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LEAN CONSTRUCTION THROUGH WASTE REGISTER METHOD: A CASE STUDIES PROJECT IN INDONESIA

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ABSTRACT

Waste in construction projects is a significant research topic globally, including in Indonesia. The lean construction concept identifies any waste as a non-value added. Different waste management techniques categorize waste as either physical or non-physical. Based on literatures explain that most of project construction is bad on waste registration. The paper focuses on implementing lean construction for physical construction waste. Furthermore, this article presents Indonesian case studies to illustrate the impact of lean construction on building projects.

The study analyses waste management impacts across three periods of time. Lean waste management provides an early warning evaluation in the short term that are used as an indicator, so the project can evaluate and follow up as an effort to reduce waste, which in this study shows a reduction of waste from 2.1% to 1.7%. Addressing common waste in the medium-term increases project productivity by 50% and improves cost and duration efficiency. It reduces many possible wastages due to defects, overproduction, non-utilized talent, inventory, transportation, motion, waiting, and extra processing (DOWNTIME). Sustainable waste reduction practices can become a productivity standard in the long term by continuously improving the cycle of writing, categorizing, analysing, and writing for each job.

KEYWORDS

Lean construction, waste, productivity, value, continuous improvement

INTRODUCTION

The complexity of project construction has been considered based on production management, that must be designed, scheduled, produced, and presented in a timely manner. It is therefore characterised by delays and has often experienced cost and time overruns. (Vidhate, Tejas et al., 2018). A significant amount of construction waste has depleted the industry's total performance and production, and thoughtful action should be taken to address the undergoing state of affairs. According to the Lean Construction Institute (2004), the construction industry accounts for approximately 57 per cent of productive time lost (Ansah, Richard et al., 2016).

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Waste in the construction industry not only a problem for the construction industry, it also has an impact on the economy of a country as a whole. The elimination of material and time wastage would improve the performance of the project, increase value for individual clients as well as providing a positive impact on the domestic economy (Polat & Ballard, 2004).

In recent years, many research studies around the world have focused on waste from the construction industry. Construction waste research suggests that a construction project produces large amounts of waste (Esin & Cosgun, 2007; Wanga et al., 2010). A variety of methods have been used over the past decades to reduce construction waste as well as its impacts. One of the most effective techniques is the adoption of a lean strategy in the construction industry. Lean construction is also the result of an innovative approach to production management to address the complexity of project construction. The fundamental idea of Lean Thinking is to cut waste in order to increase performance. Project managers generally take the view that "waste" is tangible construction waste. However, there is observable waste in the construction process, often referred to as "non-adding activities" in the lean construction method. (Hosseini, et al., 2012).

Construction management community efforts to understand waste are relatively low in comparison with other topics. Many research on waste has tended to focus on effects rather than avoidable root causes (Viana et al., 2012). Lack of integration of waste management into planning and control procedures and requirement not only to confirm but also to observe the efficiency of building processes (Formoso et al.,1999). In addition, it is necessary to enhance the model in order to obtain a precise understanding of the areas of lean construction principles and techniques where Indonesian contractors are deficient and require enhancement and promotion (Abduh et al, 2005).

Usually, project managers define waste as physical construction waste, which mostly includes material losses (Koskela, 1992). However, lean thinking focuses primarily on waste produced during a construction process, which can be separated into two main types: waste arising from the nature of the process and waste arising from work without added value (this group includes wait times, value-neutral activities and transportation of materials). It should be noted that not all waste related to the construction process can be attributed to the process itself or to non-value-added activities. But since only one class predominates, it will be assigned to each subdivision (Hosseini, et al., 2012).

Productivity and waste metrics can complement one another. There are similar fundamental reasons for waste and production research: to learn further information on the current situation in order to make improvements. Consequently, it can be useful to look at waste and productivity levels (Forsberg & Saukkoriipi, 2007). Based on literatures explain that most of project construction is bad on waste registration. This because of project complexity that effect the activity of collect and analysis waste never successful. So that, waste in the project already known large in the end of period time projects.

This research focus on the implementation of the lean construction principle in waste management, especially for physical construction wastes. We apply the Pareto item principle to the waste register method for materials such as concrete and steel works. An actual experiment is required for testing and assessing waste mitigation due to lean construction principles implementation in construction processes. The study therefore focused on strengthening operations in building projects in Indonesia.

WASTE MANAGEMENT

TYPE OF WASTE

The seven wastes of lean production that are often found are as follows: 1. Transport: unnecessary and ineffective flow of information; 2. Inventory: information waiting to be processed; 3. Motion: editing, verifying or creating inquiries; 4. Waiting: awaiting information; 5. Overprocessing: verifying, reprocessing, repeat applications, new procedural codes; 6. Overproduction: multiple bills, duplicate files, minor debt lawsuit; 7. Defects: complaints, corrupt or mis-coded data, recording and transcription errors, unauthorized procedures (Koskela et al, 2013). Several candidates were proposed for the eighth type of waste (Macomber & Howell, 2004) identify several of them, which can be categorized as: failing to use people's talents, skills and abilities; wasting information; wasting behaviours; and wasting good ideas. Waste comes in eight different forms in lean manufacturing. The seven well-known wastes focus on the production process, but the eighth has a direct impact on management's ability to employ staff (Brito et al., 2019). In this paper the eight wastes are defined by DOWNTIME (Defect, Overproduction, Waiting, Non-Utilizing Employee, Transportation, Inventory, Motion and Extra-Processing).

Waste identification will undoubtedly impact the results of the projects implemented and support sustainable development. The main pillars of the sustainable concept itself are people, planet, & profit (Crane & Matten, 2004), or the triple bottom line. Therefore, it is crucial to consider the needs of people or social aspects, the planet or environmental factors, and profit or economic aspects, especially in lean construction implementation. The waste will undoubtedly directly impact the environment, but not only that, because construction waste indeed involves collaboration on the lean principle of "respect for people," which supports the social aspects of sustainable development. In the end, the expected value in identifying this waste is to reduce costs due to waste that occurs and support profit or economic aspects to realize sustainable development.

WASTE IDENTIFICATION & REGISTRATION

As a result, we can anticipate the discovery of waste chains during the review of process waste. These are a range of causes and consequences in which one waste causes another. (Koskela, Bolviken, & Rooke, 2013). For example, one of the usual construction industry problems is the delivery process of the materials (Thomas et al., 2022). Equipment and workers are often held in abeyance because delays occur in the supply of materials and the finishing of preliminary work. This issue reduces productivity and prolongs the duration of the project (Tommelein, 1998).

However, responding to downstream demand too quickly results in a waste of inventory and may result in additional expenditures. Another fundamental lean manufacturing strategy known as "pulling" to ensures just-in-time synchronization between upstream and downstream processes. It is based on the notion that the upstream should not deliver a product or service until the downstream request it (Womack & Jones, 1996). Macomber & Howell (2004) identify other waste: failure to use people’s talents, skill and capabilities; information waste; behavioural waste; and wasting good ideas. This type of waste was categorized non utilize employee due to the practice of improvising to compensate for inappropriate upstream operations is particularly worrying as a major waste in construction (Koskela, Bolviken, & Rooke, 2013). If we compile this type of waste, there is eight waste taxonomy, defect (making defective products), overproduction, waiting (time on hand), non-utilize employe, transportation, inventory (stock on hand), motion (movement), and extra processing (over processing).

RESEARCH METHOD

This study uses trend and regression analysis to conduct studies related to the relationship between the parameters recorded in the waste register that occur in the project with other parameters in the production planning that is being carried out. The waste register in this study records two major elements: bodily waste and productivity. These two major elements are then recorded and analysed in a monthly basis according to the data realization and evaluation that can be carried out in production planning in the field, which in this case is carried out using the Last Planner System (LPS) method. Project records between the material that is recognized by the owner and the material that we bring in on a monthly basis, in order to get the trend from the pattern of waste that occur.

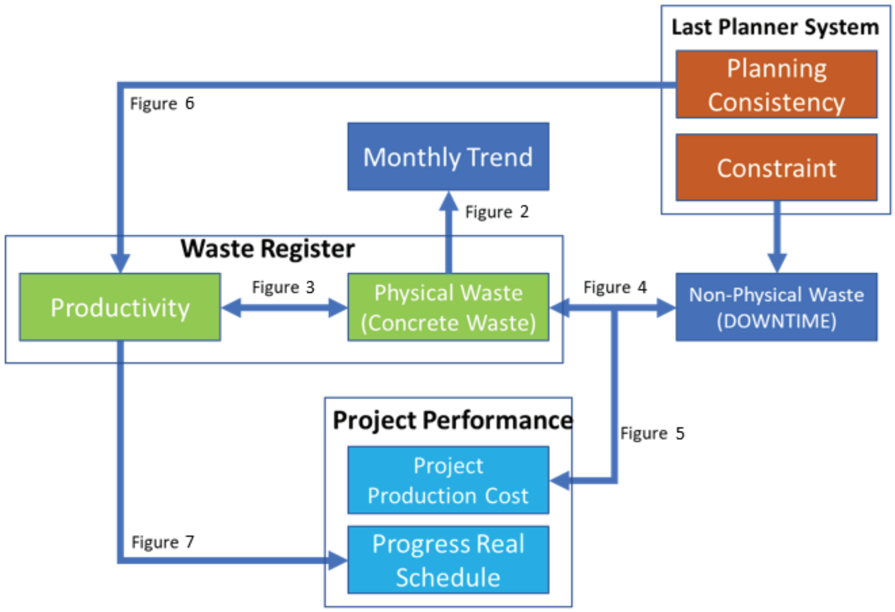

Figure 1: Research Method

The physical waste registration carried out in this study is done by examining the physical parameters that can be measured, namely concrete waste. This is done so that these parameters become a comparison with other performance parameters, which will be correlated because of using the waste register. The concrete material was chosen because it is one of the dominant (pareto) materials implemented in the work items on the project in this study.

Furthermore, an analysis is also carried out related to non-physical waste obtained from constraints that occur in the production planning stage using the Last Planner System (LPS). This constraint is then converted related to the impact of waste generated in the realm of DOWNTIME (defect, overproduction, waiting, non-utilize employee, transportation, inventory, motion, and extra-processing). In this study, the LPS result is used to see the effect of constraint analysis which then related to the concrete waste materials to be measured. This method applies so that the root cause analysis carried out in the LPS stage could become one of the tools that help to discuss the result of waste register that filled in.

Waste Register Methodology: Identify Waste & Productivity

The waste register is a tool to identify patterns that occur in projects. This pattern is a collection of data that is recorded every month by the project team. The recorded data is a comparison of material that is recognized with what the project team has worked on. recording every month, allows us to see the pattern of productivity that occurs. Productivity is below standard, there must be a waste factor that needs to be evaluated. This is where we can find the direct impact of the waste that occurs with the productivity of a job. We record this waste (physical waste and other downtime waste) per month, the monthly data will be used as an evaluation for the next month as long as the work is still ongoing. The results of the evaluation serve as an early warning if the waste that occurs interferes with the target that has become a joint agreement, both concerning cost and time. The data per month can also be a trend which we can analyse to find the patterns, which makes it possible to find the characteristics of waste based on the type of building (high risk building, hospital, airport, building revitalization."

With respects to materials, equipment and labour, and productivity parameters, we used to determine waste register as a method to require that the objectives of this research suggest various goals in the waste register over time. In the short term, the waste register provides an early warning evaluation of budget costs according to budget waste, potential waste, actual waste, and productivity. In the middle term, mitigating common waste significantly increases productivity as well as project efficiency related to cost and project duration. It reduces many possible wastages due to defects, overproduction, non-utilized talent, inventory, transportation, motion, waiting, and extra processing (DOWNTIME). In the long term, sustainable conduct of waste mitigation can become a productivity standard by iterating the cycle of writing, classifying, analysing, and writing for each work. In this waste register, the parameters of the physical waste that are recorded are concrete waste materials. The unit used in this study is the unit that applies in Indonesia where concrete waste is defined as a percentage (%) and concrete work productivity is defined as m3/OH where this unit is equal to 1 m^3 of concrete produced by one person in one day (m3/man). -days)

CASE STUDY: BUILDING PROJECTS IN INDONESIA

This study is a case study from a building project that recorded waste and productivity on the waste register tools and implemented the Last Planner System method in controlling production on the project. The following is a project profile that is the focus of this research.

Table 1: Building Project Study Case in Indonesia

Project Name	Project Value (before tax)	Project Type	Location	Duration	Contract Types
A	11.862 €	Public	West Java	21 months	Regular; Unit Price
B	60.585 €	Private	Central Java	21 months	Regular; Unit Price
C	41.363 €	Private	Jakarta	24 months	Design Build; Lump-Sum
D	8.376 €	Public	Jakarta	10 months	Design Build; Lump-Sum
E	21.189 €	Public	Bali	17 months	Design Build; Lump-Sum

ANALYSIS

WASTE TRENDS

This waste trend is an output trend resulting from the monitoring of several projects in Indonesia carried out through the waste register method as a mention earlier in the waste registry methodology. This can be concluded through the time parameter that the more waste is recorded and monitored in a project, the quantity of waste decreases every month (confidence in a trend with an R-value or confidence level of 0.647).

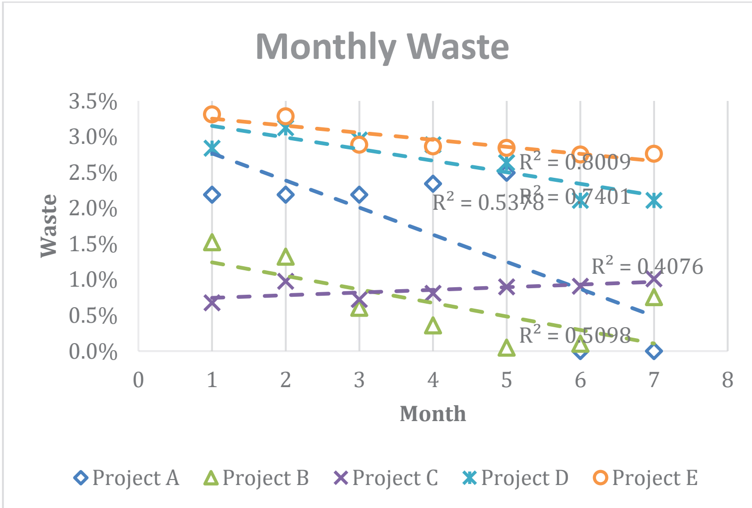

Figure 2: Comparison Between Waste & Time (Month)

The waste above is physical waste recorded in real terms from the Pareto elements in construction work, namely concrete waste. Based on the graphic in Figure 2, we can see that each project has the same linear pattern, then various trends refer to their activity according to waste monitoring in months. The high R-value means project has been considering doing waste monitoring each month; the highest order is from Project E 0.8009, Project D 0.741, Project A 0.5378, Project B 0.509, then Project C 0.4076.

The data show that Project C gets a positive gradient, meaning their waste is increasing every month. The first waste is already low; therefore, so the following record maintains the low trend baseline. Meanwhile, in the end, waste will increase. Therefore, even though the waste trend of Project C increases, the actual waste is still low. Based on the data in Figure 2, we can see that in the first month the average waste rate was 2.1%. This value shows the excess volume of concrete that occurs from the required initial volume. However, in the 7th month, the measured waste decreased to 1.7%. This indicates that the recording of waste has affected.

IMPACT OF CONTROLLING WASTE ON PRODUCTIVITY

The waste register records the productivity of Pareto items production to the amount of workforce of each work. This productivity measured in this research is the amount of concrete volume compared to the amount of workforce. The purpose of this parameter is to see how controlling waste could impact productivity results.

The data in Figure 3 shows that the most controlled waste will be the lowest; refer to evidence obtained previously. Therefore, the productivity of concrete works in all projects also will be high. The graphic also shows the trends described by a negative gradient, although this is still a low regression value. Meanwhile, the trends may be explained by the fact that waste monitoring will prevent productivity improvements in the project. The result indicates that the projects have a confident correlation within the average value of regression is 0.350 (moderate). The graph shows an average increase of approximately 50% in the productivity of concrete work based on a decrease in waste from 2.1% to 1.7%. This means that the project could control its waste management and have an opportunity to increase productivity.

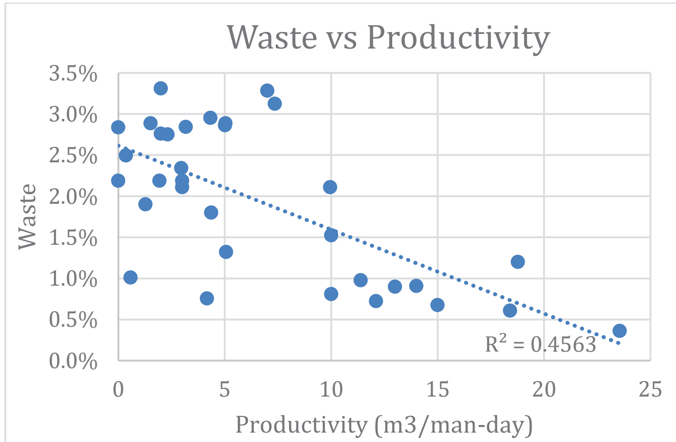

Figure 3: Comparison Between Waste & Productivity

In addition, the other tool of lean construction, the Last Planner System (LPS), already recorded the waste in terms of constraints that happen in the project. The constraint data which doesn't closed then analysed to determine a non-physical waste that we called DOWNTIME (defect, overproduction, waiting, non-utilizing people, transportation, inventory, motion, and extra-processing). This DOWNTIME score is obtained from the constraints that occur in the LPS implementation, as shown in table 2 below:

Table 2: DOWNTIME Score from LPS Constraint

CONSTRAINT / VARIANCE		D	O	W	N	T	I	M	E
1. Procurement of Materials & Equipment	INTERNAL FACTOR	1		1			1		
2. Subcontractor / Foreman (Contract)		1		1					
3. Procurement of Light Equipment / Auxiliary Equipment			1	1					
4. Payment to Vendors				1	1				
5. Design Decisions	OWNER FACTOR	1		1					1
6. Approval Shop Drawing / Method		1		1					
7. Material Approval				1			1		
8. Owner's Request		1	1						1
9. Land Handover / IMB				1		1			
10. Payment from Owner				1			1		
11. Limited Resource Subcontractor / Foreman	EXTERNAL FACTOR			1	1			1	
12. Limited Supply of Materials				1		1	1		
13. Time Limitation & Work Operations			1					1	1
14. Local Vendors Not Qualified		1			1				
15. Previous Work Not Completed		1		1					1
16. Weather / Natural Disasters				1					1

Figure 4 shows the correlation between the physical waste and non-physical waste. The graphic explains that if non-physical waste (DOWNTIME), there is a chance that physical waste will increase. One of the possible things that we can adjust is that this happens because the project cannot maintain physical waste, mostly defects and the overproduction type of waste.

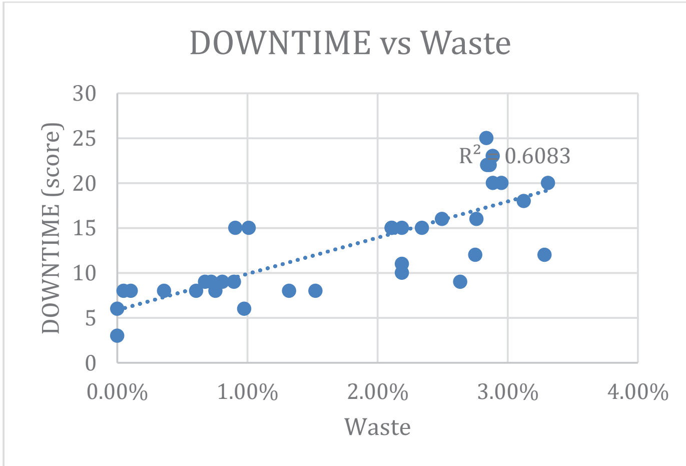

Figure 4: Correlation Between Waste & Waste DOWTIME

Waste & Project Production Cost

Ultimately, this waste monitoring will impact the project's performance. One of the indicators is cost parameters. Recording of waste which is done through the waste register form indirectly affects the cost performance parameters of the project under review. The cost parameters which are compared in the present study are monthly production costs which include direct costs and indirect costs which are reported in real terms every month along with the results of recording waste. It is shown by the percentage of the value, which is the amount of cost incurred compared to project cost, which the owner approves.

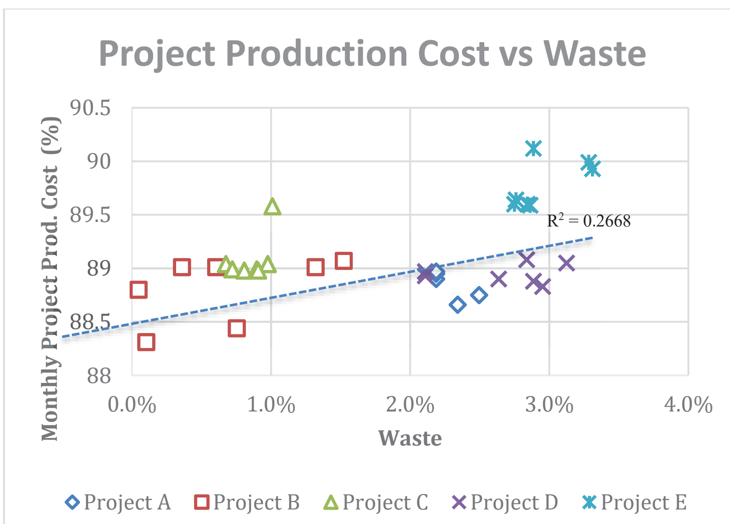

Figure 5: Correlation Project Production Cost vs Waste

The data above (Figure 5.) shows that all the projects have increased waste in the period and that increased production costs will impact on that period. This case, absolutely affected by costs incurred due to waste itself, is Pareto items, so it will impact all cost projects. In addition, if a project could control waste and reduce its value, it would decrease the monthly cost of production. We can see convincing data from the result that when the project can control waste, the cost will decrease with a correlation value of 0.2668.

PLANNING & PRODUCTIVITY

According to the waste registry method, the productivity value could be compared to the project's ability to plan better using The Last Planner System (LPS). In this case, the well-planned from the previous month will have a high consistency of planning (≥1). At the same time, the project that changes the planning to a lower target plan could be stated as not having good planning (<1). As shown in (Figure 6.), the average concrete productivity is 4.7m^3/person-day, which is considered on the basis of each of the consistent planning results for productivity.

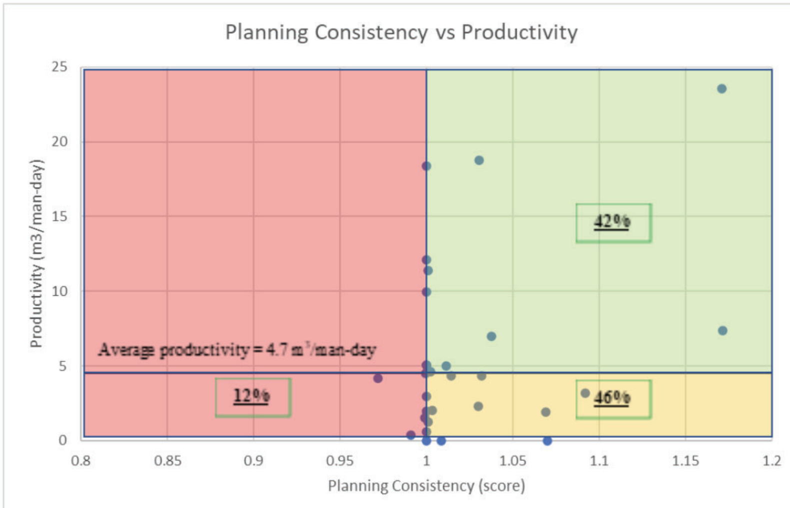

Figure 6: Impact on Planning Consistency and Productivity

The aforementioned data shows that when the consistency of planning when LPS is good (score ≥ 1), productivity is also improving. However, from the quadrant description above, there is still around 46% correlation value between planning consistency and productivity, which is below the average productivity value even though it already has good planning consistency. However, when planning consistency could be better (score <1), there is no doubt that the productivity value will be below average.

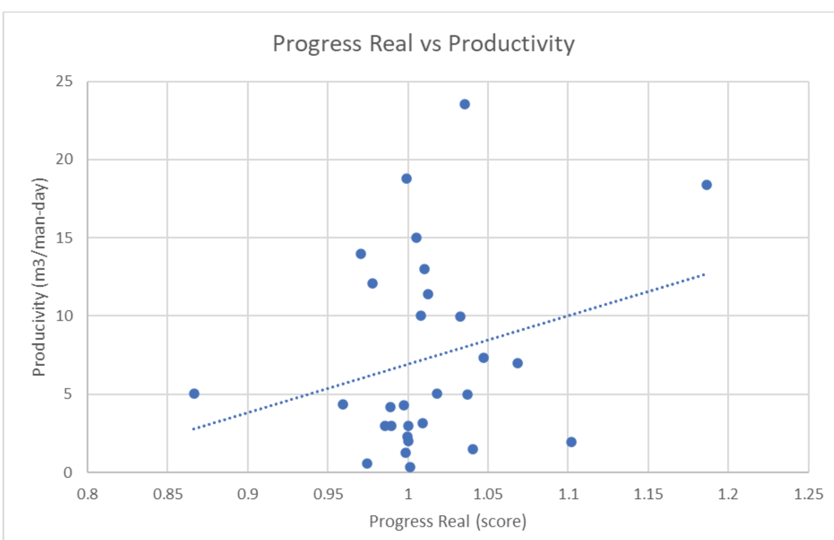

Figure 7: Correlation between Productivity with Progress Score

Ultimately, in line with the above conditions, that high productivity will benefit from a better performance in view of an excellent progress project result with improved productivity. Figure 7 explains that the correlation between productivity monitoring and progress results must be even higher. However, it also shows that the gradient value has a positive trend result. This is because physical waste and controlled productivity are just the dominant types of waste.

CONCLUSIONS AND PERSPECTIVE

The waste register method is a part of lean construction tools in the project for making a better improvement by controlling waste as a routine. Control and monitoring also do the same for the productivity from items of work. We can see from the resulting trend each month that projects with consistent waste recording will better impact the amount of waste in the project. The reason is that there is a control and monitoring process. In the final project, we will show the amount of low waste because we already have an early warning system from the internal team project to control waste. This is indeed affected by better productivity and project costs that can be reduced when controlling and monitoring waste as a routine.

In addition, recording waste project also benefits from seeing the impact of production plan control one of which is the Last Planner System (LPS) or other tools in the project that lead the lean construction concept. However, in the future, we still need to consider non-physical waste, which is being quantified and could be compared to the result based on the time and cost of the project.

REFERENCES

Abbasian-Hosseini, Ali & Nikakhtar, Amin & Wong, K. & Zavichi, Amir. (2012). Implementing Lean Construction Theory into Construction Processes' Waste Management. 414-420. 10.1061/41204(426)52.

Abduh, M., Syachrani, S., Roza, H.A. (2005). "Research Agenda of Lean Construction (in Indonesian)." Proceedings of the 25th Anniversary of Construction Engineering and Management Education in Indonesia, School of Civil and Envir. Engrg, Institut Teknologi Bandung, Indonesia.

Ansah, Richard & Sorooshian, Shahryar & Mustafa, Shariman. (2016). Lean Construction: An Effective Approach for Project Management. *ARPN Journal of Engineering and Applied Sciences*

Brito, M., Ramos, A. L., Carneiro, P., & Gonçalves, M. (2019). The Eight Wastes: Non-Utilized Talent. *Lean Manufacturing: Implementation, Opportunities and Challenges, Nova Science Publishers Inc*, 151-164.

Crane, A., Matten, D. (2004). Business Ethics, A European Perspective. *Managing Corporate Citizenship and Sustainability in the Age of Globalization. University Press, Oxford, UK.*

Esin, T., & Cosgun, N. (2007). A Study Conducted to Reduce Construction Waste Generation in Turkey. *Building and Environment*, 42(4), 1667-1674.

Formoso, C. T., Isatto, E. L., & Hirota, E. H. (1999, July). Method For Waste Control in The Building Industry. In *Proceedings IGLC* (Vol. 7, p. 325-330). Berkeley^ eCA CA: University of California.

Forsberg, A., & Saukkoriipi, L. (2007). Measurement Of Waste and Productivity in Relation to Lean Thinking. In *Annual Conference of the International Group for Lean Construction*: 18/07/2007-20/07/2007 (pp. 67-76). Michigan State University Press.

Macomber, H., & Howell, G. (2004). Two Great Wastes in Organizations. *IGLC*, *Denmark*, 1-9. Hua, D., & Schwartz, T. (2021). LPS Implementation Using Physical and Digital Visual Management-Based Tools: A Case Study in Luxembourg. In *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC)*, 65–74.

https://doi.org/10.24928/2021/0161
Koskela, L. (1992) Application of the New Production Philosophy to Construction, Technical Report No. 72. Center for Integrated Facility Engineering. Department of Civil Engineering. Stan-ford University. 75 p.
Koskela, Lauri & Bølviken, Trond & Rooke, John. (2013). Which Are The Wastes Of Construction?. 905-914.
Polat, G., & Ballard, G. (2004, August). Waste In Turkish Construction: Need for Lean Construction Techniques. In *Proceedings of the 12th Annual Conference of the International Group for Lean Construction IGLC-12, August, Denmark* (pp. 488-501).
Thomas, H. R., Horman, M. J., Lemes de Souza, U. E. and Zavrˇski, I. (2002) Reducing Variability to Improve Performance as A Lean Construction Principle. *Journal of Construction Engineering and Management*, 128 (2), 144-154.
Tommelein, I. D., Riley, D., & Howell, G. A. (1998, August). Parade game: Impact of Work Flow Variability on Succeeding Trade Performance. In *Proc. 6 th Ann. Conf. Intl. Group for Lean Constr*. IGLC-6, 13-15 August held in Guaruja, Brazil, 14 pp.
Viana, D. D., Formoso, C. T., & Kalsaas, B. T. (2012, July). Waste In Construction: A Systematic Literature Review on Empirical Studies. In *ID Tommelein & CL Pasquire, 20th Annual Conference of the International Group for Lean Construction. San Diego, USA* (pp. 18-20). sn.
Vidhate, T., & Salunkhe, A. (2018). General Overview of Lean Management in Construction Industry. In *International Research Journal of Engineering and Technology* (IRJET), 5(07), 1999-2004.
Wang, J., Yuan, H., Kang, X., & Lu, W. (2010). Critical Success Factors for On-Site Sorting of Construction Waste: A China Study. *Resources, conservation and recycling*, 54(11), 931-936.
Womack, J. P., & Jones, D. T. (1997). Lean Thinking—Banish Waste and Create Wealth in Your Corporation. *Journal of the Operational Research Society*, 48(11), 1148-1148.