the resulting product (output) will be of higher quality. JIT production also stresses the importance of accuracy and timeliness. The application of the production JIT system can provide benefits in the form of speed of the production process, so that the company is given the benefit of fast service on orders from customers [25]. If the materials are quickly processed and delivered to the orders, there is not only a reduction in work process but also a reduction in finished materials. The JIT production system will increase worker productivity because with the JIT production system workers are more empowered so that worker participation increases, resulting in efficiency and increased worker productivity, which in the end also achieve company or organizational productivity [26−28].

According to Lai and Cheng [25], the application of JIT is mainly divided into two types of applications, namely, purchasing system (JIT Purchasing) and production system (JIT Production).

One of the production processes that JIT management systems have a considerable impact on is purchasing [29]. The JIT production system requires small batches of parts to be purchased [30]. Little lots take up less room and time. To achieve the same task, less people and resources are needed in terms of both time and area. Furthermore, tiny batches are simple to inspect, and flaws can be found very away. To prevent unplanned incidents and reduce line-side inventory levels, many manufacturers have used decentralized organizations with regular small-lot deliveries [31].

To implement a JIT system, a company should understand a number of introductory principles regarding the JIT concept consisting of improvements in the workplace, production flow, raw

material operations and multi-process handling [32, 33]. According to Phan et al. [17], some requirements that must be met in implementing JIT include factory layout, employee empowerment, visual control, traffic jam elimination, production lot size and setup time, control of the production process, total productive maintenance (TPM), and suppliers. In this case, the layout of the factory is set up for maximum worker flexibility in JIT production, and it is organized by product rather than by process [31]. Furthermore, a crucial precondition for JIT success is gaining the support and consent of everyone involved in achieving corporate goals. In addition to lowering the chance of implementation issues, this can significantly reduce the time and effort required to implement JIT [30].

Utilizing demand pull ensures that a company only produces what is necessary, in the right quantity, and at the right time [31]. JIT-based approaches have the ability to significantly increase productivity and product quality, but firms must adapt their own organizational structure, design, and processes when using JIT's principles [30]. JIT is therefore essential for efficiency which is defined as the efficient use of resources, including labor force, equipment usage capacity, and materials (raw materials and semi-finished products) [34]. Moreover, the most significant factor contributing to materials delivery delays appears to be a failure to timely acquire and maintain a suitable inventory system. This is a result of the materials' requirements being identified as a result of change orders and hastily made decisions [35].

3.Methods

This research was conducted to evaluate the application of JIT production system during the production process at a readymix company and to investigate the efficacy of the production process at a RMC supply company. Research began with the preparation of a research instrument in the form of a questionnaire as seen in *Figure 1*. The questionnaire included several indicators such as the production process, factory layout, raw materials, suppliers, quality control, employees, TPM, and delivery. Data was analyzed using the weighting or scoring method. Prior to scoring, validity and reliability tests were also conducted to determine whether it's the valid or not. Reliability test is a test carried out with the aim of testing the stability and consistency of a question item when tested with the same subject. This test is carried out by calculating cronbach's alpha which is calculated using SPSS 20. Research was conducted in one of the RMC supply factories in Palembang: PT Waskita Beton Precast Batching Plant Jakabaring Palembang. The overall application of JIT was intended to reduce different types of waste and activities with non-adding value. The JIT Principle strives to provide optimum service to consumers to increase the company's productivity which will also benefit the company itself.

Data were analyzed based on the questionnaires completed by respondents working at PT. Waskita Beton Precast Batching Plant Jakabaring Palembang. The data analysis aims to ascertain how to apply the principle of JIT to production management using the scoring method. A validity and reliability test were performed to determine whether the data collected was valid or not. Invalid questionnaire data will be removed. There were 15 employees responded to the questionnaire: 3 technical and quality staff people, 4 production planning and control staff members, 4 logistics personnel, 3 financial and HR people, and 1 manager as seen in *Table 1*.

Table 1 Distribution of respondents

	The number of questionnaires returned	**The percentage of questionnaires returned**
Role of responsibilities		
Technical & quality fields	3	20%
Production planning and control	4	26.67%
Logistics sector	4	26.67%
Finance and HR	3	20%
Manager	1	6.67%
Level of education		
Senior High School	5	33.3
Diploma	3	20
Undergraduate	7	46.67
Graduate Degree	-	-
Years of service		
<3 years	4	26.67%

	The number of questionnaires returned	The percentage of questionnaires returned
3-4 years	6	40%
5 years	3	20%
> 5 years	2	13.3%

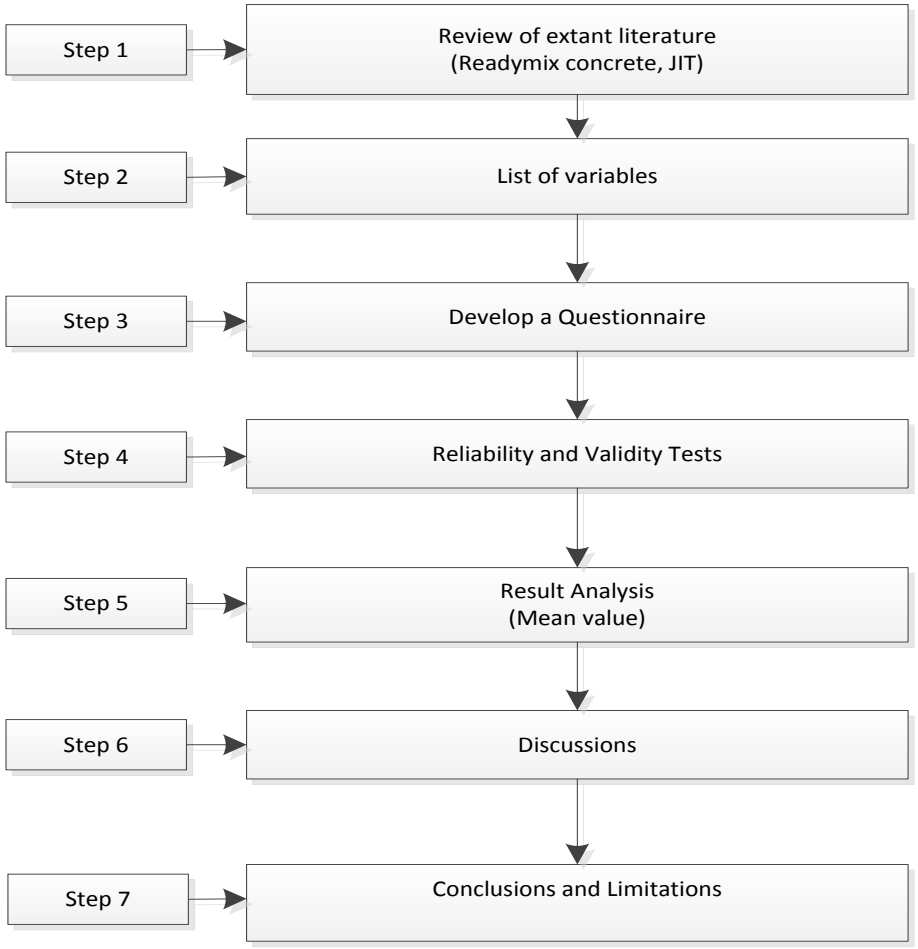

Figure 1 Research flow chart

4.Results

In order to investigate the application of the JIT production system at PT. Waskita Beton PrecastBatching Plant Jakabaring Palembang, there were eight general principles of JIT used, consisting of production processes, factory layouts, raw materials, suppliers, quality control, employees, TPM, and delivery. Based on the analysis, it was found that the Cronbach's alpha if the item deleted was 0.966, indicating its reliability (alpha count > 0.6). While, the validity test was carried out on the questionnaire using 15 respondents. If the value of r count is greater than r table then a variable can be declared valid. On the other hand, if the calculated r value is smaller than the table r value, the variable is declared invalid. After recapitulation of the results of the validity test, it was found that 62 variables are valid and 10 variables are invalid. Invalid variables include variables X1.6, X1.9, X3.6, X4.7, X4.12, X5.9, X6.9, X6.7, X8.2, and X8.4. These invalid variables were deleted and not taken into account in the subsequent analysis. The analysis of the calculated average was conducted by dividing the value of existing data. The mean value calculated and ordered data can be seen in *Table 2*.

Table 2 Application of the just in time principle

No.	Variable		Sub-variable	Total	Mean
X1	Process Production	X1.1	Supervision of production is carried out by the person in charge / production leader	58	3.87
		X1.2	Schedule or daily production time at the company has been arranged and determined	67	4.47
		X1.3	The company communicates the production schedule to all workers and suppliers to prevent production delays	63	4.2
		X1.4	There is no waiting time / queue for the process	63	4.2
		X1.5	Production preparation time (setup) does not take long	57	3.8
		X1.7	The elimination of bottlenecks in the production process immediately corrects the causes of delayed production	66	4.4
		X1.8	Production can be completed on time according to customer schedules and requests	67	4.47
X2	Layout Factory	X2.1	The company has a special design regarding the company's layout	63	4.2
		X2.2	There is a separation between the layout for production and inventory	65	4.33
		X2.3	The layout of the warehouse or storage of raw materials is regulated statistically to facilitate the movement of goods	64	4.27
		X2.4	The company has made improvements to the layout of raw material storage and place of production	65	4.33
X3	Raw Material	X3.1	The company adheres to the minimum in the procurement of raw material stock in the warehouse.	61	4.07
		X3.2	Raw material orders are calculated or estimated based on production requirements or customer requests	49	3.27
		X3.3	Raw materials used for production are never more than raw materials ordered by suppliers	33	2.2
		X3.4	Ordering of raw materials is only done if there is a customer request	61	4.07
		X3.5	The frequency of ordering raw materials to suppliers is relatively frequent but with small order lots	36	2.4
		X3.7	Procurement of raw materials is based on a scheduling system	66	4.4
		X3.8	The company has a complete recap of the quantity of usage, ordering, until the rest of the raw materials	57	3.8
		X3.9	There is a routine inspection or inspection every time the raw material will be put into the warehouse	69	4.6
		X3.10	Very low or zero frequency defective or damaged raw materials	66	4.4
		X3.11	There is a policy or action to prevent the existence of raw materials damaged or damaged due to accumulation	65	4.33
X4	Supplier	X4.1	The company selects suppliers before establishing a partnership	70	4.67
		X4.2	Supplier selection is based on supplier performance and the quality of raw materials offered	66	4.40
		X4.3	Suppliers invited to work together are suppliers who are willing to enter into long-term contracts and are willing to serve whenever the company requires raw materials	41	2.73
		X4.4	The company has only a few suppliers for each type of raw material needed	32	2.13
		X4.5	Suppliers deliver raw materials in small quantities but with more frequent frequency	34	2.27
		X4.6	The company communicates in detail with suppliers about the quality and shipping specifications	70	4.67
		X4.8	Suppliers who work with companies always deliver goods in the right amount and time.	58	3.87
		X4.9	Suppliers that have contracts with companies are quality certified suppliers	66	4.40

No.	Variable		Sub-variable	Total	Mean
		X4.10	The supplier's location is in the vicinity of the production area	35	2.33
		X4.11	There is a routine evaluation of the performance of suppliers involved in contracts with companies	53	3.53
		X4.13	Suppliers are fully responsible for raw materials that are damaged or not in accordance with the contract agreement	63	2.8
		X4.14	The company makes a list of material issues that have been received for reporting to suppliers	47	3.13
		X4.15	Disqualify suppliers who do not make improvements and improve the quality of goods sent	67	4.67
		X4.16	Arrival of scheduled materials	63	4.2
X5	Quality Control	X5.1	There is a special scheduling regarding checking the quality of raw materials and the quality of products	41	2.73
		X5.2	Check the raw materials sent by the supplier	66	4.4
		X5.3	The remaining raw material after production is rechecked before use	36	2.4
		X5.4	There is a complete record or archive of quality control that has been carried out	66	4.4
		X5.5	In every production process quality checks are carried out	40	2.67
		X5.6	There are special characteristics for quality checking	69	4.6
		X5.7	The company has all necessary equipment used for quality checking	68	4.53
		X5.8	In checking quality, the company has a standard that is used as a reference for checking	70	4.67
X6	Employee	X6.1	The company provides training to employees regularly to improve employee quality	55	3.67
		X6.2	The company involves the opinions of employees in decision making	66	4.4
		X6.3	Communication between managers and employees is well established	66	4.4
		X6.4	Company managers encourage employees to work together in teams	70	4.67
		X6.5	Employees can carry out a number of tasks assigned without being fixed in one area (multi-functional employees)	40	2.67
		X6.6	Employees complete tasks before the allotted time	64	4.27
		X6.8	Employees can understand the work that must be done properly	57	3.8
		X6.10	The company always evaluates and measures employee performance results	37	2.47
X7	Total Productive Maintenance	X7.1	The tools or machines used in production are cleaned and given regular maintenance	70	4.67
		X7.2	There are maintenance and service schedules for production machinery	51	3.40
		X7.3	There is a routine checking of tools or machines used before production	71	4.73
		X7.4	The company requires all employees to understand how to operate the equipment	41	2.73
		X7.5	Cleaning or maintenance of a tool continues for no more than a predetermined time to avoid delays in production time	67	4.47
		X7.6	The company has reliable operators who can carry out preventive maintenance of a machine	69	4.6
X8	Delivery	X8.1	Minimal shipping errors occur	70	4.67
		X8.3	The company has a delivery schedule that has been arranged before production	70	4.47
		X8.5	The company has prepared a solution if there are problems or delivery problems	66	4.4

No.	Variable		Sub-variable	Total	Mean
		X8.6	Transportation used in shipping is company property or in a long-term contract with the company	68	4.53

5.Discussions

This section presents the discussion related the application of JIT in the project site.

Production process

Based on the analysis, it is shown that the most significant variable related to the incorporation of JIT into the production process is that production can be completed on time according to customer schedules and requests as seen in *Figure 2*. The daily production time at the company has been arranged and determined before production. For production scheduling, the company has arranged daily production time, but the production process often does not adhere to the existing schedule. The production time in a day may be uncertain, varying depending on the volume of the order and on the delay in working time that often occurs because the setup process takes a long time. The extension of work time also occurs due to employees' lack of discipline regarding adhering to a predetermined schedule. Regarding the elimination of congestion, the company has tried to make improvements as soon as possible so that the cause of any delay in production can be eliminated quickly. Therefore, the production process can be completed on time according to schedule and can minimize lead time. This is in accordance with the principle of JIT, namely reducing lead time which can allow companies to be more responsive to a buyer's demand [36].

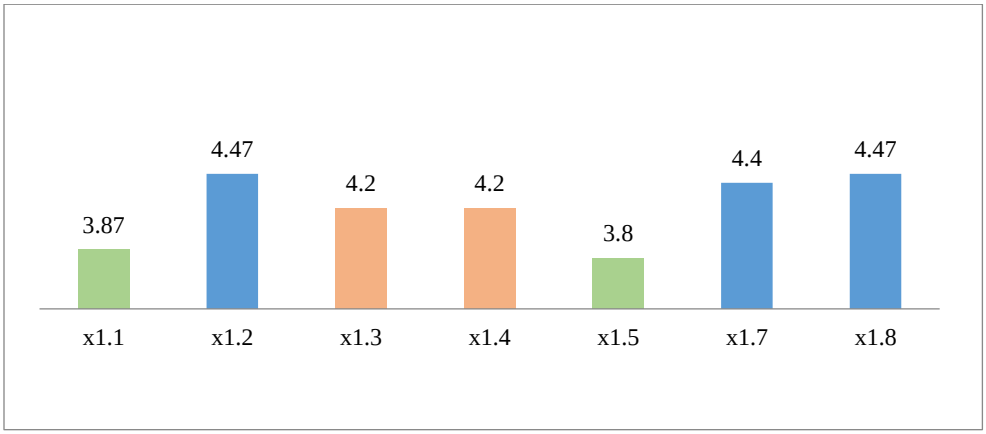

Figure 2 Mean value for variable X_1 (Production process)

The supervision of the production process should also be given enough attention by the production leader [37]. In this case, JIT strongly emphasizes the control of the production process to create a production system that is in line with expectations without any bottlenecks and damage to the process. In addition, production or preparation set up requires more unexpected additional time that often causes a delay in production time. The set up time for this company needed is around 1.5 hours including the preparation of tools, machines, and workers. This shows that the company has not yet implemented one of the JIT principles as explained in *Table 2*, which is to reduce production preparation time or set up time. The company has also communicated the production schedule to all workers and suppliers to prevent production delays. In this case, the production manager communicates the production schedule only at the beginning of the production period and controlling the production scheduling is very rarely done. While in the process of implementing its production, waiting time or queue on the process has been reduced to a minimum so as not to interfere with the smooth production process. The RMC production process at PT. Waskita Beton PrecastBatching Plant in Jakarta Jakabaring can be seen in *Figure 3*.

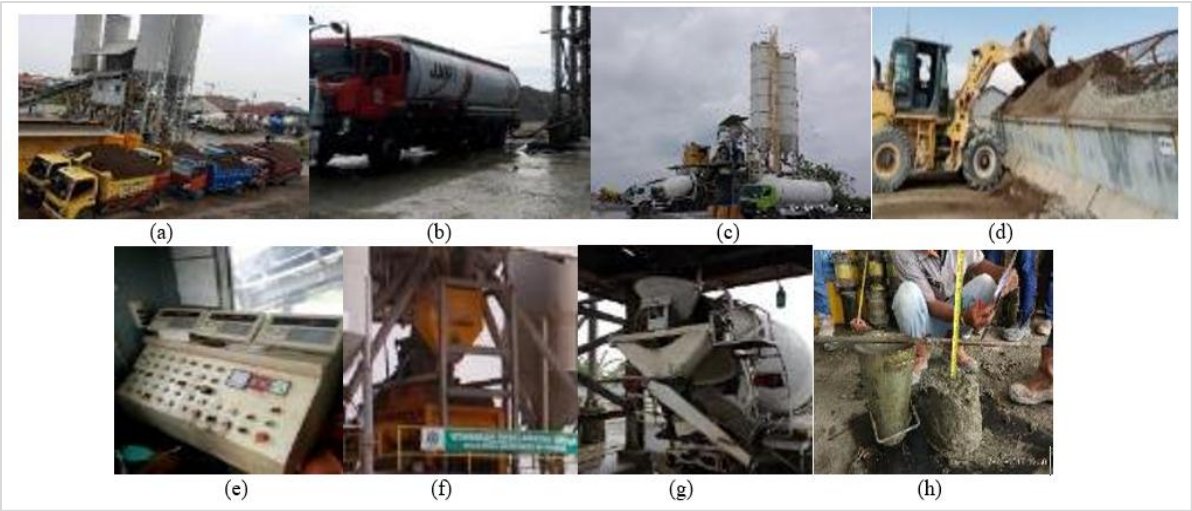

Figure 3 Production process
(a) Preparation of sand and split material, (b) Preparation of additive material, (c) Preparation of cement material, (d) Transfer material (sand, split) to cold bin, (e) Weighing each material, (f) Mixing of material in a batching plant, (g) Pouring concrete material into the truck, (h) Slump test

Factory layout
Factory layout needs to be considered in production management. The company has tried to facilitate the movement of tools and production machines using a separation between the layout for the production and inventory as indicated by a 4.33 mean value. Likewise, the layout of the storage areas for raw materials was arranged to facilitate the movement of goods. There may also be improvements to the layout of raw material storage and production sites when needed. However, it can be seen that the company does not pay a great deal of attention to the specific design of the factory layout. Recall that the principle of JIT showed that the layout of machines and production equipment was designed based on function. But this principle is not applicable to the readymix production layout because the tools and machines in readymix production are not as numerous as the tools and machines in the manufacturing industry.

Raw material
Orders made by the company are carried out in accordance with production requirements and are not specifically scheduled. For example, in a period of 6 months the company is bound by contracts for several projects; for that period the logistics staff calculate how much raw material is needed for the entire customer order volume. The company has a monthly production target of 7000 m^3 and if there is a shortage or run out of raw materials more will be ordered. This indicates that the company has implemented one of the JIT principles in ordering raw materials (variable X3.4), where ordering raw materials occurs only based on customer requests.

The frequency of ordering raw materials by companies to suppliers is uncertain because it adjusts the order requirements and factory production targets. This indicates that the company has not been consistent in applying the JIT principle where raw material orders are carried out fairly frequently but with small order lots (variable X3.5). The relatively frequent frequency of ordering raw materials with small shipping lots can also avoid the accumulation of raw materials and eliminate storage costs if there are damaged raw materials. However, the company has tried to minimize or prevent any raw material damaged by accumulation (X3.10) by taking precautionary measures (X3.11), such as separating old raw materials from new raw materials so that old raw materials can first be used for production activities.

Raw materials are the main factors that must be considered in production management [32]. Without the existence of raw materials, the production process cannot be executed. If the raw materials can be managed properly, the production process will run well too. In the readymix production process at PT. Waskita Beton PrecastBatching Plant in Palembang Jakabaring, raw materials used include sand, split, cement, additives (silicafume, viscocrete, plastiment V50), diesel and clean water. The process of ordering raw materials is done by sending a material order letter (MOL) to the head office. Submission of MOL

is based on the number of customer order volumes or as needed in 1 month. After MOL is issued to the relevant suppliers, ordering new raw materials can be done.

Based on *Table 2*, it is known that the lowest mean values are at variables X3.3 and X3.5. The low mean values indicated that the company has not ordered raw material in accordance with the customer's demand capacity (X3.3). From the results of interviews conducted, it is known that the company conducted estimation of raw materials before ordering (variable X3.2). However, the company always orders more raw materials than customer demand indicates are needed. That is because the company plans for sudden, unexpected orders or requests from consumers. The company has adhered to the minimum in providing safety stock material (variable X3.1).

Regarding routine inspections of raw material arrivals, the company has also checked raw materials, even quite rare. As for the recapitulation of the quantity of usage and ordering, the company has not fully implemented it. In JIT principle, the complete summary can be useful as a reference for evaluating the performance of raw material management that has been carried out, so that the company's performance in the implementation of production can improve in the future.

The supplier

The company also has a large list of suppliers for each type of raw material needed for the production process. This is contrary to the principle of JIT where the company has only a few suppliers for each type of raw material needed (X4.4). It is stated (variable X4.5) that based on the principle of JIT, the delivery of raw materials is done by suppliers in small quantities but more frequently. While at PT. Waskita Beton Precast Batching Plant Jakabaring delivery of raw materials by suppliers is done in large quantities with a small shipping frequency. The company choosed this approach because the supplier's location is outside the production area so that shipping is better done in large quantities to prevent any production process delays. Instead, for the JIT principle, the location of the supplier should be close to the production area (X4.10) in order to avoid delays in the delivery of raw materials by the supplier which can delay the production process.

According to the JIT principle, the supplier must be fully responsible for raw materials that are damaged or not in accordance with the contract agreement (X4.11). But based on respondents' answers, suppliers who work with companies pay less attention to this. Companies also very rarely make a list of problems with accepted materials that can be reported to suppliers (X4.13); generally a list of such problems is maintained only in cases when the problems are very large and cannot be tolerated. Furthermore, suppliers who work closely with companies do not always send goods in the right amounts and correct timeframes. Delay in the delivery of raw materials often occurs because suppliers are located far from the place of production [38].

Good cooperation between companies and suppliers is needed to support the smooth production process. That is because suppliers play an important role in shipping raw materials. If the delivery of raw materials is hampered, the implementation of production will also be hampered. In meeting its needs for raw materials, PT. Waskita Beton Precast Batching Plant in Jakarta Jakabaring has several suppliers that have been selected and regulated by PT. Waskita Beton.

From the results of obtained respondents' answers, it is known that PT. Waskita Beton Precast Batching Plant Jakabaring lacks the application of JIT management principles with respect to its suppliers. But there are things that have been implemented by the company, like selecting suppliers before entering into a partnership. Supplier selection is also based on supplier performance and the quality of raw materials offered. However, not all suppliers possessing contracts with companies are quality certified suppliers. There are also suppliers who do not have quality certificates but have performed well in terms of shipping raw materials. Suppliers who work with companies are suppliers who are willing to enter into long-term contracts, but the delivery of raw materials by suppliers must be based on an agreement between the two parties. Suppliers cannot serve if the company requires raw materials suddenly without an agreement in the future. That is the opposite of the principle of JIT, where companies need suppliers who can deliver raw materials on time, and in small lots and frequent shipments. Suppliers must be able to provide what is needed in the right amount when needed.

Quality control

The company has implemented checking of raw materials sent by suppliers, even though checks are not carried out on a scheduled basis as seen in *Figure*

4. The company also has a record of quality control that has been implemented. Quality checks are also carried out based on guidelines with special provisions. Quality control is divided into several parts, such as the incoming process, ingoing process, and outgoing process. For the incoming process, the quality of the material is checked to maintain the quality of production and must also be in accordance with procedural standards. The stockyard and stockpiling processes must be well maintained to achieve better quality of the material.

The company does not have a specific schedule for checking the quality of raw materials and the quality of products. From interviews, quality checking of raw materials has only been carried out several times after the arrival of raw materials, and checking is not done routinely. Normally checking the production results is only done if there is a checking request. For residual raw materials after production, there is no re-checking but the remaining raw materials are separated from new raw materials so that there is no accumulation of raw materials. Quality checks are not carried out on every production process that takes place but quality checks are usually carried out after the production process.

In the ingoing process, quality control consisted of checking material, checking equipment, and controlling production. Material checking consists of checking moisture, sludge and organic content. Production tools must be properly checked to maintain production flow and the entire production team must carry out work instructions according to the SOPs specified. Quality control for the outgoing process is a quality check consisting of yield tests, slump tests, and visual checks to determine the delivery of a good product. There is also quality assurance by conducting concrete sampling according to project specifications, carrying out test specimen maintenance and testing on time and monitoring quality control. In the company, there is also an evaluation of the quality control that has been done already. The following is the documentation for evaluating quality control as seen in *Figure 5 to 7*. A complete list of abbreviations is shown in *Appendix I.*

Figure 4 Quality control of the quality checking process

Figure 5 Quality control in ingoing process

Figure 6 Quality control in outgoing processes

Figure 7 Quality control evaluation

Employee

During corporate decision-making, the company tends to include the opinions of employees. Communication between managers and employees is well established. Company managers always try to encourage employees to work together in teams, since employees' involvement in group collaboration is considered very important. The production process is expected to be able to run properly and employees can complete their tasks within the expected time. It is also expected that employees can understand when the work is done properly without any more mistakes and delay.

The company does not really expect multi-functional employees able to carry out a number of tasks instead of focusing on one field. Company employees are already in their respective fields so there is little need for multi-functional employees. However, the principle of JIT requires that workers receive adequate training so that they are able to perform different tasks. Based on interviews, the company indeed often conducts training in each field, so that each employee gains knowledge of and understands the tasks of employees in other fields in a transparent manner. However, this kind of training is not carried out routinely or in a regularly scheduled way. The company also lacks the application of assessment and measurement of employee performance results. According to the employees, the company does not conduct an evaluation of the work of each employee.

Total productive maintenance (TPM)

JIT systems require TPM where machines and tools are regularly cleaned and lubricated. This activity is to ensure that machines and production supporting devices can run well so as to guarantee the production of quality goods. Based on the analysis, it can be seen that the company has applied some of the principles of TPM as seen by the mean value 4.67. The company has carried out cleaning and maintenance of tools and machines used in production on a regular basis. Cleaning is done after the production process is complete while maintenance is only carried out occasionally without any regular scheduling. Before concrete production, there is also checking of tools and machines used in the production process. Cleaning or maintenance of equipment is also strived so that its implementation does not exceed a predetermined time to avoid delays in production time.

The company also has reliable operators able to carry out preventive maintenance of machines. However, according to employees, delays in starting production often still occurs due to the length of time for preparation and cleaning of the equipment and the lack of individual employee discipline. Because the company already has an operator who manages or controls the equipment during the production process, the company does not require all employees to understand how to operate the equipment.

Delivery

Delivery is also important in a production activity, starting from the mixing sites to the final installation sites. If the production is sent safely to consumers, the company's productivity will also increase. Based on the data, all indicators of JIT implementation in terms of delivery are almost entirely applied. Shipping errors should be minimized in order to reduce the transportation cost. The company had a delivery schedule arranged before RMC production and is encouraged to minimize shipping errors. However, there used to be some challenges impacting shipping, such as weather and poor road access conditions. Therefore, it is important to coordinate delivery with the project on sites. It can be concluded that since RMC production is a semi-manufacturing industry, the JIT practices cannot be fully applied 100% as in the manufacturing industry. There must be room left for some adaptation since the construction industry is different than the manufacturing industry.

6.Conclusion and future work

Due to the characteristics of readymix production as a semi-manufacturing industrial activity, JIT concept has not yet been fully applied to RMC production at PT. Waskita Beton Precast Batching Plant Jakabaring. This is due to several obstacles. Furthermore, readymix production is a semi-manufacturing industry activity so that JIT cannot be applied 100% as it can be in the manufacturing industry. Thus the application of JIT requires some adaptation in order to apply it to the production of RMC. However, the company already has a delivery schedule that has been prepared before production. The company has also tried to minimize delivery errors and provide solutions if errors or obstacles occurred during product delivery. However, delivery problems often occur due to bad weather and road access conditions, thus improving coordination among project parties is essentially required.

The application of the JIT principle in the production process in the RMC process can provide benefits in the form of increasing company productivity in the eyes of customers because it is able to provide the best service and quality and timeliness. The results of this study could be viewed in light of some limitations. This paper is limited to specific to one case study and cannot be generalized to other case study. Thus, this paper should be able to be applied in a larger context. However, this research could be used as a reference toward implementing JIT in the construction industry.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Author's contribution statement

Heni Fitriani: Conceptualization, investigation, data curation, analysis and interpretation of results, draft manuscript preparation, writing – review and editing. **Luxi Dailinda Rizki:** Data collection, writing – original draft, analysis and interpretation of results.

References

[1] Hussin JM, Rahman IA, Memon AH. The way forward in sustainable construction: issues and challenges. International Journal of Advances in Applied Sciences. 2013; 2(1):15-24.

[2] Arif U, Javid M, Khan FN. Productivity impacts of infrastructure development in Asia. Economic Systems. 2021; 45(1).

[3] Asian Development Bank. Infrastructure for supporting inclusive growth and poverty reduction in Asia. Asian Development Bank; 2012.

[4] Darvik L, Larsson J. The impact of material delivery-deviations on costs and performance in construction projects. Chalmers University of Technology. 2010.

[5] https://www.nbmcw.com/product-technology/construction-chemicals-waterproofing/concrete-admixtures/ready-mix-concrete-helping-the-construction-industry-achieve-sustainable-development.html. Accessed 1 August 2022.

[6] Delnavaz M, Sahraei A, Delnavaz A, Farokhzad R, Amiri S, Bozorgmehrnia S. Production of concrete using reclaimed water from a ready-mix concrete batching plant: life cycle assessment (LCA), mechanical and durability properties. Journal of Building Engineering. 2022.

[7] Kashwani G, Liu E, Atif A. Safety review of the quality ready-mix concrete (RMC) and workmanship in the construction industry. Journal of Safety Engineering. 2019; 8(1):1-8.

[8] https://www.ny-engineers.com/blog/ready-mix-concrete-and-site-mixed-concrete. Accessed 1 August 2022.

[9] Mishra AK, Sudarsan JS, Nithiyanantham S. Feasibility study on application of ready mix concrete in construction projects in Nepal. International Journal of Environmental Science and Technology. 2022: 1-8.

[10] Tommelein ID, Li A. Just-in-time concrete delivery: mapping alternatives for vertical supply chain integration. In proceedings IGLC 1999 (pp. 97-108).

[11] Melo JC, Bezerra BS, De SFB. An analysis of JIT from the perspective of environmental sustainability. Magazine Production Management Operations and Systems. 2022; 17(2):111-35.

[12] Arjona AJ, Giménez MJA, Ferrús CG, Alonso IGN, Calabria L, Lara J. Enabling a green just-in-time navigation through stakeholder collaboration. European Transport Research Review. 2020; 12(1):1-11.

[13] Pasławski J, Rudnicki T. Agile/flexible and lean management in ready-mix concrete delivery. Archives of Civil Engineering. 2021; 67(1):689-709.

[14] Mankazana S, Mukwakungu SC. The impact of just-in-time (JIT) in inventory management system and the supplier overall performance of South African's bed mattress manufacturing companies. In proceedings of the international conference on industrial engineering and operations management, Johannesburg, South Africa 2018.

[15] Pheng LS, Shang G. The application of the just-in-time philosophy in the Chinese construction industry. Journal of Construction in Developing Countries. 2011; 16(1):91-111.

[16] Kong L, Li H, Luo H, Ding L, Zhang X. Sustainable performance of just-in-time (JIT) management in time-dependent batch delivery scheduling of precast construction. Journal of Cleaner Production. 2018; 193:684-701.

[17] Phan AC, Nguyen HT, Nguyen HA, Matsui Y. Effect of total quality management practices and JIT production practices on flexibility performance: empirical evidence from international manufacturing plants. Sustainability. 2019; 11(11):1-21.
[18] Kabzhassarova M, Kulzhanova A, Dikhanbayeva D, Guney M, Turkyilmaz A. Effect of lean4. 0 on sustainability performance: a review. Procedia CIRP. 2021; 103:73-8.
[19] Pai RR, Hebbar S, Kamath V, Kamath G. Improvement of process productivity through just-in-time. Research Journal of Management Sciences. 2013; 2(12):1-6.
[20] Green KW, Inman RA, Sower VE, Zelbst PJ. Impact of JIT, TQM and green supply chain practices on environmental sustainability. Journal of Manufacturing Technology Management. 2018.
[21] Jinturkar PU, Mundada AR. Effective implementation on JIT for material management in construction industry in India. International Journal of Innovative Research in Science, Engineering and Technology. 2020; 9(6):4993-5004.
[22] Jadhav JR, Mantha SS, Rane SB. Analysis of interactions among the barriers to JIT production: interpretive structural modelling approach. Journal of Industrial Engineering International. 2015; 11(3):331-52.
[23] White RE, Ojha D, Kuo CC. A competitive progression perspective of JIT systems: evidence from early US implementations. International Journal of Production Research. 2010; 48(20):6103-24.
[24] Golhar DY, Stamm CL. The just-in-time philosophy: a literature review. The International Journal of Production Research. 1991; 29(4):657-76.
[25] Lai KH, Cheng TE. Just-in-time logistics. Routledge; 2016.
[26] Lai CL, Lee WB, Ip WH. A study of system dynamics in just-in-time logistics. Journal of Materials Processing Technology. 2003; 138(1-3):265-9.
[27] Patel V, Solanki J. Just in time concept used in construction project. International Research Journal of Engineering and Technology. 2020; 7(6):3298–3303.
[28] Kilic R, Erkayman B. A simulation approach for transition to JIT production system. International Journal of Simulation Modelling. 2021; 20(3):489-500.
[29] Kaynak H. Implementing JIT purchasing: does the level of technical complexity in the production process make a difference? Journal of Managerial Issues. 2005: 76-100.
[30] Javadian KA, Babu KN, Talari H. Just-in-time manufacturing system: from introduction to implement. Available at SSRN 2253243. 2013.
[31] Zhou B, Peng T. Scheduling the in-house logistics distribution for automotive assembly lines with just-in-time principles. Assembly Automation. 2017; 37(1).
[32] Choeriyah SS, Setiawan EB. Supply chain management implementation on snacks production process. International Journal of New Media Technology. 2018; 5(2):62-70.
[33] Vikaliana R, Sofian Y, Solihati N, Adji DB, Maulia SS. Manajemen persediaan. Media Sains Indonesia; 2020.
[34] Oluwaseyi JA, Onifade MK, Odeyinka OF. Evaluation of the role of inventory management in logistics chain of an organisation. LOGI–Scientific Journal on Transport and Logistics. 2017; 8(2):1-11.
[35] Rahman MM, Yap YH, Ramli NR, Dullah MA, Shamsuddin MS. Causes of shortage and delay in material supply: a preliminary study. In IOP conference series: materials science and engineering 2017 (pp. 1-7). IOP Publishing.
[36] Dong Y, Carter CR, Dresner ME. JIT purchasing and performance: an exploratory analysis of buyer and supplier perspectives. Journal of Operations Management. 2001; 19(4):471-83.
[37] https://www.netsuite.com/portal/resource/articles/inventory-management/just-in-time-inventory.shtml. Accessed 5 August 2022.
[38] Andari B. The importance of raw materials inventory supervision for production process. Journal of Academic Research and Sciences. 2016; 1(1):53-60.

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Appendix I

S. No.	Abbreviation	Description
1	JIT	Just-in-Time
2	MOL	Material Order Letter
3	RMC	Readymix Concrete
4	TPM	Total Productive Maintenance