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An analysis and design of mobile business intelligence system for productivity measurement and evaluation in tire curing production line

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Abstract

Business intelligence (BI) system as an architecture of competencies, processes, technologies, applications and practices to support productivity measurement. It obviously needs a BI that support organization to declare any production constraints that currently or already occurred in such as tire curing industry. Overall Equipment Effectiveness (OEE) is used as a quantitative productivity measurement and become the base of company continuous improvement and evaluation. The objectives of this study are to identify critical parameters of production line in effectiveness measurement and machine utilization, analyze the requirement of information system as an Android based mobile BI System and to integrate the design into a mobile system. System requirement analyzed each interdependent measure in the real world of complexity by using BPMN 2.0. These measures are part of dashboard components in the proposed BI. The acquired data from a National forefront tire industry shows the OEE in three ratio measurement of availability, performance, and quality with 78%, 82.5% and 99.8% of scorecard respectively. In order to determine the status of production, the deployment of k-nearest neighbour (k-NN) gives 67.5% of accuracy rate. The critical parameters identification results to 8 (eight) significant constraints, which calculated using distance-based RELIEF attribute selection. Eventually this approach results big four constraints to be noted: (a) mold repair, (b) mold setting, (c) green tire shortage and (d) defect cure.

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1. Introduction

Productivity is one of the company success indicators in producing goods and improving service quality to consumers or related parties. Productivity is a measurement level to obtain the results with a variety of available resources [1]. To regain their competitiveness within the market, companies should apply the Total Production Management (TPM) for cost efficiency and higher profit margin. Most of multinational tire manufacturers are Original Equipment Manufacturer (OEM) for automotive industry; hence the critical parameters are pointed on how they produce goods with right quantity at the right place and at the right time, or termed as just-in-time [2]. Just-in-time (JIT) is now often termed as lean manufacturing that would have become issues for production strategy. Recently, business need a method to repair and reveals the problem as solution due to dynamic events and incidents in production. Core problems could be revealed using business intelligence (BI) by applying dashboard to measure and monitor performance of production. Productivity measurement within BI systems is able to combine data gathering, data storage, and knowledge management with analytical tools to present complex internal and competitive information to planners and decision makers. Some organizations use BI to gain data-driven insights on anything related to business performance. Enterprise can build business intelligent (BI) system using analytics insight to trigger business event [3]. Any measurement from analytics insight is shown at specific parameters on dashboard that reflect the definition of productivity scorecard to support decision making.

In this paper, we focus on productivity data mining using Overall Equipment Effectiveness (OEE) as indicators. OEE is an appropriate method to measure tire curing as products are discrete and able to reveals the six big losses in productivity. According to Maran et.al (2012) six constraints are divided into three categories which provide major influences on productivity [4]. Constraints could be minimized by predicting and determining the priority constraints to be solved from a variety of constraints that may occur during the production process. Predicting and sequencing the constraints are likely to support management to decide preventive action for coming period – especially with a mobile and friendly-practical dashboard to monitor the reports. This paper is merging the powerful business analytics and fundamental OEE measurement (using data mining) to reveal the silver lining of production and reduce business friction with mobile BI dashboard to trigger business action in real time.

Based on the motivation above, the objectives of this paper are to identify critical parameters of production line in effectiveness measurement and machine utilization, analyse the requirement of information system as a mobile BI system and to integrate the design into a mobile system. Critical parameters obtained by production constraints OEE values of some production lines. OEE production lines with the lowest value will be analysed further in the form of predictions for the next period of production status using algorithm k-nearest-neighbour [5]. Priority is determined using RELIEF algorithm [6]. Both algorithms are used as a loss of transparency in the production process so as to facilitate efforts to reduce such losses.

2. Research Method

This paper is written in on-field experience, which all the data was acquired from one of the biggest tire multinational company in Indonesia. The facts of production activity lead to build the systematic methodology to solve the production constraints. Frequency of constraints could be minimized with anticipation and preventive action. Categorization of constraints will ease the user to determine right treatment for the constraints and computational calculation. Constraints should be prioritized and first priority or main constraints should be placed on top of all production constraints which effectively reduce total both major and minor constraints and briefly increase the production quality. All classification and sequencing result should be monitored (dashboard) to trigger management decision in order to maintain production quality. Hence, the sequences above are elaborated in the methodology explanation below.

2.1 Constraint analysis

3.1. Overall equipment effectiveness (OEE) measurement

OEE is a combined measurement of the effectiveness of the time (availability), machine performance (performance) and product quality (quality) [7]. The general formula used to calculate the OEE value is written in equation.

$$OEE = availability \times performance \times quality \quad (1)$$

The effectiveness of the time (availability) shows the ability of a machine to produce product production. As seen in equation (1.2), this parameter is the result of a comparison between the times spent during the production takes place with a total time available for such activities.

$$\text{Availability=Runtime/Loading Time} \quad (2)$$

Engine performance shows the ability of a machine to produce product production (performance). This parameter is the result of a comparison between the achievements of production that should result in a net time used for production activities take place. Calculation engine performance levels seen in equation.

$$\text{Performance= total production/target production} \quad (3)$$

While the level of product quality (quality) on OEE is the ratio between the total products is acceptable (good) with the total product produced. This measurement is closely related to the number of defective products (defects / scrap).

$$\text{Quality=good product/total production} \quad (4)$$

2.2 Prediction of Production Status

Prediction production status with k-nearest neighbor algorithm aims to predict the classification status of production in the next period. Principle of this algorithm is to find a pattern of a data set (training tuples) and the classification of data of unknown classification (unknown tuple) [5]. Classification is done by measuring the distance to the k nearest training tuples where item data as reference and fix data in the problem domain and unknown tuples which indicate data to be classified within the proposed solution. In this study, the closest distance is calculated by Euclidian distance (1.5).

$$dist(x_1, x_2) = \sqrt{\sum_{i=1}^{n} (x_{1i} - x_{2i})^2}, x_1 = \text{ training tuple; } x_2 = \text{ unknown tuples} \quad (5)$$

Company's historical yields data indicate the amount of production losses caused by any constraints have different ranges. Normalization of data needs to be done so that any outcome classification has a valid value. The item of normalized data represented as *v*' where normalization process of data on each attribute constraints made possible using the following equation.

$$v' = \frac{v - \min_A}{\max_A - \min_A},\ v = \text{unnormalized data, } A = \text{ value on dataset} \quad (6)$$

2.3. Production constraints sequence

Recursive Elimination of Features or RELIEF technique in attribute selection algorithm is used to give weight to each constraint to a production status. Weight values will be sorted as priority constraints most exhibited significantly causing losses in production. RELIEF is the principle of the technique using the Euclidean distance to the data (instance) of the other data in the same attribute. Instance classified into two, namely Near-hit and Near-miss. Near-hit are the instances that are in one classification while Near-miss has a different classification [6]. In this study, the classification is determined by *k*-nearest neighbour algorithm.

3. Result and discussion

3.1 Production constraint analysis

Study case was conducted using multinational tire company production data which has been collected in several weeks. The OEE was calculated using the three ratios include the level of effectiveness of the time (availability), engine performance (performance) and product quality (quality). Based on the data available, the results are shown in Fig. 1 as follows. Data was compared with world standard of OEE in manufacturing.

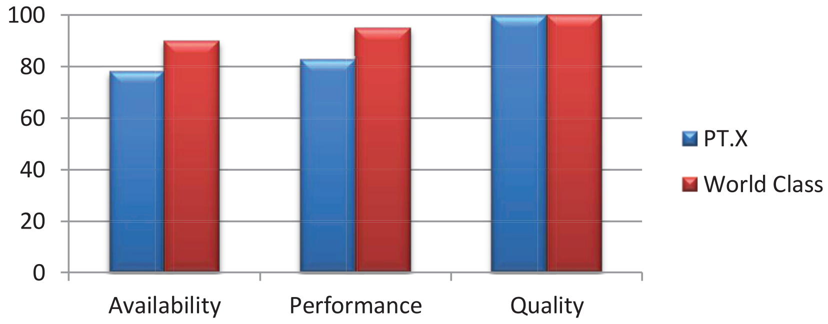

Fig. 1. OEE ratio

In relation to the six big losses components, the production constraints in tire manufacturer were directly observed on field. The result of 8 (eight) main constraints of tire manufacturing (please note that constraints were only focused on machinery issues) and explanation will be spelled out in Table 1. *M/C Trouble* is one of the biggest breakdowns of a machine because its failure in tire curing. *The Backward 1st Cure* and *Green Tire Shortage* are constraints caused by mismatch in scheduling or undeliverable production target which will impact the next production activities. *Mold Setting* and *Mold Repair* are some constraints that impacted the performance of production which caused by adjustments of tire size that to be cured. *Bladder Changes* is activity to change the bladder due its durability to maintain quality of tire curing which could easily downgrade quality tire or so called *defect*.

Table 1. Six Big Losses Identification

No.	Constraints	*Six Big Losses* Category
1.	M/C Trouble	Breakdowns
2.	Backward 1st Cure	
3.	Green Tire Shortage (GTS)	Setup and Adjustments
4.	Mold Setting	
5.	Mold Repair	
6.	Cleaning Tools	
7.	Bladder Changes	
8.	Defect	Reject

As mentioned above, the constraints should be classified and sequenced in order to conclude the production and trigger management action. The classification process is using *k*-nearest neighbour (KNN) as one of data mining technique. The principle of K-Nearest Neighbour (KNN) is looking for the shortest distance between the data to be evaluated with K neighbour in the closest training data. K value can be determined experimentally and we used k=2 with 67,5% accuracy rate. Then do the classifier data test based learning data to obtain production status as can be seen in the Table 2.

This classification helped user to determine the data classification of unknown tuples. Each tuple represents daily production. The classification will be interpreted in dashboard to measure the quality of production as key performance index (KPI) i.e. 85% is classified as G or *good,* 75%-85% will be classified as A or *acceptable* and the rest will be classified as NG or *not good*. This method is the most appropriate compared to other technique which has 67.5% accuracy rate, higher than other method i.e. Naïve Bayes classifier or support vector machine (SVM).

While there are many NG classifications, there should be an in-depth analysis to identify the critical parameters of tire curing. Refer to frameworks that have mentioned above, the constraints should be sequenced or weighted to identify the most impacting constraint in tire curing. Constraints on the production of the weight calculation to determine the constraints that have the most impact on production failures. In this study the method used to calculate the RELIEF weight of each constraint. The principle of the calculation is to calculate the *miss* and *hit* each attribute to each classification [5]. This technique resulted weight and ranked to know the most affecting attribute (constraints) on the field. Graph of ranked weight is depicted in Fig. 2.

Table 2. Classification sample of Production Status

M/C Trouble	Bladder Change	GTS	1st Cure Backward	Mold Setting	Mold Repair	Cleaning Tools	Defect Cure	Others	Classification
0,735	0,552	1,000	0,000	0,000	0,769	0,000	0,245	0,746	A
1,000	0,966	0,835	0,000	0,000	0,000	0,800	0,531	0,302	A
0,000	0,793	0,628	0,000	0,000	0,000	0,000	0,367	0,127	NG
0,295	1,000	0,728	0,000	0,000	0,308	0,000	0,327	0,444	NG
0,344	1,000	0,504	0,000	0,500	0,000	0,000	0,082	0,667	A
0,049	1,000	0,444	0,000	0,000	0,000	0,000	0,000	0,508	NG
0,328	0,188	0,813	0,000	0,000	0,000	0,000	0,000	0,413	NG
0,590	0,906	0,834	0,000	0,000	0,000	0,000	0,143	0,571	NG
0,000	0,204	0,733	0,179	0,000	0,179	0,000	1,000	0,000	A
0,098	0,463	0,382	0,000	0,000	0,000	1,000	0,347	0,000	A
0,000	0,778	0,421	0,000	0,000	0,000	0,000	0,163	0,000	NG

Note:
A = Acceptable
NG = Not Good

Those calculations above will become the core computational calculation for the monitoring dashboard of business intelligence application. The model and system architecture will explained below.

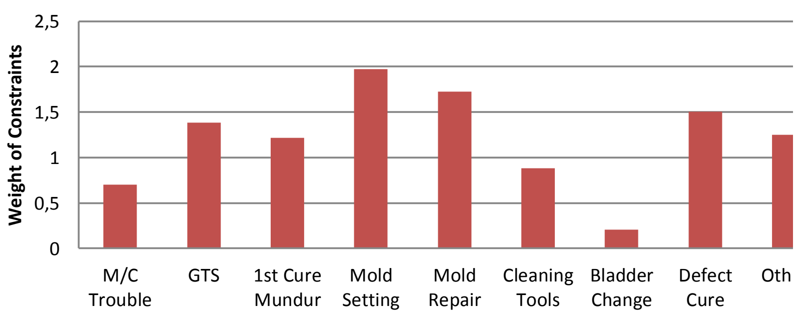

Fig. 2. Critical Constraints on Tire Curing

3.2 Business intelligence system model and mobile-based software for productivity evaluation

The relation of productivity measurement and business intelligence are interpreted in KPI and dashboard. The numbers that have been calculated using methods above become the parameters to determine the quality of production. The dashboard itself helps management to decide dynamic-based events that usually happens during production. All the data were collected in data warehouse from any stakeholders. Data were processed in computational exercises that consist of data mining technique to extract information and conclusion over the scattered data. The illustration of real time BI concept is Fig. 3.

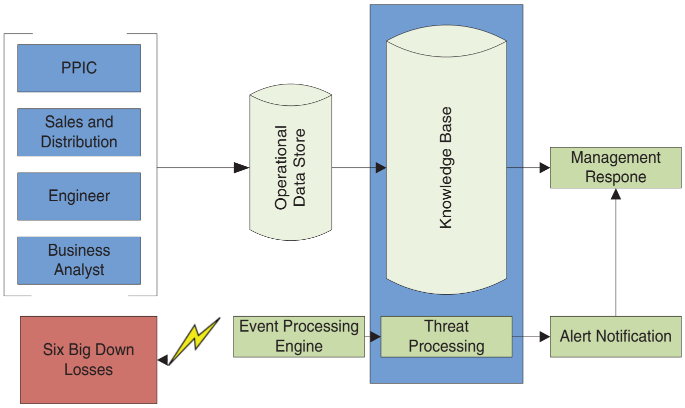

Fig. 3. Business Intelligence Concept

The requirement will be elaborated using business process model. Business process model is a model to help identifying, illustrating and elaborating a problem in a business. Business process is one or more procedures to reveal business objectives, usually in the context of organizational structure that define the functional role and its relation [9]. The model is using Business Process Model Notation 2.0 that defines the process of information and become the basis of business intelligence system architecture. Business process model is illustrated in Fig.4. The highlighted process is the critical business intelligence components that will translated into dashboard (Fig.5).

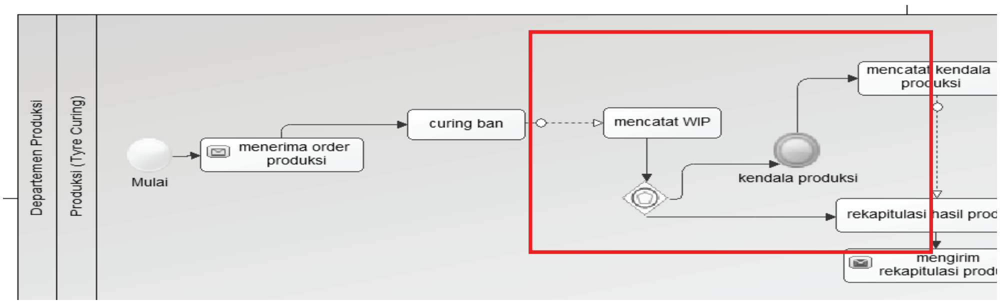

Fig. 4. Process basis fragment of business intelligence

Design an information system into mobile-based package were then compiled with object-oriented programming using Unified Modelling Language (UML). UML is used to meet the visual modelling needs in specifying, illustrating, building and documentation of software system. UML is also termed as visual language for modelling and communication in relation to a system using supporting diagram [10]. In this paper, the software was built using Android platform, which could be applied in any recent devices. The software is real-time connected to the server and other PC.

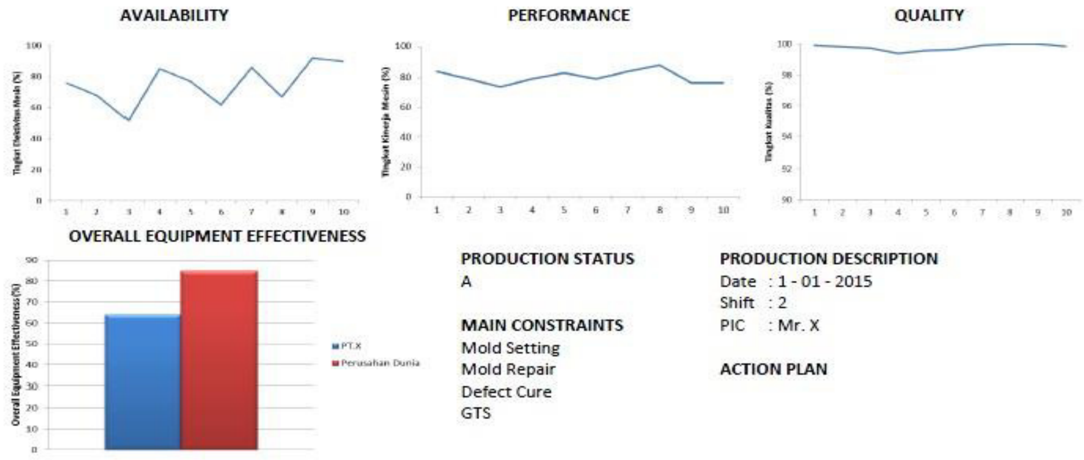

Fig. 5. BI Dashboards for Productivity Measurement

4. Conclusion

This paper proposed a construction to build Android based mobile Business Intelligence application by first identifying critical parameters of production line in effectiveness measurement and machine utilization, and then by analyzing the requirement of information system as a mobile BI system and eventually by integrating the design into a mobile system. These computational exercises were elaborated as Key Performance Index (KPI) to be monitored on dashboard and likely to trigger management decision which naturally to cover the dynamic-based production events production. By compiling end to end critical factors in tire curing production, the dashboard would inform operators and management the real time situation in production line as the core of business intelligence (BI) concept. This mobile BI-system of production evaluation is the initial steps and expected to develop whole tire production process or other manufacturing company. Furthermore, in order to enhance the focal point of business intelligence and OEE as an integrated system of enterprise resource planning (ERP) with Overall Financial Effectiveness (OFE) to measure the cost reduction and asset depreciation of machinery and equipment.

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