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Translating OEE Measure into Manufacturing Sustainability

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Abstract. This paper focus on the translation of Overall Equipment Effectiveness (OEE) measure into manufacturing sustainability based on literature study. It examines the three OEE contributing factors; availability, performance, and quality; and the sustainable manufacturing components including environmental conservation, social efficiency, and economic enhancement. The OEE measure is not only possible to improve productivity through the identification and elimination of manufacturing major losses but its implementation has its own merits towards sustainable manufacturing. The findings can be used as an initial reference for manufacturers to consider OEE measure to advance the goal of manufacturing sustainability.

Introduction

Increasing costs of materials, energy, and compliance coupled with higher expectations of stakeholders, manufacturing industries are facing challenges and pressures fora more environment- and resource-friendly production. The goals are not just for the future success of the firms, but also for the health and well-being of future generations. In response, manufacturing firms recently have shown more interest in sustainability and have begun to seriously consider reduction of hazardous substances, pollution prevention, redesigning products to be environmentally sustainable for the benefit of society.

It is a globally emerging concept that recognises the interdependence of the economy, society, and the environment; frequently referred to as the three pillars of sustainability. Economic sustainability promotes profitability through the efficient use of resources, while environmental sustainability prevents harmful and irreversible effects on the environment by efficient use of natural resources and social sustainability responding to the needs of society. In manufacturing, sustainability is a part of the optimisation of the overall efficiency of enterprises, products and processes in achieving growth in economically, environmentally and socially viable [1].

Overall Equipment Effectiveness (OEE), introduced by Nakajima [2], is a comprehensive matrix for evaluation of asset performance drivers for improving productivity of the business. Three factors that define OEE are system availability, equipment performance and production quality by considering elimination of six big losses (breakdowns, setup and adjustments, small stops, reduced speed, start-up rejects and production rejects). All these factors affect the efficiency of the machine and material usage, quality of products and the time utilisation for the overall process [3].

Conventionally, OEE measure is convenient as benchmark in comparing the performance of a given manufacturing asset to industry standards, to similar in-house assets, or to results for different shifts working on the same asset [4]. However, OEE measure is also useful as a foundation to track progress over time in eliminating waste from a given manufacturing asset inherent to organisation commitment for sustainability. Indeed, OEE gained increasing interest as a key measure of considerable relevance for sustainability in manufacturing [5].Therefore, this paper will explore and discuss the translation of OEE measure into manufacturing sustainability. The findings could provide an insight for practitioners and academics on the prospect of translating OEE into

manufacturing sustainability for the future. The structure of the paper is as follows. First, OEE factors are introduced. Next, the discussions on translating OEE measure into manufacturing sustainability are presented. Finally, the conclusions and avenues for further research are disclosed.

Overall Equipment Effectiveness Measure

OEE can provide topical information for daily decision making by utilizing largely existing performance data, such as preventive maintenance, material utilization, absenteeism, accidents, labours recovery, conformance to schedule, set-up and changeover data [4]. This is generally governed by the cumulative impact of the three OEE factors: availability, performance and quality [5-7].

Availability in manufacturing system is the operating time (uptime) of equipment for the scheduled production. System availability is heavily affected by equipment downtime. Downtime losses happen when breakdown arises, an unplanned maintenance task must be done in addition to the set-up and adjustment time. These activities reduce equipment availability and, hence, affect the OEE of the firms. OEE measures system availability in percentage of actual operating time divided by the planned operating time. Actual operating time is the planned operating time minus unplanned stoppages like equipment failure, and setup and adjustments. Planned operating time is actual time i.e. 24 hours, shift hours minus time allocated for planned maintenance and planned stops. Planned operating time is scheduled before the start of the period or shift.

Meanwhile, performance of equipment is a measure of how well the machine runs within the operating time (uptime). It is the ratio between the actual number of units produced and the number of unit that theoretically can be produced and is based on the standard speed the equipment is designed for. OEE speed losses happen when equipment speed decreases but there is a discrepancy between the speed reading and the actual speed. It can come from normal malfunction, small technical imperfections, like stuck packaging or because of the start-up of the equipment related to a maintenance task, a setup or a stop for organisational reasons. Performance rate can be expressed in percentage of actual production output divided by scheduled production output.

Production quality is the measure of the number of parts that meet specification compared to total product produced per time frame. When the produced output does not confirm to quality specifications, it is considered as quality loss and this reflects on the quality rate of products within the firms. Quality losses occur because equipment, in the time between start-up and completely stable throughput, yields products that do not conform to quality standards. Quality losses can even happen because an incorrect functioning of the equipment or because process parameters are not tuned to standard during production. The quality rate can be expressed as the percentage of production input into the process or equipment minus the volume or number of quality defects then divided by the production input.

OEE is being used increasingly in the industry as it reveals inefficiencies in manufacturing by screening how well a production line is functioning overall. OEE not only captures downtime reasons, but also shows capacity loss and cycle times. With this information, management can better judge the most appropriate allocation of staff to optimise the line balance and the utilisation of resources as well. Analysis of the equipment effectiveness loss mechanisms as well provides management with improvement opportunities for the operation results in more outputs with required levels of availability and optimum capacity utilization while minimizing the use of resources. Thus OEE improves enterprise efficiency, reduce manufacturing costs, and improve product quality and others, so as to promote rapid and sustainable manufacturing[8].

Translating OEE measure into Manufacturing Sustainability

The translation of OEE measures into manufacturing sustainability for greater environmental conservation, social efficiency, and economic enhancement can be seen in Fig. 1. Combination of system availability rate, equipment performance rate, and production quality rate are the three essential factors for OEE measurement and each of these factors can be translated in all three perspectives of sustainable manufacturing. However, OEE measurement may differ amongst applications and authors as data may not be available or feasible to collect in the form required for each formula [9].

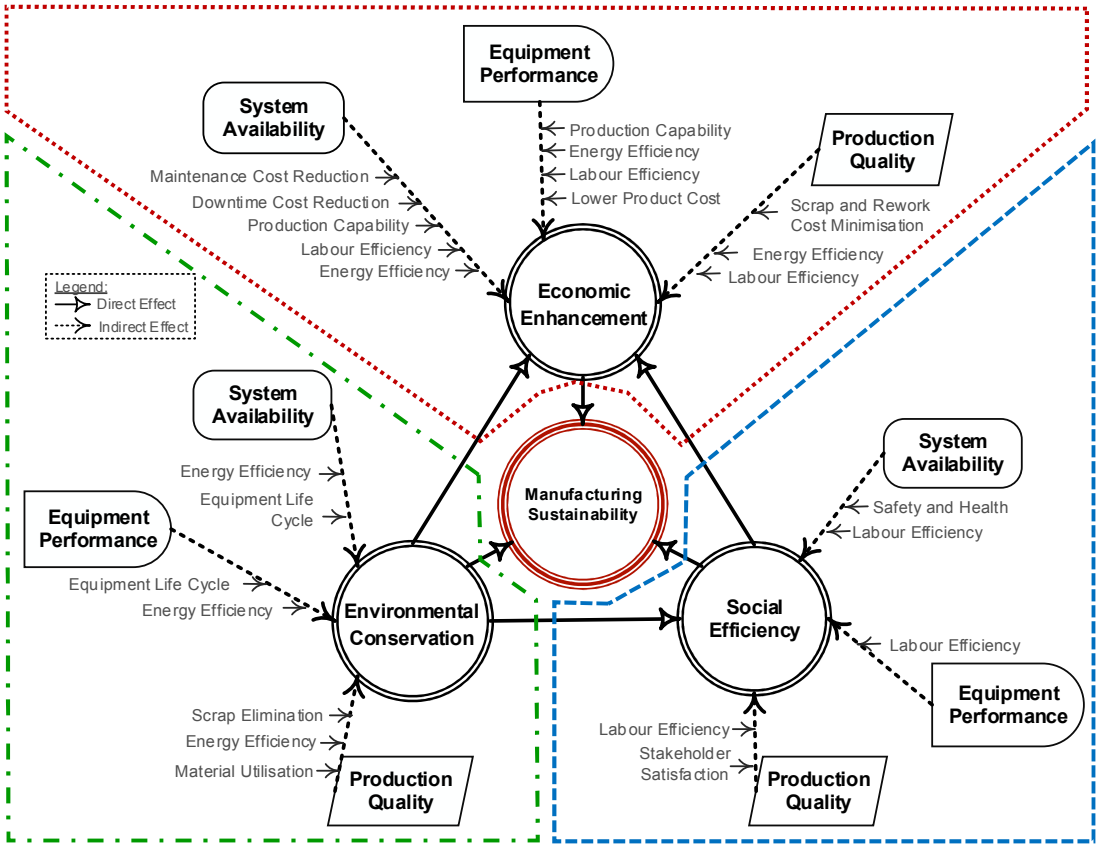

Fig. 1 Translating OEE measure into Manufacturing Sustainability.

From Fig. 1, environmental conservation is the first element considered in manufacturing sustainability. This element further benefits social efficiency, and both environment and social elements support manufacturing firms for economic enhancement.

Environmental impact is the most pressing issues as manufacturing firms are confronted with demands to play an active role to reduce environmental burdens effectively and to help in achieving environmental sustainability. Rising OEE brings a better environmental conservation through identification and elimination of major losses in manufacturing. Consequently, manufacturing can be advanced by efficient use of natural resources, consumption of energy and reduction of production rejects and waste so as to prevent harmful and irreversible effects on the environment. Monitoring and controlling system availability and equipment performance support manufacturing sustainability for better energy efficiency and prolong equipment life cycle. This is achievable by minimizing breakdown, setup and adjustment, minor stops, and speed losses. Unpredictable and uncontrollable nature of breakdowns are typically the main source of safety and environmental hazards [10]. By tackling breakdowns losses, manufacturing gains benefits in term of additional output, safety, environmental health, quality of end-product, customer service, competitiveness or unit costs.

Through improvement of production quality, increase in OEE scores is indirectly related with energy savings, material utilisation and scrap elimination. It also results in prolonged equipment life cycle that would in turn produce lesser waste and lesser scrap and thus keep environmental load at

minimum. A smaller amount of investments for same amount production volume with less waste and scrapping of machine equipment with longer lifetime can be reached with OEE employment.

Social efficiency is influenced by system availability, equipment performance, and production quality indirectly. Social components include labour and stakeholders. OEE encourages labour efficiency and productivity by improving visibility into operations and empowering operators. This includes instantaneous identification of the actual causes that adversely impact production, whether through human input (process / labour issues) or equipment / material issues. The net effect of reduction in machine downtime, escalation productivity of labours, and minimisation of defects is the ability to achieve higher production levels with the same amount of resources. Besides, high OEE performance can reduce incidents and accidents (safety issue) and other health hazard issues and encouraging a healthy work culture [11]. Labour efficiency is also further reflected in the joint effects of many influences, including capacity utilisation, energy efficiency, and materials utilisation, the organization of production, and managerial skill. Moreover, managing OEE also can support the enterprises to enhance their competitive position and create additional shareholders value and satisfaction. From this, manufacturing firms also can provide equitable opportunities, encourage diversity, promote connectedness within and outside the community, ensure the quality of life and accountable governance structures for social sustainability.

Vitality of economic performance can be realised in sustainable manufacturing operation through promoting asset management discipline and comprehensive measurement systems. This can assist in identifying asset performance and its consequential impacts on profitability and competitiveness by OEE. Additionally, OEE also can provide solution in its entirety for the process industry with an objective to reduce the overall costs, bringing in a change and savings in resources through and return on assets and maintenance investment. Greater machine availability results in more products, more income and thus higher value and lower maintenance costs produce higher value by avoiding expenditure [12]. This includes allocation repair labourers from an existing group of resources instead of hiring someone on an emergency basis. Thus can result in huge savings compared to repairing a machine after the breakdown has happened.

OEE identifies lost production and the hidden potential in a machine or a cell that can deliver additional throughput and increase production capability. Cost savings through production consistency improvement and waste minimization also contribute for economic vitality. Reduction of scrap and rejects directly improve production quality. Hence it leads to a better energy efficiency, labour efficiency and lower product costs, besides higher customer satisfaction. OEE plays an important role in sustaining firms' competitive advantage because moderate changes in OEE can result in significant changes in return on investment since it reduces the production cost per product volume, yielding a higher profit margin and/or providing more flexibility in potential price wars [10].

The decision making of OEE is undertaken at all levels to achieve elimination of material, energy consumptions and waste production, while taking advantage of cost benefits leading to manufacturing sustainability development. These imply less environmental pollution on account of system longevity and optimum utilization of material and energy for the limited resources scenario that governs the development of future systems [12].

Conclusion

Conclusively, the study indicates that the OEE measure can be translated into manufacturing sustainability. Any improvement made in the OEE factor (system availability, equipment performance, and production quality) will have an indirect and positive impact on environmental conservation, social efficiency, and economic vitality of the manufacturing firms. The manufacturing sustainability objectives to increase the productivity, besides elimination of consumed resources without compromising product or service quality, competitiveness and profitability can be realised with the support of employing OEE in the firms. This study provides an insight for manufacturers on how OEE influences manufacturing sustainability. Manufacturers also

may reflect this exploration as an initial reference to consider OEE measure to advance the goal of manufacturing sustainability.

Future studies might improve this conceptual model by adding other factors and losses that are not considered in OEE measurement such as planned maintenance, shortage of raw materials, unavailability of labour, etc. These additional essentials may cover the whole issues in manufacturing firms therefore expand the effect of OEE on manufacturing sustainability in particular.

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