Alwi, Sugiharto, Mohamed, Sherif, & Hampson, Keith
(2002)
Waste in the Indonesian Construction Projects.
In Boshoff, F (Ed.) *Proceedings of the 1st CIB-W107 International Conference - Creating a Sustainable Construction Industry in Developing Countries.*
CSIR, Pretoria, South Africa, pp. 305-315.

Ref No:	W107-063p
Title:	Waste in the Indonesian construction projects
Authors:	Sugiharto Alwi[1] Keith Hampson[2] Sherif Mohamed[3]
Address:	[1] Lecturer, School of Civil Engineering, Tarumanagara University, Jakarta – Indonesia [2] Professor and CEO of CRC for Construction Innovation, Queensland University of Technology, Brisbane, QLD 4000, Australia [3] Senior Lecturer, School of Engineering, Griffith University, Gold Coast, QLD 4217, Australia
E-mail address:	[1] SugihartoAlwi@hotmail.com [2] k.hampson@qut.com [3] s.mohamed@mailbox.gu.edu.au
Keywords:	Non value-adding activities, Contractors, Indonesia, Lean Production

Alwi, S.; Hampson, K. and Mohamed, S. (2002) Waste in the Indonesian Construction Project. *Proceedings of the 1st International Conferences of CIB W107 – Creating a Sustainable Construction Industry in Developing Countries*, 11-13 November 2002, South Africa, ISBN: 0-7988-5544-4, pp. 305-315.

Abstract

Waste can significantly affect the business performance and productivity of contracting organisations. This paper aims to investigate the incidence of waste within contractors companies in Indonesia, focusing on non-residential building and infrastructure projects. Based on respondents' perceptions, data was collected through questionnaires and followed up by personal interviews. Paired-samples t-test was performed to group the importance of waste variables and waste causes variables. The findings suggest that six factors were found to be the key variables of waste including repair on finishing works, waiting for materials, delays to schedule, slow tradesmen, waste of raw materials on-site and lack of supervision. Whereas design changes, slowness in making decisions, lack of trades' skill, inappropriate construction methods, poor coordination among project participants, delay of material delivery to site and poor planning and scheduling were identified as the key variables causing waste. This paper recommends a simple method of waste identification to assist construction managers to detect any waste that may occur during the construction process. To provide the best outcome of contractors' performance, several alternative solutions were suggested to be applied on-site.

1 INTRODUCTION

Construction projects are an important priority in Indonesia's national development. The construction industry in Indonesia is the third most important for absorbing human resources after the food and textiles industries (Royat, 1994). In 1978 the construction industry employed approximately 400,000 people or about 1.57% of the total work force. In1997, there were about 4.2 million people employed by the industry, which contributed about 4.83% to the total work force. Therefore, the manpower employed by the construction industry has had an annual growth of 13%. The growth in the construction work force was almost twice the growth in the manufacturing industry. However, 88% are unskilled or with low skill levels, 11% with medium to high skill levels and the rest (only 1%) are at managerial levels. As a developing country, one of the serious problems occurring in the construction industry in Indonesia is the shortage of high levels of skilled labour.

Other problems identified by Royat (1994) included equipment shortages, inefficiencies in using materials, imbalances in organisational structure, unfair competition, limited funds, planning uncertainties and a lack of human resource development.

During the last ten years, little research has been conducted in Indonesia on the incidence of waste in the construction industry. If any, research carried out to date has been concerned only with waste materials on-site (Alwi, 2002). In general, project managers define the term “waste” rather as physical construction waste than the real concept of waste. Based on previous research conducted by the authors, there has been concern with the high level of waste within the Indonesian construction industry. Recent study conducted by Alwi et al. (2002) suggested that waste can significantly affect the performance of the construction projects. Hampson (1997) believed that construction performance may affect productivity across all sectors of the economy. Measuring performance for construction projects is a complex problem. Every project is unique in terms of design specifications, delivery methods, administration, and participants. Evaluation of performance has been a challenge for the construction industry for decades. However, such waste has not been identified clearly by project managers. No accurate method has been developed to quantify the incidence of waste in Indonesia. In addition, no practical and acceptable means has been agreed by all parties involved in construction projects in reducing the waste significantly.

What is needed now in the Indonesian construction industry is to have a better understanding of the concept of waste and to identify the significant waste variables and the their causes. These factors may assist project managers to find alternative ways to increase their project's performance. This paper aims to identify the factor of waste in the Indonesian construction projects. A questionnaire survey was used for the mail data collection, followed-up by intensive interviews. Collected data was analysed using the paired-samples *t*-test to determine the most important waste variables and waste causes variables. This paper also provides a simple method of waste identification and alternative solutions to assist contractors to achieve better performance.

2 WASTE IN CONSTRUCTION

Industry researchers and practitioners acknowledge that there are many wasteful activities during the design and construction process, the majority of these consuming time and effort without adding value for the client (Love, 1996). From the beginning of a construction project, Construction Managers have to deal with many factors that may negatively affect the construction process, producing different types of waste (Serpell et al, 1995). Waste can include mistakes, working out of sequence, redundant activity and movement, delayed or premature inputs and products or services that do not meet customer needs (Construction Industry Board, 1998). According to the new production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered necessary in the production of a building (Formoso et al., 1999). Waste includes both the incidence of material losses and the execution of unnecessary work that generates additional costs but does not add value to the product (Koskela, 1992). Moreover, some researchers, Alarcon (1993), Ishiwata (1997), Koskela (1992) and Serpell et al. (1995) stated that waste in construction and manufacturing include delay times, quality costs, lack of safety, rework, unnecessary transportation trips, long distances, improper choice of management, methods or equipment and poor constructability.

Koskela (1992) gave an alternative for construction project participants to measure the quantity of waste in production costs by using indirect or partial measures. Some examples of the indirect or partial measures can be formed by identifying: the defects rates, the accident rates, the cycle time process and the effect of schedule delay. Therefore, waste should be defined as any losses produced by activities that generate direct or indirect costs, but do not add any value to the product from the point of view of the client.

Construction waste can be divided into three principal components, namely, labour, material and machinery waste. Accounting for these waste areas is urgently required. The main objective of accounting for waste is to assist management in improving resource allocation, minimising waste and increasing productivity (Pheng and Meng, 1997). With the currently tight and busy project schedules in the construction industry, there is a tendency for practitioners to take process time for granted. Supremely, it is important to acknowledge that daily physical site observations must be made and carefully recorded in order to provide a realistic interpretation of waste.

Construction Managers often fail to identify or address waste in the construction process. One reason why waste is not properly recognised, is the absence of appropriate tools for measuring waste (Lee et al., 1999). Chilean building construction projects experience waste variables such as waiting time, idle time and travelling time (Serpell et al., 1995). The problem related to unskilled labourers was identified in the Sri Lanka construction industry. Jayawardane and Gunawardena (1998) indicated in their study that the work force consisted of 51% unskilled workers. Kaming et al. (1997) identified lack of material, rework/repair, lack of equipment and supervision delays as factors influencing productivity in the Indonesian construction industry. The construction industry in Nigeria has similar productivity problems as Indonesia. A recent study conducted by Alwi et al. (2001) stated that construction supervision is one of the crucial elements in the construction projects in Indonesia. The study of material management in Malaysia (Abdul-Rahman and Alidrisyi, 1994) identified the nature of problems such as delay in the delivery of materials, lack of planning and material variances.

3 METHODOLOGY

A quantitative research approach was adopted for this investigation requiring the development and dissemination of a questionnaire survey. Three hundred questionnaires were sent to 125 different contractor firms in Indonesia and responses were requested based on projects they were currently undertaking or projects that have been completed within the last 5 years. Ninety-nine of questionnaires from 46 different contractors in Indonesia were returned which represented an average response rate of almost 40%.

Fifty-three (53) variables that related to waste activities were derived from literature review and pilot studies. The variables were then separated into two classifications: *waste variables* (22 variables) that contributed to a reduction in the value of construction productivity and *waste causes variables* (31 variables) that could be defined as factors producing waste. Similar categories of variables in each classification were then grouped together. *Waste variables* were grouped into 5 categories – *Repair*, *Waiting Periods, Materials, Human Resource* and *Operations*. *Waste causes variables* are grouped into 6 categories – *People, Professional Management, Design and Documentation, Materials, Execution* and *External*.

The survey was designed into three sections questioning about the characteristics of waste during the construction process. Respondents, projects and company profile were detailed. The first section contained questions relating to the frequency of waste and the level of effect of waste on construction projects. Respondents were able to identify how frequently the waste occurred using five categories: (1) Never; (2) Rarely; (3) Occasionally; (4) Often; and (5) Always. In order to score the level of effect of waste categories on construction, respondents were provided with five different scales from 1 (no significant effect variable) to 5 as (high detrimental effect variable). Section 2 dealt with the causes of waste. The questionnaire gave each respondent an opportunity to rate variables perceived as likely to contribute to construction performances on a scale from 1 (not at all or not relevant) to 5 (most relevant). For the last section, respondents were asked to provide comments on responses provided. In order to clarify the survey results, interviews were conducted with the people who work both at management and operational levels in construction. The interviewees included: Project Managers, Site Managers, Supervisors, Foremen and Labourers.

4 DATA ANALYSIS

The collected data was analysed using the paired-samples *t*-test. A weighted score model was used to achieve a greater degree of certainty in determining key waste variables. This model assigns a weighting to each criterion depending on the product of its frequency and its level of effect. The most important criteria is awarded the highest weighting. The weighted score was calculated by multiplying the frequency and effect scores. The mean scores and the standard deviation (SD) were calculated to determine the rank order of the variables. The determination of the most important variables was based on the ranking of the variables using the paired-samples *t*-test, at a 95% confidence interval. This analysis was used for calculating the means of two variables. The researcher calculated the ρ-value using the SPSS 10.0 package program. The procedures are used to test the null hypothesis of no difference in the means of two groups. The null hypothesis is rejected if the ρ-value obtained is less than the 0.05 level of significance. In other words, the means of the two groups represented by the variables are different.

5 RESEARCH FINDINGS

5.1 Respondents' profile

The average work experience of the respondents involved in the construction industry is 13 years. This indicates a reasonably high work experience profile within the Indonesian construction industry. Approximately 85% of the respondents were involved in the daily activities as they worked either as Project Managers, Site Managers or Construction Managers. Another 15% of the respondents were categorised as those who did not actively work daily on the construction site. However, they support the construction team in order to carry out the project. They included the Estimator, Plan Manager, Contract Administrator, Architect and other consultants.

5.2 Waste variables

Waste variables were classified into five categories; Repair, Waiting periods, Materials, Human resources and Operations. The mean of the weighted scores were listed in descending order as shown in Table 1. The results of the paired-samples *t*-test reduce the 22 varies in ranking order to 5 groups of variables, in which each group contains variables that are not significantly different from each other even though their observed sample mean is different.

Table 1. Waste Variables Ranking and Grouping

NO.	WASTE VARIABLES	*n*	Mean	SD	*p*	Group	Category
A3	Repair on finishing works	96	10.21	5.64	0.00	1	Repair
B2	Waiting for materials	97	9.36	5.54	0.27	1	Waiting Periods
E4	Delays to schedule	96	9.25	5.75	0.21	1	Operations
D2	Tradesmen slow/ineffective	97	9.04	5.68	0.11	1	Human Resource
C1	Waste of raw materials on site	97	9.01	6.20	0.07	1	Material
D1	Lack of supervision/poor quality	97	8.94	6.40	0.11	1	Human Resource
B1	Waiting for instructions	96	8.71	6.11	0.00	2	Waiting Periods
C3	Loss of materials on site	98	8.24	4.93	0.69	2	Material
A1	Repair on structural works	96	7.85	5.73	0.30	2	Repair
A4	Repair on formwork/falsework	97	7.31	5.44	0.07	2	Repair
E2	Equipment frequently break down	97	7.29	4.73	0.00	3	Operations
B5	Waiting for labour	97	6.92	5.80	0.57	3	Waiting Periods
B3	Waiting for equipment repair	97	6.75	4.43	0.21	3	Waiting Periods
B4	Waiting for equipment to arrive	98	6.51	5.01	0.17	3	Waiting Periods
C6	Damaged materials on site	96	6.49	5.06	0.09	3	Material
C4	Too much material inventory on site	97	6.28	4.52	0.00	4	Material
C2	Material does not meet specification	97	6.18	5.27	0.85	4	Material
D3	Idle tradesmen	98	5.93	5.12	0.58	4	Human Resource
E3	Unreliable equipment	98	5.89	4.48	0.47	4	Operations
C5	Unnecessary material handling	95	5.81	4.71	0.13	4	Material
A2	Repair on foundation works	98	5.43	5.73	0.23	4	Repair
E1	Excessive accidents on site	96	4.14	3.04	0.00	5	Operations

Based on the results in Table 1, it can be seen that group 1 of waste variables which contains the variables *repair on finishing works, waiting for materials, delays to schedule, tradesmen slow/ineffective, waste of raw materials on-site* and *lack of supervision/poor quality* is ranked as the most important group of variables. Group 2 contains 4 variables and is ranked as the second most important group, and so on. Of the most important variables, three were found to be the most common variables mentioned by the interviewees. The variables are *repair on finishing works, waiting for* materials and *delays to schedule*.

Repair is defined as an activity that must be redone or altered (Alwi et al., 2002). Repair includes variations and can occur at any time and within any activity during construction. In this case, *repairs on finishing works* include tiles works, ceiling works, painting, brick-works and plastering. Four of the Project Managers interviewed believed that this variable is a common variable contributing to waste. They stated that certain construction requires specific tools that need a higher skilled labour force in order to fulfil the clients' finishing requirements. A Site Manager working in the construction industry for 25 years stated that the incidence of repair to finishing works is not only due to a lack of labour skill and the poor quality of materials used, but also due to the failure of other construction works such as structural works and mechanical-electrical works. For example, in the case of structural failures (beam or column), floors, tiles-works may need to be redone.

Waiting for materials consists not only of waiting for material deliveries to site by external deliveries, but also waiting for material deliveries from storage on site to certain areas of the construction site (internal delivery). From the Project Managers' point of view, in order to minimise the waiting time of materials during the construction process (internal and external), two main issues should be considered. Firstly, site layout needs to be designed appropriately to ensure that the material flows could proceed smoothly without any interruptions. Secondly, efficient communication links must be established with suppliers. The suppliers must know and monitor each stage of work-in-progress. This can be achieved with ease by contractors giving authority to their site management to communicate directly with the suppliers of site materials.

Delays to schedule was a concern of all contractor companies, especially for respondents from Private companies. They agreed that *delays to schedule* was one of the most important variables affecting construction projects. This evidence is supported by Al-Khalil and Al-Ghafly (1999) in their study in Saudi Arabia. They stated that delays in project completion are a major problem leading to costly disputes and acrimonious relationships between the parties involved. In Nigeria, project delays were identified as the principal factors leading to the high cost of construction (Okpala and Aniekwu, 1988). Projects can be delayed for a large number of reasons, usually impacting on project cost and schedule. Interviews identified important variables causing delays such as inclement weather, lack of trade skill, poor planning and scheduling, delay of material delivery to site, design changes, and slow decision making.

5.3 Waste causes variables

The waste causing variables were grouped into the six categories: People, Professional Management, Design and Documentation, Material, Execution and External. The questionnaire gave each respondent an opportunity to rate a variable that contributed to construction performance on a scale from 1 (not at all or not relevant) to 5 (most relevant). A Paired-samples *t*-test was also conducted on waste causes variables. The results were listed in Table 2, which reduced the 31 ranked variables to 5 ordered groups. Similar to waste variables, each group contained variables that were not significantly different in their importance from each other, even if their observed sample mean is different.

Table 2. Waste Causes Variables Ranking and Grouping

NO.	WASTE CAUSES VARIABLES	*n*	Mean	SD	*p*	Group	Category
C5	Design changes	99	3.62	1.18	0.00	1	Design and Documentation
B4	Slow in making decisions	99	3.59	1.18	0.79	1	Professional Management
A1	Lack of trades' skill	98	3.57	1.18	0.60	1	People
E2	Inappropriate construction methods	99	3.52	1.30	0.44	1	Execution
B3	Poor coordination among project participants	99	3.47	1.15	0.23	1	Professional Management
D2	Delay of material delivery to site	99	3.47	1.15	0.29	1	Material
B1	Poor planning and scheduling	99	3.46	1.31	0.24	1	Professional Management
C4	Slow drawing revision and distribution	99	3.39	1.28	0.00	2	Design and Documentation
A6	Inexperienced inspectors	99	3.37	1.20	0.88	2	People
C3	Unclear site drawings supplied	99	3.34	1.29	0.61	2	Design and Documentation
D4	Poorly scheduled delivery of material to site	99	3.34	1.14	0.67	2	Material
C6	Poor Design	99	3.33	1.32	0.58	2	Design and Documentation
D1	Poor quality of materials	99	3.33	1.31	0.61	2	Material
D5	Inappropriate/misuse of material	99	3.32	1.32	0.67	2	Material
F2	Weather	98	3.32	1.09	0.51	2	External
A5	Lack of subcontractor's skill	99	3.31	1.23	0.51	2	People
C2	Unclear specifications	99	3.30	1.36	0.46	2	Design and Documentation
B2	Poor provision of information to project participants	99	3.28	1.24	0.31	2	Professional Management
E5	Outdated equipment	98	3.24	1.32	0.21	2	Execution
E3	Equipment shortage	98	3.14	1.19	0.00	3	Execution
A4	Too few supervisors/foremen	99	3.10	1.09	0.88	3	People
D6	Poor storage of material	99	3.08	1.22	0.67	3	Material
F1	Site condition	99	3.08	1.17	0.69	3	External
E4	Poor equipment choice or ineffective equipment	99	3.06	1.24	0.44	3	Execution
E1	Too much overtime for labour	98	3.04	1.10	0.45	3	Execution
D3	Poor material handling on site	99	3.03	1.16	0.49	3	Material
E6	Poor site layout	99	3.01	1.27	0.39	3	Execution
A3	Supervision too late	99	2.98	1.21	0.22	3	People
C1	Poor quality site documentation	99	2.88	1.12	0.00	4	Design and Documentation
A2	Poor distribution of labour	99	2.70	0.99	0.12	4	People
F3	Damage by other participants	99	2.52	1.17	0.00	5	External

Group 1 of waste causes variables contains 7 important variables relating to the most relevant causes of waste during the construction process. The variables are *design changes, slow in making decisions, lack of trades' skill, inappropriate construction methods, poor coordination among project participants, delay of material delivery to site* and *poor planning and scheduling.* Of the seven variables listed in the first group, three were from the category of Professional Management. This indicated that the act of Professional Management plays an important role in contributing to waste activities. Professional Management includes the ability of the contractors' personnel to plan and to carry out each activity effectively. Activities are affected by the skill of the personnel to cope with problems quickly and effectively when they arise and the flexibility of the personnel to work as a team and communicate with other participants.

However, during the interviews with project participants, the researchers concluded that three variables, *design changes, slow in making decisions* and *lack of trades' skill*, were identified as the key causes of waste during the construction process. Design changes can be categorised as variations and are described by Choy and Sidwell (1991) as any change to the scope of the work as defined by the contract documents following the creation of legal relations between the principal and contractor. Often the changes are no fault of the contractor. *Design changes* may occur in architectural, structural, plumbing and drainage, siteworks or other aspect of design. Interviewees confirmed that design changes were the result of owner demands or client requests for changes to design in order to meet changing requirements and preferences. In certain cases, design changes were caused by problems in material acquisition, and unforeseen circumstances such as statutory requirements.

Most managers, including Construction Managers, regard decision-making as a key aspect of their work. Studies have shown that while managers may not always spend a lot of time on decisions, a good decision is often the result of careful information gathering and analysis, involving discussions with a wide range of people, scrutiny of recorded information, and for some, decisions and manipulation of data using computer programs. A decision involves choosing between several courses of action. If the choices are well-defined, the decision problem can be come routine. If the choices are unclear, the problem is non-routine and the managers may spend large amount of time looking at options before reaching a final decision. The decision will be more difficult if the number of choices are large or the outcomes are hard to compare. If managers lack information about the problem, or about the options available, the decision can become very difficult. Slow decision-making may be caused by the contractor's personnel, clients, or consultants. From the contractors' point of view, the slow decision making of clients leads to delays in schedule. A company Vice-President noted that slow decision-making is common for government projects.

According to the respondents, contractors are still facing a *lack of trades' skills* to complete a project satisfactorily. In fact, interviewees stated that "skilled" operators were often not skilful, having gained their experience on the job site, learning construction skills through trial and error. The trend observed with activities on the project was that, labourers do not use their own initiative, and instead rely on both the foremen and the supervisors' ability to check and approve all works. For many activities, labourers are unable to interpret site drawings. Most labourers require instruction from foremen and/or supervisors.

Most Project Managers identified that the main reason of lack of labourers' skill in Indonesia are self-employed and often being farmers from rural areas. Typically young workers are often recruited through friends or relatives (often of the foremen). To overcome this problem, Mohamed and Yates (1995) suggested that management should encourage labour to undertake training programs. However, training institutions that may educate construction workers are limited in Indonesia. As a result, contractors have developed their own formal "in-house" training and evaluation progress and generally they do not share their programs with competitors (Alwi et al., 2001). Labour as a resource has specific characteristics. The production output of labour is a function of skill and motivation.

6 METHOD OF WASTE IDENTIFICATION

This paper recommends that to minimise the negative impact of waste, contractors should maintain detailed records of all events which occur on-site in relation to the incidence of waste. From the contractors' point of view, the quality of site documentation is most important. Comprehensive and qualified waste documentation should enable Project Managers to detect and solve every problem that might come up not only during the construction process, but also to anticipate the same problems occurring in the following projects. Therefore, waste documentation must be done as early as possible at every stage once the construction begins. Researchers may establish a deep cooperation with contracting organisations in order to provide an appropriate waste identification tool to properly identify waste and the causes, and lead to better alternative solutions to be applied on-site. A questionnaire survey with easy-to-answer questions may be used by contractors to provide comprehensive waste documentation. The identification and measurement of the quantity of waste might be conducted by site engineers who are supervised by the project managers. Using their own site-documentation, problems related to waste are recorded during the construction process and reported daily to the project managers. In this report, project managers are able to identify clearly what the problems are; why, when and where the problems occur; who initiated the problems; and how the problems were overcome. This also includes the estimation of the waste costs. The project managers need to approve each report before authorising any waste.

This paper presents a methodology which provides a useful tool to identify the incidence of waste in the field using a questionnaire survey. By using the flowchart in Figure 1, researchers and contractors are able to maintain regular measurement of waste and obtain other benefits including: providing comprehensive documentation of waste during the process; increasing understanding of waste variables; measuring the contractors' performance; and providing alternative solutions to be applied on-site.

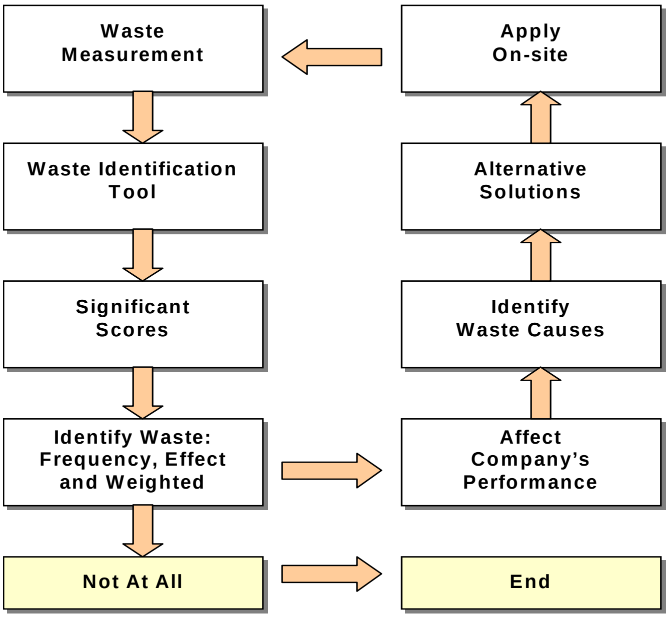

Figure 1: Method of Waste identification

7 ALTERNATIVE SOLUTIONS

In the event that the waste was found to be very high and significantly affected contractors' performance, an important contribution of this research lies in the provision of a reliable means of identifying and positively addressing the significant waste variables and waste causes variables. Once the causes have been identified clearly, alternative solutions can be suggested. Best solutions can be achieved by establishing comprehensive cooperation between industry and researchers. In the context of this research project, contractors can consider several alternative solutions as follows:

- Establish long-term relationship with manufacturers and suppliers to develop methods of delivery that avoid excessive inventory and delays;
- Consider a greater use of local materials and natural resources as much as possible;

- Conduct regular training programs for foremen and labourers, and educate them to understand the concept of waste;
- Make the construction process transparent on-site, such that every person involved in the process is able to identify any problems during the project; and
- Establish cooperation and regular meetings amongst project participants, involve all construction personnel from different levels, increase trust with one another and encourage working together as partners.

To provide the greatest impact on contractors' performance, each alternative solution should be applied and monitored regularly and continuously. Every step should be measured, recorded and evaluated properly.

8 RESULTS VALIDATION

The majority of the primary data collected for this research was the respondents' perception towards the activities of waste during the construction process. Due to the subjectivity of the respondents' responses and in order to clarify the results, a focus group discussion was carried out. The group consisted of 16 people from industry and academia. The focus group discussion was conducted over approximately two hours, beginning with a 30 minute-presentation of the research's results. This provided opportunities for the clarification of responses, for follow-up questions, and for the probing of responses. Each of the group members was free to express his/her minds openly and without concern for whether others in the group agree with the opinions offered.

9 CONCLUSION

The application of methods of waste identification is urgently required within the Indonesian construction industry. The methods are needed to assist Construction Managers to understand the whole construction process, identify waste within it, and eliminate it step by step. The responsibility of the elimination of waste does not depend only on Construction Managers, but also on the client, consultants, suppliers, foremen and labourers. This means all project participants need to be committed, involved, and work together to detect any waste and minimise it as soon as the waste occurs. As a consequence, it is recommended that workers should be more highly trained and multi-skilled.

Waste is not only associated with waste of materials in the construction process, but also other activities that do not add value such as repair, waiting time and delays. Concepts such as waste and value are not well understood by construction personnel. They often do not realise that many activities they carry out do not add value to the work. These issues contribute to a reduction in the value of construction productivity and could reduce company performance. By identifying the incidence of waste during a project, construction managers are able to easily identify the best solutions and ways to apply any new technique for reducing the amount of waste, leading to increased project productivity.

Through measurements, it is possible to initially reduce the cost of waste. Every action to reduce waste should focus on measurable and actionable improvement. No accurate measurement of waste has been implemented by Indonesian contractors during construction projects. This evidence was confirmed by respondents during pilot studies and focus group discussions. All construction personnel need to be kept informed of construction progress including project time and cost targets by use of information displays so everyone is able to monitor the status of the construction process.

10 REFERENCES

Abdul-Rahman, H. and Alidrisyi (1994) A Perspective of Material Management Practices in a Fast Developing Economy: The Case of Malaysia. *Journal of Construction Management and Economics,* Vol. 12, pp. 413-422.

Alarcon, L.F. (1993) Modelling Waste and Performance in Construction. In Alarcon, Luis, (Ed*.) Lean Construction*, A.A.Balkema, Netherlands 1997.

Al-Khalil M.I. and Al-Ghafly, M.A. (1999) Important Causes of Delay in Public Utility Projects in Saudi Arabia. *Journal of Construction Management and Economics,* Vol. 17, pp. 647-655.

Alwi, S. (2002). Non Value-Adding Activities in the Indonesian Construction Industry: Variables and Causes. *Unpublished Doctoral Thesis*, Queensland University of Technology, Brisbane – Australia.

Alwi, S.; Hampson, K. and Mohamed, S. (2001) Effect of Quality Supervision on Rework in the Indonesian Context. *Asia Pacific Building and Construction Management Journal*, Vol. 6, pp. 2-6.

Alwi, S.; Hampson, K. and Mohamed, S. (2002) Factor Influencing Contractors' Performance in Indonesia: A Study of Non Value-Adding Activities. *Proceedings of the International Conference on Advancement in Design, Construction, Construction Management and Maintenance of Building Structure*, Bali, pp. II-20-34

Choy, W.K. and Sidwell, A.C. (1991) Source of Variations in Australian Construction Contracts. *Building Economist,* Vol. 30, No. 3, pp. 25-30.

Construction Industry Board (1998). Lean Construction. *Adopted from Construction Industry Board Web Site: http://www.ciboard.org.uk/lean.*

Formoso, C.T.; Isatto, E.L.and Hirota, E.H. (1999) Method for Waste Control in the Building Industry. *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction*, Berkeley-USA.

Hampson, K. (1997) Construction Innovation in the Australian Context. *International Workshop on Innovation Systems and the Construction Industry,* Montreal.

Ishiwata, J. (1997) IE for the shop floor: Productivity Through Process Analysis. *Thomson-Shore, Inc.*

Jayawardane, A.K.W. and Gunawardena, N.D. (1998) Construction Workers in Developing Countries: A Case Study of Sri Lanka. *Journal of Construction Management and Economics,* Vol. 16, pp. 521-530.

Kaming, P.F.; Olomolaiye, P.O.; Holt, G.D and Harris, F.C. (1997) Factors Influencing Construction Time and Cost Overruns on High-Rise Projects in Indonesia. *Construction Management and Economics,* Vol. 15, pp. 83-94.

Koskela, L. (1992) Application of the New Production Philosophy to Construction. *Technical Report No. 72,* CIFE, Stanford University.

Lee, S.H., Diekmann, J.E., Songer, A.D. and Brown, H. (1999) Identifying Waste: Applications of Construction Process Analysis. *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction*, USA, pp. 63-72.

Love, P.E.D. (1996) Toward Concurrency and Integration in the Construction Industry. *The 3rd ISPE International Conference on Current Engineering*, Canada.

Mohamed, S. and Yates, G. (1995) Re-engineering Approach to Construction: A Case Study. *Proceeding the 5th East-Asia Pacific Conference on Structural Engineering and Construction*, Griffith University, Australia, Vol. 1, pp. 775-780.

Okpala, D. and Aniekwu, A.N. (1988) Causes of High Costs of Construction in Nigeria. *ASCE Journal of Construction Engineering and Management, Vol.* 114, No. 2.

Pheng, L.S. and Meng, C.Y. (1997) Managing Productivity in Construction. *Ashgate Publishing Limited,* England.

Royat, S. (1994) Development Strategy of Construction Industry in Indonesia*. Workshop on Strategic Management in Construction Industry*, Bandung.

Serpell, A.; Venturi, A. and Contreras, J. (1995) Characterization of Waste in Building Construction Projects". In Alarcon, Luis (1997, Ed.) *Lean Construction,* A.A. Balkema, Netherlands.