Material Handling Performance Measurement and Metrics for Internal Milk-Run Area using Overall Transportation Effectiveness. Case Study: Automotive Industry

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Abstract. Overall Equipment Effectiveness (OEE) is a formula that is used to measure productivity and diagnose system deficiencies in equipment level. In traditional usage, these matrix formulas have the disadvantage of detecting the internal milk-run method in its application. In order to address this gap, Overall Throughput and Overall Transportation in milk-run concept were developed to understand the overall productivity in manufacture using milk-run concept. The goal is twofold: measuring the productivity in manufacturing ratios seen from the product flow during entering the plant and when it exits from the production process, and can be carried out diagnostic internal milk-run on the production area. This journal describes the OTE(Tr) development methodology, which can improve productivity with continuous production of products and engine capacity flow in manufacturing, which is the combination product and more supply in raw material supply in the production line. The OTE(Tr) is only used for material handling outside of manufacture, metrics transportation in this case will be adjusted in material handling equipment concept. Framework Implementation in the study case: Industry automotive can be identified as a whole plant.

1. Introduction
In Indonesia, Small and Medium Enterprises (SMEs) have significant roles for national economic development [1]. According to reference [2] and [3], the SMEs have several characteristics that make their business significant for national economic development. Despite the contribution of overall of SMEs for national economic development, it can be found that many of SME of Indonesian manufacturing do not have environmental consciousness and have a significant contribution for a large amount of pollution and resource depletion due to inefficient equipment usage [4]. According to Blackman [5], SMEs are more ‘pollution-intensive’ than ‘big businesses’ although their real environmental impact is not known and may be difficult to assess. Estimates of their contribution to pollution are as high as 60% to 70% of total industrial pollution [6]. Since the SMEs in Indonesia play a crucial role for national economic development and it is found that many of SMEs of Indonesian manufacturing have a contribution for a large amount of pollution and resource depletion, one of the strategies to face this condition is implement the green manufacturing (GM) practice. There are so many definitions of GM. GM is also known as ecologically conscious manufacturing, environmentally conscious manufacturing, environmentally friendly manufacturing, manufacturing for the environment, clean production, and sustainable manufacturing. One definition is given by Govindan et al [7]. According to them, GM can be defined as GM as a system that integrates product and process design...
issues with issues of manufacturing planning and control in such a manner as to identify, quantify, assess and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while also trying to maximize resource efficiency.

Overall Equipment Effectiveness (OEE) is one of the old methods in measuring equipment performance since the late 1980s and 1990s [1]. Today, it is accepted as a primary metric to standardize measurement. In automotive industry, transportation is the shifting process from a storage site to where demand occurs [2]. The concept of Just in Time (JIT) in automotive manufacture is important to implement in line production. This concept is a combination of supply and material flow in manufacture to make sure it does not have any bottleneck or failure in time online production. Material handling embraces the basic operations in connection with the movement of bulk, packaged and individual products in a semi-solid or solid state by means of gravity manually or power-actuated equipment and within the limits of individual producing, fabricating, processing or service establishment [3][5]. In automotive industry, supply process is general the activity of the flow of goods in the production process uses Milk-run (MR) concept, namely the delivery of goods from the logistics area or warehouse to the production / assembly area in order to save storage space in the production area. This is what makes the JIT concept work harder to balance the flow of incoming and outgoing systems and sub-systems and the integration of the two activities.

Focusing the importance of efficient Material Handling Systems (MHS) for manufacture, by assuring right product to the exact place with proper quantity and condition, companies not only can decrease their operational costs, but also can eliminate/decrease unnecessary buffers within the shop floor. Nevertheless, material and information flow are highly intertwined in logistics, and for that reason information link is the keystone for efficient MHS [4][8][9]. Problems that make it more complex in supply manufacture using Internal milk-run (IMR) concept are management of delivery time, this makes shipping not necessarily following the period of demand for the manufacture line. In the process of sending raw materials / semi-parts into the manufacturing area, it cannot be done at once. This is what forces delivery sometimes to experience the variance of delivery time in the same period and job. The application of MHE in the share of the production process is very much needed, this is closely related to productivity. Where activity in the manufacture area is very bound and takes each part as important which is very binding. This dependence is caused by the inability to deliver supply of raw materials properly and the ability of the engine in the production area that has a certain capacity. As engineer is more complicated to how control the capacity and time of delivery in line production as general activities.

For example: complete count for all actual time is performed, it is obtained that the accuracy and GAP of overall record accuracy are drawn in the Figure 1 as follow:

![Figure 1. Comparison of Delivery Time shift 1 and 2 supply process/cycle](image-url)
From Figure 1, it can be seen that the comparison of record in shift 1 and 2 in Supply Material Handling in IMR Plant (Minomi area) Process to Line production. It does not have a standard time productivity of delivery time because quantity of product does not have fix the amount each deliver in plant. This reference is an illustration in company where the system developed in this company becomes standard for several leading manufacturing. The total cost required for operation in each delivery process in minomi area without using OTE Tr analysis is delivered in Figure 2 below [10].

![Figure 2. Illustration Scope of Research Minomi concept in Area Internal Plant](image)

Costs of delivery are often underestimated. Beyond the impact of fuel consumption, the environmental impact of poor driving behavior, such as harsh acceleration or braking, or of poorly planned routes leading to unnecessary miles, should be monitored and minimized to keep field operations costs down [12]. In this case, cost assumption is to improve time of delivery. It is important to make measurements of productivity standards to understand the condition of the analysis between productivity gains made between the two work shifts.

In production systems, in turn, cyclic schedules play the role of specific production flow patterns (scenarios) in steady-state/ordinary situations (i.e. excluding states associated with production start-up and shut-down) [4][8][10]. JIT concept implemented in manufacture has more section. In this context, it is also worth highlighting the relationships that exist between a clock-face schedule or a cyclic schedule and a timetable, which is a list or a table of events arranged based to the time when they take place and when delivery do in logistic area (Minomi). Therefore, a good management system requires a good work measurement system to determine the percentage of performance and capability from the logistics area into the production area. Ideal condition between the field conditions and the concept of delivery that conceptualizes JIT. Then company needs the appropriate framework to measure productivity using internal IMR concept in plant.

2. Research Objective and Methodology
Conventional or unit-based OEE measures the equipment’s productivity relative to its maximum capability, performance, and quality. Where we assume each subsequent period must be the same as the previous period, it is more complicated if we implement with shutdown or if there is any failure system in production.
The research described in this paper adopted the design science application methodology [6] as seen in figure 3. In the development of the methodology provided, only to obtain performance indicators that are integrated with transportation flow materials in combination product deliver in plant. Research start with extensive literature review based on the approach of Wolfwinkel et.al [7]. Authors propose the framework can be visualized with dashboards in application to help engineer understand more. We hope there will be each framework matrix dashboard in the next research. It is to make engineer understand more about analysis of gap, which happens in every metrics in internal milk run, both of actual process, and plant actual planning.

Despite the changes in its application, this does not change the basic principles of formulas that have been formulated in various journals, only undergoing modification of traditional methods that are less applicable in the 2000s, this also becomes the next paper to continue developing this method on other industry characteristics. Which might need adjustments. Conformity of literature review tailored to frame work needs in business process analysts. Where calculations use Overall Transportation Effectiveness (OTE Tr) with matric, compared with Overall Equipment Effectives (OEE), this is based on the IMR business process. Where in the delivery of part / raw material using MHE in the production line depends on the ability, performance, quality of the machine and the process in the production line to manage the raw material.

3. Result and Discussion
In this case, we propose the Overall Transport Effectiveness (OTE Tr) framework (table 1) that can practically be implanted in one categorized dashboard. The dashboard makes it possible to steer on strategic, tactical, operational level and visualize performance. Previously it was hard to create one overview at each level because of shifting periods. Therefore, it is necessary to conform the subject to the accuracy of the metrics on the measurement of productivity. While some similar studies have never been done but there are some similarities in the development of metrics.
Table 1. OEE Development Framework and Implementation

| Model/Framework | Metrics/Indicators/Criteria | References |
|-----------------|-----------------------------|------------|
| Overall Equipment Effectiveness (OEE) | \(A_{\text{eff}}, P_{\text{eff}}, Q_{\text{eff}}\) Machining, OEE | Muchiri, P. et al (2011) |
| Automotive Industry | GAP Analysis | Parida, A. et al (2015) |
| Overall Throughput Effectiveness (OTE Th) : Manufacture Concept | \(A_{\text{eff}}, P_{\text{eff}}, Q_{\text{eff}}\) Material Flow, OEE | Samuel H. Huang et al (2010) |
| | (Overall Equipment Effectiveness) | Kanthi M. N et al (2006) |
| Overall Throughput Effectiveness (OTE Th) : Automotive Industry | \(A_{\text{eff}}, P_{\text{eff}}, Q_{\text{eff}}\) Flow Material, OEE | Samuel H. Huang et al (2010) |
| | (Overall Equipment Effectiveness) | Little (1961) |
| Overall Transportation Effectiveness (OTE Tr) : External Milk-run | \(A_{\text{eff}}, P_{\text{eff}}, Q_{\text{eff}}\) External Material Handling, OEE (Overall Equipment Effectiveness) | Simon Dalmon (2013) |
| Overall Factory Effectiveness (OFE) : Automotive Industry | \(A_{\text{eff}}, P_{\text{eff}}, Q_{\text{eff}}\) Machining, OEE | Samuel H. Huang et al (2002) |
| | (Overall Equipment Effectiveness) | Huang et al (2003) |

In this paper literature review is split in an assessment of literature on development Overall Equipment Effectiveness (OEE) in manufacture or business implemented. In addition, for future implemented GAP analysis in application using develop OEE Concept.

3.1. Overall Transportation Framework

OTE Th can be used from a MHE perspective and up down to levels with categories. OTE Tr is a hierarchy of metrics to show how effectively transportation is executed. Where in the comparison of OTE Tr, OTE Th and OEE, it will be linked to the base on existing business processes, where in the business process the relationship between transportation and production is in the accuracy of the delivery itself. On the shipments made and cycle process in the production it will be found that the metrics has an irritating each other. OTE Tr and Th Framework can be seen in Figure 4.

![Figure 4. OTE Tr and Th Framework (Simon, 2013)](image)

The combination of the two matrices can be used to measure the concept of IMR, which consists of two main components, namely transportation and material flow. Hence, the development of metric combinations is in accordance with the internal conditions of milk run. Based on combination of three factors for each framework, authors decided to adopt the hypothesis that the IMR can be improved concurrently, but only in the form of corporate productivity and actual gap, while in the development of the matrix it only supports the related analysis without really improving the system. The matrix model can be a development reference to the next study in future.
3.2. Matrices of KPI Framework

Each of availability, performance and quality, points to an aspect of the process that can be targeted for improvement. OTE Tr may be applied to any individual transportation vehicle, or rolled up to units that consist of multiple vehicles, e.g., trip level, transportation type level, planning team level, location level [11]. The comparison efficiency based on OTE Th and OEE covers a variety of similar aspects such as Performance, Availability and Quality. Based on the relationship between the attachment of supply and the logistics area that supports business processes in the automotive industry. Where the correlation between OTE Th and OTE Tr is the similarity of matrix that are mutually exclusive because they have a related business process, this will facilitate the mapping of sub-matrix calculations that are good and suitable for industries in large scale that have varying degrees of production product in one line production. Where the industrial scale of this industry places a significant quality of time and process in each every cycle in processing.

4. Case Study and Analysis

The refined definitions of stake and stakeholder are in terms of an interest and activity. This avoids all extensions of meaning introduced by defining particular types of stakeholders and/ or their degrees of impact. It also resolves the multiplicity of conflicting meanings possible when silent or assumed qualifiers of a word are ignored, restricting definition to, for example, project stakeholders or stakeholders of a firm/company. These definitions are carried forward into a mapping of the stakeholder locus of interest on an activity rather than a company base, enabling generic categorization of stakeholders to be proposed for use in both private and public sectors. To identify we can use classification stakeholder to know how many subject in business process can be included in system of internal Milk Run. In addition, we get five subject to related with IMR area, which are:

- **Engineering Serves (ES)**: To understand condition and analyze the needs of logistic area to distribution area
- **Logistic Area (LA)**: Checking product and calculated the number of part and spare part needed in line production
- **Minomi Area (MA)**: Spare part classification and part to distribution area to production in line production
- **MHES**: Delivered Trolley from Minomi Area to Production Area
- **Production Area (PA)**: Production of the Product and assembly every part that has been delivered from Logistic Area.

The classification we need to understand is business process of logistic area in minomi to calculate and identify the process Business need in collected data state. This classification aims to find out every object involved and has certain roles and aspects to analyze the influence of the matrix determination process. Where this process aims to determine the level of importance in the data processing that will be carried out in the next stage of implemented framework.

Besides of the subject mapping, in this case, mapped business process will make it simple to design the flow of goods/raw material transport in MR concept from the logistic area into the production area that has a very complex level of bureaucracy. This will facilitate the involved subject to know the role of the part in analysing the role of the subject in the automotive industry. Where in the author’s case study, the factory has four main machines and 4 special areas for the distribution of parts for shipping, where parts to be shipped are divided by type of destination and form and number, then a mapping concept correlation is needed to describe the relationship between the dominant production and logistics areas. That it can measure performance and not deviate into just one area in plant. Figure 5 explains business Process of Internal Milk-Run in Automotive Industry.
Data collection is the process measuring information on variables of interest in this paper is quality, performance and availability metric. In an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes. And to compare KPI process after calculate of OTE Tr and OTE Th to have analysis diagnostic of problem in industry. The data collection component of research is common to all fields of study including physical and engineering sciences, logistic performance measurement and etc. and some analysis of python code to have more analysis statistical data processing in this paper. While methods vary by discipline, the emphasis on ensuring accurate and honest collection remains the same.

The business process is obtained based on field studies and deepening to the Toyota Production System (TPS) where a series of operations carried out are adjusted to the production area. This creates a variety of relationships between the logistics area and the production in which shipments are carried out using MHE. This also changes the calculation of OTE and OEE which must adjust to the needs of the TPS. In Figure Calculation using matric variables is obtained by doing a process of mapping data based on overall Transportation Equipment which is adjusted to the business processes carried out in the industry. This changes some designation concepts in various related variables without changing the previous function of the formula.

5. Calculation

Improvement performance metrics used to measure internal milk run performance is production throughput (OTE Th), Transportation (OTE Tr), Availability (Aeff), Performance (Peff), and Quality (Qeff) (table 2). The relationship between these metrics is given by Little’s and Simon. Table 2 summaries the OTE Tr and Th metrics reviewed and critiqued in this section. This section also has a detailed analysis of application tools available for performance measurement. It is followed by the motivation for a factory level performance diagnostics approach and the proposed framework especially in internal milk run concept.
Table 2. Calculation OTE Th and Tr

| Period | Qeff, Aeff, Peff (Throughput) | OTE (Th) | OTE (Transportation) | OTE (Tr) | OTE (Transportation) |
|--------|-------------------------------|----------|----------------------|----------|----------------------|
| 1      | High, High, High              | Medium   | 0.852334             | High, High, High | High | 1.00                |
| 2      | High, High, High              | High     | 0.862522             | High, High, High | High | 1.00                |
| 3      | High, High, High              | High     | 0.87441              | High, High, High | High | 1.00                |
| 4      | High, High, High              | High     | 0.895852             | High, High, High | High | 1.00                |
| 5      | High, High, High              | Low      | 0.816798             | High, High, High | High | 1.00                |
| 6      | High, High, High              | Medium   | 0.858669             | High, High, High | High | 1.00                |

In Table 2, the data obtained above is based on the calculation of grouping process based on the formula set. The difficulty in mapping will affect the number of errors in the calculation by describing the best functions by matching similar variables. The calculation becomes 6 clusters wherein the calculation dimension will still focus on measuring the performance of MHE on the internal milk-run (IMR) on the production line from the logistic area (Figures 6 and 7).

![Overall Equipment Effectiveness Chart](image1)

![Comparison OTE Tr v. OTE Th](image2)

**Figure 6.** Overall Equipment Effectiveness Chart  
**Figure 7.** Comparisons OTE Tr v. OTE Th

The value of the OTE Th is an indication of the size of the technical losses (machine malfunction and process) as a whole. The gap between the value of the OEE and 100% indicates the share of technical losses compared to the Loading Time. Gap Analysis is the comparison of actual performance with potential or desired performance. Chart Above shows a comparison of the OTE Tr measurement when compared to Plant industry performance. Where delays in the shipment process will indirectly affect the production process [13]. In other words, inappropriate shipping process will have an impact on the leading production line on automotive industry, which implements IMR.

6. Conclusion and Future Work

This research was conducted to assess design of monitoring system IMR base on automotive industry in logistic production. Max value of OTE Th is 89% and OTE Tr is 100%. Based on the results of calculations and observations regarding internal milk-run (IMR) metrics, the Overall Transportation Effectiveness model that has been adjusted to the business process in the case:

- Combination model of OTE Tr and OTE Th is a better formula to calculate productivity in the industry using internal milk-run (IMR) concept.
- Minomi concept is best related formula in logistic area in automotive industry it can use OEE to calculate performance of transportation.
- Matric in OTE Th using development-related in assembly industry will match with formula using OTE Th and OTE Tr.
- Identification of bottleneck can be assumed with GAP of OTE Th and OTE Tr in calculation, with JIT concept.
- Framework can be implemented in monitoring system in next future research, but need more implemented model to adapt with any situation in plant. In this concept just implemented in internal milk-run (IMR).
This paper is a combination of OTE Tr and OTE Th Framework. The framework can be utilized as an instrument to grasp the performance correlation between logistic and production area. Although there are still very few literatures that can be used as a reference to understand such a combined framework, but in the meantime analysts have found a significant relationship in the business processes obtained. Future research hopes to develop the model more significantly.

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