Targeting overall equipment efficiency for small medium enterprises with irregular production system

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Abstract. Overall Equipment Effectiveness (OEE) is widely used to measure the maturity of a production system. The company will be considered as World Class Manufacturing if it reaches more than 85\% value, with near perfect value for availability, performance and quality factor. This assessment is usually taken on industries with regular production times named shift system. A typical 8 hours shift system is used in OEE measurement and performance monitoring. There are few Small to Medium Enterprise (SME) perform regular production times with shift systems, others using irregular production systems. The irregular production time in the SME production system is used because of demand fluctuations. This paper shows a quantitative analysis as a part of manufacturing system design to achieve a specific value of OEE for SME with irregular production systems, for individual businesses as well as collective business systems (some companies use the same production facilities for several processes). The results of experiments on several companies are presented, as a basis for determining the technical strategy of achieving OEE values.

1. Introduction
In today's current competition between manufacturing companies, world class manufacturing status is no longer a guarantee to become a winner. Some companies that already have that status has been forced to close their production facilities because they think their competitors are small companies. Innovation is becoming the key to winning the competition. In fact, efficiency is also a major factor run the business for a sustainable development path\cite{1}\cite{2}. Thus, innovation is used as a breakthrough competition, while efficiency (such as lean manufacturing implementation) is a fuel for businesses to achieve the true benefits of product development in numbers and variants \cite{3}-\cite{5}. SMEs in current tight business competition contribute to economic development through an innovation \cite{7}-\cite{10}.

OEE has been widely used by various manufacturing industries. Some companies use OEE as the main indicator of production system performance. Availability is used to ensure that the various equipment is ready to be used when needed or ready to be used at any time. Performance is used to ensure that the production system is running at the expected level or even faster speed to undertake other problems that can decrease availability. Quality is used to ensure that all raw materials are in good condition and can be converted into finished goods. These three factors are not easily achievable indicators but need to be attempted in a systematic and integrative way \cite{11}. Otherwise, a decrease in one value may have a direct or indirect impact on other indicators.
The calculation of indicators in OEE is commonly used in regular shift-based production systems. SMEs generally have an irregular production system, with various conditions. The objective of measurement is the same as OEE in a regular production system. However, some modifications need to be made so that the measurement can provide a genuine picture of the availability, performance, and quality. SMEs do not use all the available time (for example 8 hours of work) to conduct production activities and not all the weekdays are used. In addition, SME performs production under varying conditions between a process and the subsequent process [12]. Thus, the unequal processing time becomes a problem. Moreover, the availability of raw materials based on intermittent order (not continuous order) produce another serious problem [13]-[14].

It is important to have an OEE target values in SME with the irregular production system. Simple technical strategy by placing maintenance activities in time lags between productions is also a good way to increase availability [15]-[17]. Other factors such as precise estimation of demand, good production scheduling and the availability of raw materials, supporting materials, reliable operators are the success of achieving OEE target [18]-[22]. The identification of other factors in SME is also important to reduce unproductive factor [23]-[25]. The pyramid of business orientation needs to be designed with the target value of OEE as its peak and man-money-material-machine-method element as the basis [26]. Followed by the middle part - a technical strategy that needs to be created in managing the basic elements [27]-[28].

This research presents the results of a technical strategy designed based on OEE targets. Technical strategies are made for SMEs that have an irregular production system. The approach of irregular production time (non-full-time) is done to measure availability. The time as described in Standard Operating Procedure along with various modifications is measured to acquire performance. While the quality measurement is approached with the ability maximizing the conversion of raw materials into main and additional products. Such efforts to achieve the highest level of availability, performance, and quality is done by finding the best combination of various factors that have been commonly done in a manufacturing system. Thus, the technical strategy can be done quickly without major manufacturing configuration changes.

2. Methods
First, the OEE formula is acquired in order to have the main expected parameter when performing the manufacturing system design. The value of OEE consist of availability (A), performance (P) and quality (Q) element. The variable of Running Time (RT), Planned Production Time (PPT), Theoretical Cycle Time (TCT), the quantity of Finished Goods (FG) and Good Product (GP) were involved to seek the value of each element. Thus, the typical OEE formula will be as follows,

\[
OEE = A \cdot P \cdot Q \tag{1}
\]

\[
A = \frac{RT}{PPT} \tag{2}
\]

\[
P = \frac{(TCT \cdot FP)}{RT} \tag{3}
\]

\[
Q = \frac{GP}{FP} \tag{4}
\]

It can be seen that A, P, and Q are connected. It is difficult if we are only focus on increasing RT to have greater A as the consequences of getting lower P. Having greater number of finished product might increase P but reduce Q. For SME, bigger PPT means having more demand to be finished and gain more profit. However, RT will depend on the availability of all resources – man as the problem of operator skill, machine as the problem of facilities, material as the problem of accessibility, method as the problem of technology capability and money as the problem of investment. Further, producing zero defect product might the biggest challenge of all as the low confidence of doing the better production system is still a problem in SME. Then, irregularity can be described as the proportion of doing manage process (MP) as the strategic business activities, doing core process (CP) to fulfil the demand (main activity to build OEE) and support process (SP) to enhance the overall capability.

Second, the OEE element should be further explored towards the production consideration within SME. It is proposed that SME should do the following simple steps:
• PPT, it depends on how the SME can get the order from the customer. The number of product variant will also contributes to complexity of calculating overall production time. Moreover, creating an accurate Standard Operating Procedure (SOP) contains production activities and estimated cycle time is mandatory.
  • PPT1 – capability of get order
  • PPT2 – capability of innovation and diversification (product variant)
  • PPT3 – capability of creating accurate SOP to estimate cycle time
• RT, the availability of man, machine, material, method and money is important. Such availability of man can be derived from manpower working hours, availability of machine can be derived from time between failure and time to repair within reliability aspect, availability of material can be derived from service level of inventory and supplier connection, availability of method can be derived from degree of adaptation and innovation, and availability of money can be derived from revenue generation or capital inquiries
  • RT1 – increase the availability of resources
  • RT2 – decrease the unavailability of resources
  • RT3 – increase operation continuity
• FP, reaching the production target should be done within the PPT. However, create product faster will be beneficiary in order to get higher performance.
  • FP1 – follow the SOP instruction to reach TCT
  • FP2 – seek for efficiency to reach faster cycle time
  • FP3 – possibility of involving external resources
• GP, it involves engineering drawing that contains product specification. Further, implementation of good quality control (including quality assurance and quality management) is an obligation to reduce defect.
  • GP1 – clear engineering drawing equipped with product specification
  • GP2 – good quality control procedures (can be advanced with quality assurance and quality management)
  • GP3 – reliability of material and manufacturing process

Considering those supporting factors, a weighted proportion (range 0 – 1) is created to have clearer description. SME then can use the simple equation to analyse OEE target.

\[
W_{PPT} = \frac{W_{PPT1} + W_{PPT2} + W_{PPT3}}{3} \tag{5}
\]

\[
W_{RT} = \frac{W_{RT1} + W_{RT2} + W_{RT3}}{3} \tag{6}
\]

\[
W_{FP} = \frac{W_{FP1} + W_{FP2} + W_{FP3}}{3} \tag{7}
\]

\[
W_{GP} = \frac{W_{GP1} + W_{GP2} + W_{GP3}}{3} \tag{8}
\]

Where,

\( W_{PPT} \) is weighted factor for PPT, so does \( W_{PPT1}, W_{PPT2}, W_{PPT3} \) is related steps as described
\( W_{RT} \) is weighted factor for RT, so does \( W_{RT1}, W_{RT2}, W_{RT3} \) is related steps as described
\( W_{FP} \) is weighted factor for FP, so does \( W_{FP1}, W_{FP2}, W_{FP3} \) is related steps as described
\( W_{GP} \) is weighted factor for GP, so does \( W_{RT1}, W_{RT2}, W_{RT3} \) is related steps as described.

Third, a technical strategy should be built based on all the supporting factors of OEE element. The strategy should be just determining the target of an individual factor and describing how to achieve. Moreover, the scheme of a complete business process will also be included (27). These are manage process (MP), core process (CP), and support process (SP). The proportion of doing each process within a day is defined as an irregularity. The proportion of CP is considered as production time. Thus, SME is not always doing 8 hours production process like a regular manufacturer. However, a weekly basis will be used to simplify the term. A typical path of technical strategy can be seen in Figure 1.

\[
WH_{MP} = \sum_{i=1}^{n} WH_{MP_i}. W \tag{9}
\]

\[
WH_{CP} = \sum_{i=1}^{n} WH_{CP_i}. W \tag{10}
\]

\[
WH_{SP} = \sum_{i=1}^{n} WH_{SP_i}. W \tag{11}
\]

Where,
\text{WH}_{\text{MP}} : \text{Working hours of MP in day } i \\
\text{WH}_{\text{CP}} : \text{Working hours of CP in day } i \\
\text{WH}_{\text{SP}} : \text{Working hours of SP in day } i \\
W : \text{number of week within a year} \\
n : \text{number of operation day within a week}

Finally, the proposed method is also considering a collective production system. In fact, several SME can share a particular production process in order to have better capabilities and flexibility. In collaboration, the predictive result can be determined by a pessimistic value such as several SME who shares production facilities will depend on the slowest production time within members. Thus, for all the elements the weighted factor (range 0 – 1) for collective operation will be the minimum value of all SME member.

\[
\text{W}_{\text{RTall}} = \text{Min} (\text{W}_{\text{RTSME1}}, \text{W}_{\text{RTSME2}}, \ldots, \text{W}_{\text{RTSME}n}) \\
\text{W}_{\text{PPTall}} = \text{Min} (\text{W}_{\text{PPTSME1}}, \text{W}_{\text{PPTSME2}}, \ldots, \text{W}_{\text{PPTSME}n}) \\
\text{W}_{\text{FPall}} = \text{Min} (\text{W}_{\text{FPSME1}}, \text{W}_{\text{FPSME2}}, \ldots, \text{W}_{\text{FPSME}n}) \\
\text{W}_{\text{GPall}} = \text{Min} (\text{W}_{\text{GPSME1}}, \text{W}_{\text{GPSME2}}, \ldots, \text{W}_{\text{GPSME}n})
\]

Where,
\text{W}_{\text{RTall}} \text{ is collective weighted factor for RT} \\
\text{W}_{\text{PPTall}} \text{ is collective weighted factor for PPT} \\
\text{W}_{\text{FPall}} \text{ is collective weighted factor for FP} \\
\text{W}_{\text{GPall}} \text{ is collective weighted factor for GP} \\
n \text{ is number of SME within the shared production facilities.}

3. Results and Discussion
A survey has been done in several SME, gathering data for testing the proposed method. A various result of OEE has been found in different SME (Figure 2). Testing the improvement scenario trough technical strategy shows significant improvement. Shared production facilities will be beneficiary mostly for SME with lower capability. Thus, the cooperation scenario should be then discussed and improved in order to have more mutual benefit. However, testing the different scenario of MP, CP and SP proportion showing a relatively unpredictable result. This might can be a future reference of improvement.

Considering all the involved factors and capturing the observation within several SME, some consideration of targeting OEE value can be described as follows.
To increase availability, it is necessary to have a focus on increasing the availability of man, machine, material, and money in order to have more RT. Avoiding unavailability is difficult because maintenance and repair activity requires a high cost. SME should focus on ensuring the sufficient operational funds to guarantee the accessibility of required resources. Thus, providing the effort to reach maximum irregularity is crucial.

To increase performance, it is better to have a focus of reducing the processing time. Running the production process in its fastest way should be carefully done to avoid a lower quality rate. SME should focus to find alternatives of a better operator, better machine and better method in order to have shorter processing time. Thus, seeking the most flexible option to face irregularity is necessary.

To increase quality, it is important to have a focus on increasing the proportion of good product rather than increasing the number of the finished product. Expecting high demand must be followed by a near defect free production system for the whole process. SME should focus on producing the number of product based on the normal operation time. Thus, leveraging irregularity of operation time is important.

4. Conclusion
The advantage of an irregular production system in SME is about to face the problem of limited resources. The proportion of production time (core process) can be somehow altered, in order to have sufficient time for doing manage process and support process. The targeting process is easily done by controlling the number of expected finished good, ideal cycle time, planned production time and running time as the main variables of OEE. The approach of collective production process should be done very carefully as it can decrease the individual OEE of SME. The more combination of both individual and collective production system can be handled by the proposed method. Therefore, seeking the best value of OEE by optimizing the involved variable can be used to determine the required technical strategy.

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