Information system design using labor productivity measurement for construction

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Abstract. Labor utilization in construction project is the most critical because it costs 30-50% of the total cost. In many projects, the labors e.g craftman are hired outside the company. Contractors and owners need sufficient information related to those labors whom they will work with. It is necessary for clients understanding each labor productivity performance in order to achieve the project quality. This study aims to provide the infomation needed by designing an information system that can be easily accessed. This is also to support clients for decision making in terms of teamwork project involved. The level of productivity is measured by Labor Utilization Rate (LUR) using three variables: effective working time, contributory working time, and ineffective working time. Software Development Life Cycle (SDLC) is applied in designing the information system. The finding showed that information system is properly implemented to assist clients in determining workers using productivity calculation. The system can inform the recommended workers by calculating and sorting their level of productivity that support client's decision making towards construction workers.
Keywords: information system, labor productivity, construction, SDLC

1. Introduction

Good project management in construction must vigorously pursue the efficient utilization of labor, material, and equipment. Improvement of labor productivity should be a major and continual concern of those who are responsible for cost control of constructed facilities. The high cost associated with budget and schedule overruns in the heavy construction can often be traced to low worker productivity. Labor cost is less predictable and runs a greater chance of overruns than either equipment or material cost. A significant factor influencing construction costs is the wages of construction labor, including additional expenses such as travel costs, insurance, pensions, and other benefit of worker [1]. Workers in New York and Zurich have the extreme wage close to USD100/hour, compared to an average labor rate of USD28/hour accross all region. Labor costs can reach 50 % or more of construction project cost, management of the work process presents the greates opportunity to reduce project cost [2]. Another reported that the labor cost component of a building project ranges from 30 to 50% or even up to 60% of the overall project cost [3]. Since construction labors affect each part of the project, it becomes clear that construction labor is a critical section of a construction project.

Whereas, another problem of skill shortage has arisen within the construction industry. There are 24 of 43 markets analyzed in the skill shortage of labor including Singapore, Hong Kong, and Tokyo [1]. Skill shortage is linked to productivity (labor's production rate). It is defined as the number of units of work produced by a person in specified time. Production rates may also specify the time in man-hours or man-days required to produce a specified number of units of work. The time that a labor will consume in performing a unit of work varies between labors and between projects and with climatic conditions, job supervision, complexities of the operation and other factors. For instance, it requires more time for erect shutters for stairs than for foundations. [4] have reevaluated the factors affecting the productivity of workers in the construction field such as cooperation factors, economic conditions, physical conditions and socio-physiological factors. The existing of high labor productivity at every stage of a project's development plays a significant role in a project success [5]. A standardization of guidelines for measuring labor productivity for building construction work with exploratory methods through the identification of needs and problems in the field [6]. However, productivity measurements using daily, weekly and monthly reports that are always made by building supervisors or consultants are easier to obtain information compared to methods commonly used in manufacturing such as time study, time and motion study and work sampling as it requires measurement actual productivity in the field [7]. In addition, [8] emphasized that manufacturing and construction have differences which companies engaged in manufacturing are serial and repetitive, and have short production cycles as well. This productivity measurement is very useful for companies as a reference to improve the performance of companies or groups of workers in the construction field. Likewise, in order to meet the consumers, it also required a good performance provided by companies or groups of workers in construction.

Regarding the productivity information of the construction workers, a client needs an information system providing a comprehensive information related to performance of workers in the construction field. Thus, a company can evaluate their workers as well as get the availability of workers based on their productivity as a key indicator for a company to hire the worker for a project. Software Engineering is the area which is constantly growing [9]. It is very interesting subject to learn as all the software development industry based on this specified area. There exist various models to develop software. But most of the existing Software Development Models pay less or very little attention towards client satisfaction. Client satisfaction is crucial, not only to the client, but even more to the developer because it costs far less to retain a happy client than it does to find a new client. Satisfying client is an essential element for staying in this modern world of global competition. Client satisfaction is very necessary for the acceptance and delivery of the software product. In terms of client satisfaction of worker productivity information, this study is to design an information system of worker productivity of a project using SDLC (Software Development Life Cycle) approach. The SDLC is initiated by the client's needs. In the beginning, these needs are in the mind of the client. The software developer by using a software development model has to identify, discover, understand and fulfill the requirement of the client in order to satisfy the client.

2. Method

Productivity in construction is often defined as output per labor hour. Since labor constitutes a large part of construction cost and the quantity of labor hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, this productivity measure is often referred to as labor productivity. However, it is important to note that labor productivity is a measure to the overall effectiveness of an operating system in utilizing labor, equipment, and capital to convert labor efforts into useful output, and is not a measure of the capabilities fo labor alone. The research conceptual model explains every detail of this reseach that can be seen in Figure 1.

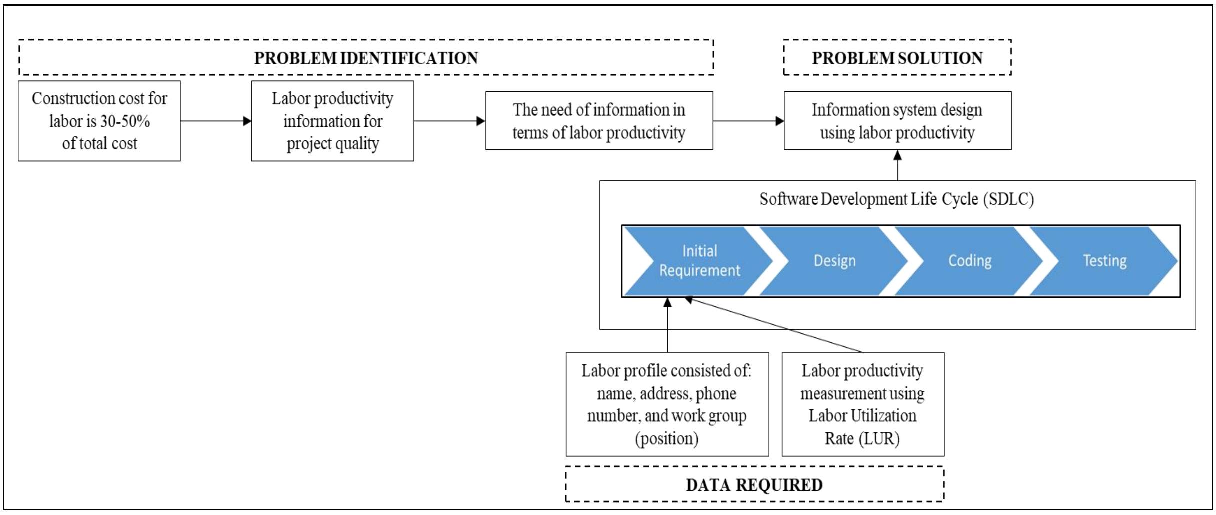

Figure 1. Research conceptual model

Four major steps are employed in designing the information system using SDLC (Software Development Life Cycle) approach.

- The first is initial requirement. It is to determine the factors required within the system developed. Regarding the labor profile, several factors that must put into the information system: name, address, phone number, work group (position), and the labor productivity. The productivity measurement employs Labor Utilization Rate (LUR). There are 3 data needed for calculating LUR: effective work, essential contributory work, and ineffective works. As the example of the calculation, previous research data [10] measuring the productivity of 5 workers is used. The observation was conducted for 3 days to identify the duration of each category of work. The work group or position refers to the work group explained in previous Figure 1: foreman and craftman (carpenter, bricklayer, etc)
- The second is design. It aims to change the results of the needs analysis stage into a structure [11]. For this reason, a number of tools are needed including data flow diagrams (DFD), entity relationship diagrams (ERD), and user interface designs. There are 3 external entities involved within the system designed namely the administrator, foreman, and user. The administrator is in charge of managing and giving access to every foreman who registers to the system. The foreman served as a construction project supervisor who then assessed and recorded the level of productivity of each craftman. The user is the end user or client of the system created such as the project managers. The information system framework is proposed as follows.

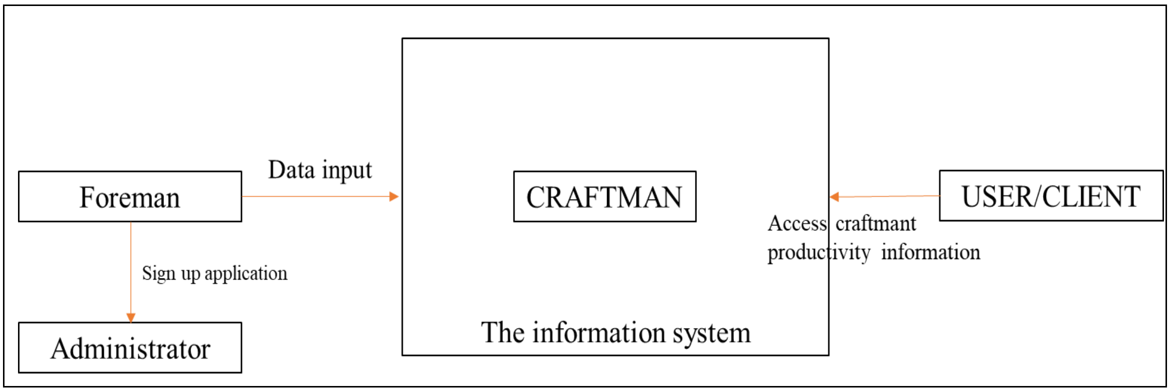

Figure 2. Information System Framework

- The third step is coding. This section focuses on the algorithm used to calculate LUR that is implemented into the Java programming language for android applications on mobile phones. The following algorithms are used for the implementation of LUR /worker/day calculations:
  1. Enter the total effective working time, total contibutory working time, and total ineffective working time;
  2. Calculate total time (total effective working time + total contibutory working time + total ineffective working time);
  3. Calculate the numerator (total productive working time + [¼ x total contributory working time worked]);
  4. Calculate LUR = Total time / numerator

  Calculating the average LUR is by adding the LUR / day value divided by the number of working days. Ordering the value of productivity can be carried out after getting the average value of LUR for each worker or craftman.
- The fourth is testing. It is required to test the results of the calculation of productivity of each worker or craftman. LUR calculation using both the system generated and manually calculated must have similar result. Likewise, the system can order the value of worker productivity from the biggest to the lowest value.

Based on the provisions set forth in the SKKNI published by the Construction and Human Resources Development Agency, the Construction and Competency Training and Development Center (BPKSDM-KPK), the classification of workers involved in a construction project is distinguished based on one's ability based on knowledge, skills and work attitudes include experts and skilled presence personnel. This study employs 2 categories of labor: foreman and craftman. Foreman is the supervisor who will examine the craftman's performance by assessing his productivity and record the calculation into the information system.

2.1. Labor Utilization Rate

LUR is the percentage obtained from the sum of effective work added with ¼ essential contributory work, then divides the sum by the total observations [12].

$$\text{LUR} = \frac{Effective\ Work + (\frac{1}{4}\ Essential\ Contributory\ Work)}{Total} \quad (1)$$

LUR is used for productivity measurement where the input used as the output comparator is the time variable. The calculations used are relatively easy, so it can simplify the process of calculating and developing the system. Yet, the factors affeting the low productivity of workers cannot be known through this formula. In construction projects, there are 3 category of activities to be considered [12]:

1. Productive/effective activities are contributing directly to the output expected from an activity, for example: pouring fresh concrete on the place to be cast, installing red bricks for wall pairs, and others.
2. Contributory activities do not directly affect the expected output of a construction project, but are often crucial or must be conducted in order to support productive activities carried out, for instance: reading work drawings to be carried out, receiving instructions or orders from foreman, etc.
3. Productive/Ineffective are idle activities, waiting, or other activities that do not contribute positively to the progress of the project being worked on, such as: smoking during working hours, or talking useless topics which are not related to the tasks given.

3. Results and Discussion

This study aims to build an information system related to the availability of construction workers or craftman as well as to provide construction workers productivity in order to prevent hiring less producticity workers. Several information needed to display the availability of construction workers in this system including profiles of companies or groups of workers providing construction services (name, phone number, address, expertise/position), level of productivity (average level of productivity for each worker and groups of workers, the order of productivity levels for each worker or group of workers). The process of calculating the level of productivity can be seen in the picture below:

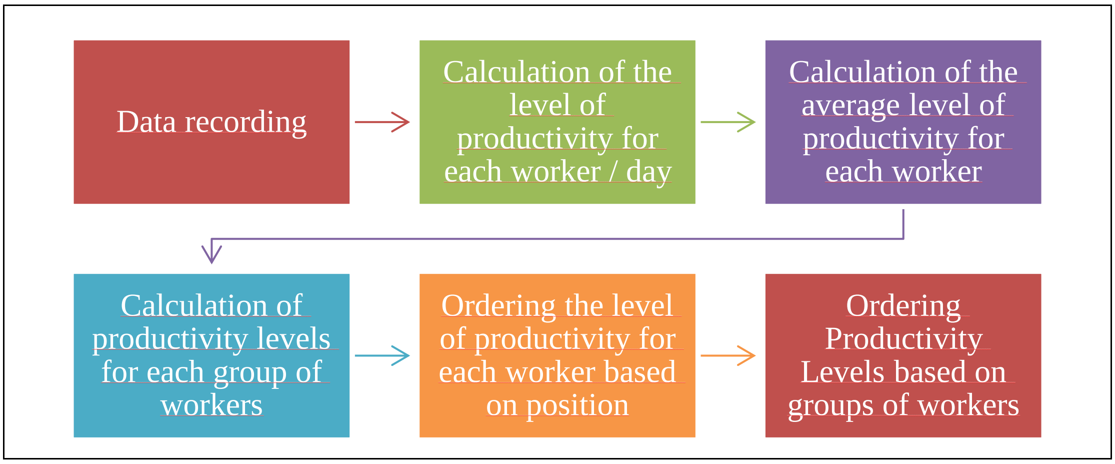

Figure 3. Productivity Level Calculation Process

Foreman is responsible to input 3 variables of each worker or craftman assessed into the system: total effective working time, total contributory working time, and total ineffective working time. In order to test the information system, the secondary data taken from research conducted by [10] is applied. LUR calculation for each worker on the first day and 3 days observation can be seen in following Table 1 and Table 2. For example, Tohir, his LUR is:

$$\text{Tohir LUR}=\frac{\mathbf{339+(\frac{1}{4}\times 58)}}{\mathbf{(339+58+23)}}=\frac{\mathbf{353.5}}{\mathbf{420}}=\mathbf{0.841667}\times\mathbf{100\%}=\mathbf{84.17\%}$$

Table 1. Calculation of LUR for day 1

Name	Total Effective Working Time (minute)	Total Contributory Working Time (minute)	Total Ineffective Working Time (minute)	LUR (%)
Tohir	339	58	23	84.17
Pudin	283	127	10	74.94
Wahyu	309	91	20	78.99
Sigit	261	126	33	69.64
Heri	299	95	26	76.85

Table 2. Calculation of LUR for 3 working days

Name	Day 1 (%)	Day 2 (%)	Day 3 (%)	Average (%)
Tohir	84.17	78.15	70.89	77.74
Pudin	74.94	59.58	66.9	67.14
Wahyu	78.99	82.56	75.71	79.09
Sigit	69.64	65.48	75.48	70.2
Heri	76.85	74.7	81.19	77.58

Using the results obtained from LUR calculation above, then the system created will sort the LUR to show the productivity level of each worker from the highest to the lowest productivity. This will facilitate the client in choosing construction workers or craftman according to his productivity. The productivity sequence is showed in Table 3 below.

Table 3. LUR rank of each worker

Rank	Name	Average (%)
1	Wahyu	79.09
2	Tohir	77.74
3	Heri	77.58
4	Sigit	70.2
5	Pudin	67.14

The output of LUR rank will be provided in information system. Contex diagram describes the system in general which is then downgraded to level 1 DFD. Then each sub system at level 1 (account management and productivity information management) is broken down again into level 2 DFD. Designing DFD, ERD, and User Interface are the next phase describing below.

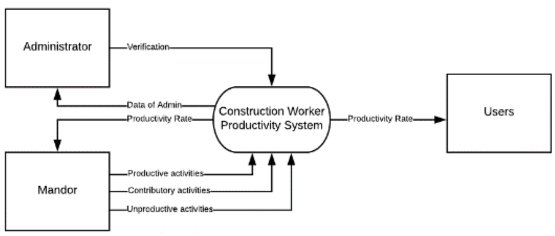

Figure 4. Context diagram

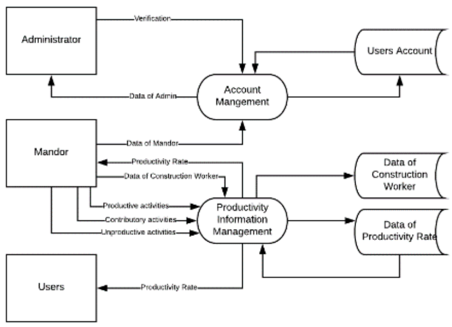

Figure 5. DFD level 1

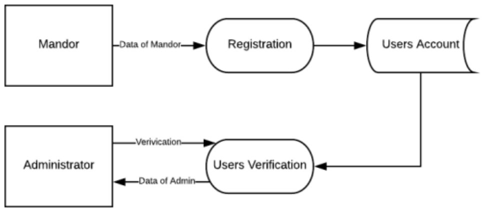

Figure 6. DFD level 2 of account management

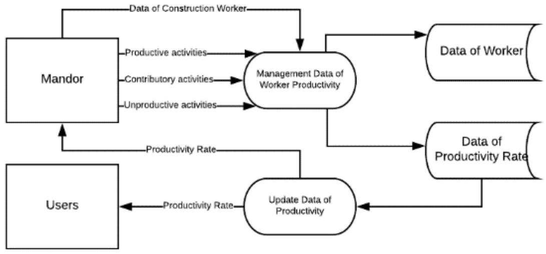

Figure 7. DFD level 2 of productivity information management

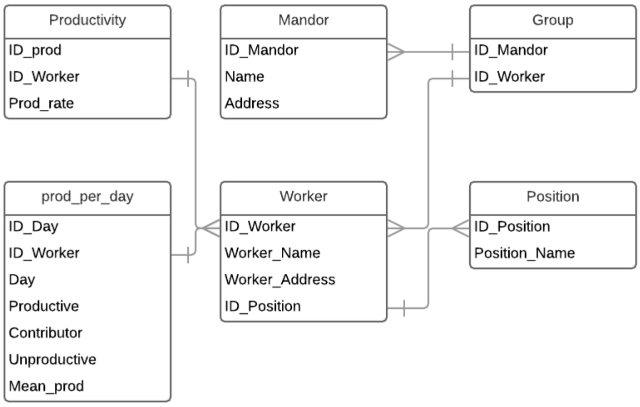

Figure 8. ERD Information System for Construction Worker Availability

User Interface (UI) design is important in a system design and has a lot of attention in recent years [13]. It is useful as an interaction between humans and computers that can increase the usefulness of a product [14]. If the UI is made worse, the ability to absorb the capabilities of the system will be reduced (Susanty et al, 2016). In this paper, we discuss some of the things in the UI that are made, namely input of labor productivity, results from productivity and sorting and search for workers.

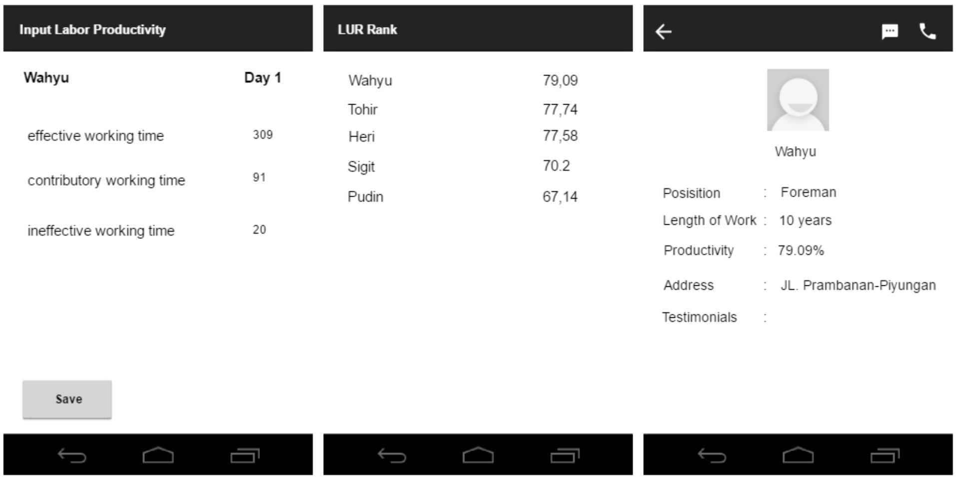

Figure 9. User Interface

4. Conclusion

This paper has presented the results of designing an information system of construction workers availability in terms of productivity level using mobile phone media. This system employs LUR formula in order to obtain the productivity level of each worker. Hereinafter, the information system given to the client can also inform the worker performance so foreman, as a supervisor, will evaluate and motivate those whose productivity level is below the minimum standard (LUR <50%). The LUR method has been easily operated by foreman to record worker productivity since the variables used are few (effective working time, contributory working time, and ineffective working time) and the unit used is time. In addition, it also facilitates the design of the system. However, there is still a shortage of LUR method, that can not capture and record the detail factors led to uneffective activities and workers as well. Further research can apply more advanced methods for productivity-based system design linked to internet era things. So that, it can be real time monitored by workers who can be integrated with the system designed.

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5. References

[1] Cost of labour in the construction industry, International Construction Market Survey 2017 retrieved from: http://www.turnerandtownsend.com/en/insights/international-construction-market-survey-2017/cost-of-labour-in-the-construction-industry/
[2] *Measurement and Analysis on Heavy Construction Projects* 2013 PicardConsultLLC
[3] Elbegati Emad *Cost estimating: Cost of Construction Labor and Equipment* (Egypt: Mansoura University/Faculty of Engineering) chapter 4 pp 64-96
[4] Kazaz A Ululbeyl S Acikara T Er B 2016 *Procedia Engineering* **164** pp 28 – 34
[5] Nasirzadeh F Nojedehi P 2013 *International Journal of Project Management* **31** pp 903–911
[6] Wuryanti Wahyu 2010 *Prosiding PPI Standardisasi*– Banjarmasin, 4 August 2010
[7] Wulfram I. Ervianto *Jurnal teknik sipil* **9** pp 31 – 42
[8] Loera I Espinosa G Enríquez C Rodriguez J 2013 *Procedia Engineering* **63** pp 947 – 955
[9] Kumar N, Zadgaonkar A Z and Shukla A 2013 *International Journal of Soft Computing and Engineering (IJSCE)* **3** pp 2231-2307
[10] Aprilian T 2010 Analisis Produktivitas Tenaga Kerja Pada Pekerjaan Struktur Rangka Atap Baja. (Surakarta: Universitas Sebelas Maret)
[11] Aggarwal K K and Singh Y *Software Engineering* 3rd Ed.
[12] Olomolaiye P O, Jayawardane A K W and Harris F C 1998 *Construction Productivity Management.* (Singapore: McGraw-Hill, Inc.)
[13] Hsiao S W, Lee C H, Yang M H and Chen R Q 2017 User interface based on natural interaction design for seniors. *Computer in Human Behavior* 75.147-159.
[14] Finstad K 2010 The usability metric for user experience. *Interacting with Computers* **22**(5) 323-327.