CLEANER PRODUCTION IMPLEMENTATION IN AN E-WASTE RECOVERY PLANT BY USING THE VALUE STREAM MAPPING

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Article History: Received 4 August 2017; Revised 19 October 2017; Accepted 6 December 2017

ABSTRACT: This study aims to determine the manner in which the Cleaner Production (CP) sustainability measures would be embedded into the altered Value Stream Mapping (VSM), which is a Lean Manufacturing tool. The typical VSM technique does not consider the societal and the environmental metrics that are imperative for determining the sustainability for any production line. Additionally, the Guidelines for Green Industry Auditor, 2014, published by the Department of Environment, Malaysia, have made no mention regarding the proper lean tools which need to be applied to the audit systems as per the USEPA for improving the system. The VSM ability to determine the environmental, economic and societal performance would help VSM be a useful tool. Also, many companies can apply the data generated in a better manner and change their operations to fit the technology for improving the manufacturing. This paper has presented a CP implementation with the help of a VSM technology, based on the earlier literature. One pilot case study has been conducted in the local e-Waste Recovery Plant, ABC Sdn. Bhd., which demonstrated that this VSM approach, could capture the environmental, economic and societal sustainability for a specific process and has also, recommended some future researches.

KEYWORDS: *E-Wastes; Lean Manufacturing; Carbon Footprint; Value Stream Mapping; Small and Medium Industries*

1.0 INTRODUCTION

It is possible to create an environmentally sustainable society that meets the current needs without compromising the needs of the future generations. A similar feeling was put forth in the Kyoto Protocol, wherein the legislation and the industrially-recognised emission targets were established [1]. Earlier to this, e-wastes that arise from households, industrial and institutions were categorised as municipal solid waste. An improper e-waste management by the households has forced the Malaysian Government to implement a measures to manage the toxic and hazardous wastes, since 2005, as per the norms of the Basel Convention [2]. Additionally, in the case of e-wastes which are more economically favourable, but environmentally harmful, has brought in a closer policy attention amongst all the levels of the society, authorities and the industries. Furthermore, a drastic increase in the e-waste production has led to many serious environmental issues, which needs a better method of handling e-wastes [3-5].

One such method, Cleaner Production (CP) involves minimization of the pollution and waste load in the environments [6-7]. Furthermore, Lean Manufacturing strives to eliminate waste at every production step to lead to a very efficient production process [8-9]. In the CP method, a preventive approach is implemented, which helps in improving the production processes and decreases the environmental wastes and waste generating process [10]. Currently, the implementation of the CP process is restricted in Malaysia due to a limitation of the resources and voluntary approaches that make the process very not popular and difficult to maintain.

In this study, the authors aim to determine the manner in which the CP sustainability measures are embedded in the VSM (called as CPVSM), as the novel e-waste management system, mainly with respect to the recycling and the recovery processes for boosting the environmental control benefits. The lean manufacturing is considered as the prerequisite for pursuing the sustainable manufacturing process [11-12]. Hence, it becomes important to learn the way the Lean Manufacturing tools are extended for considering the environmental issues.

The Value Stream Mapping (VSM), which originated in the Toyota Production System, is a very important process that is used in the lean manufacturing process for waste identification [13]. A VSM for all actions, including the value-added and the non-value added actions, need a product to be brought through all the major flow essentials for each product, i.e., the production flow of the raw materials to the customer, along with the design flow of the product from its concept to its launch [14]. The conventional VSM processes do not consider the environmental and the societal metrics that are very important for assessing the production line sustainability. The capacity to capture the environment and the societal performance of the process visually would greatly help the VSM to become a very useful CP and lean tool. In this study, the authors have presented a very comprehensive framework for developing the case study for the implementation of the CP through the VSM technique. The main aim was developing a Current State Map (CSM) and then determining the wastes (environmental, economic, and societal metrics) that were identified after CSM analysis. These results could be used as inputs for developing the Future State Maps (FSM) for further improvements. This case study would be further implemented in the e-waste recovery facility at the Copper and Fibre recovery process. The authors selected this facility as it was a major production unit with a high rate of production along with high energy and water consumption which could drastically affect the environment, economy and the society.

1.1 Research Background

The Agenda 21 states that "sustainable production and consumption" is a strategy for ensuring a healthy economic and industrial development at manageable and viable levels. In this report, the committee has also stated that for a safer environment, the industry could adopt various positions which ranged from environmental strategies which complied with the regulations by the pro-active initiatives. In any case, the environmental concerns need the manufacturing companies to develop relevant strategies, practices and technologies which would decrease the environmental effect on the local or the global scales. Refering to [15], currently, the Lean practitioners and the environmentalists are involved in an "in-silo". The business can garner massive benefits if these two are grouped together. The environmental wastes are difficult to be seen and when embedded with the Lean Wastes, they are commonly called as the Seven Deadly Wastes [15]. Also, learning the process of eliminating the environmental wastes using lean tools, helps in improving the process, and furthermore, strengthens the lean results along with several environmental benefits. In Malaysia, based on guidelines which were published by the Department of Environment, 2014, many CP implementations were carried out in the country, called as the Green Industries audits. However, these guidelines require an overall precise CO2 activity measurement and profiling, which are not focused primarily on the conventional mainstream activities, and hence, it can be very difficult to conduct the various Kaizen activities [16].

1.2 Literature Review

For improving the efficacy of the lean implementation, along with addressing the environmental waste problem, the USEPA has created a lean and an environmental toolkit. In this toolkit, the environmental wastes can be described as any kind of redundant use of resources or substances released into the environment, which affect the human and animal health or are toxic to the environment [16]. They also designed a second toolkit, which addressed the energy consumption using the VSM process [17]. Based on this process, the USEPA suggested observing and estimating the energy consumed while carrying out in-house energy audits. Additionally, the USEPA has encouraged the energy efficiency using visual controls like energy dashboards for visualising whether the energy goals are successfully met. Similar to the earlier USEPA toolkit, the process has no mention regarding the proper tracking and visualisation of the multiple metrics at the same time using the same VSM. With the help of the tracking and the visualising of the environmental metrics like material or water usage, in addition to the general VSM metrics, many industries have been able to recognise and eliminate the environmental wastes. This toolkit also contains the process of adding an EHS (Environmental, Health, and Safety) stamps for identifying the processes having EHS opportunities. In Table 1, several studies have been outlined which used the USEPA's VSM method [17] that combined the environmental and/ or the societal metrics.

Table 1: Various studies using the extended VSM methodology

References	Case Study	Method Used	Main Findings
[18]	A Lean Sustainable Production Assessment Tool	EE-VSM	Proposed a Lean sustainable tool to be used in a real-time dashboard along with a continued improvement in the chosen sustainability metrics like material use, energy and water consumption, and CO_2 emission during the method. However, the energy consumed while transporting, speciality storage and in societal metrics has not been considered for validating this case study.
[19]	Environmenta l Value Stream Mapping (EVSM) as Sustainability Management Tool	EVSM	They evaluate the water consumption in detail by dividing the water losses into a latent, real, intrinsic, functional, and a real functional loss. Their results are confusing to the user who is unfamiliar to these terminologies. Also, their process makes it difficult to identify the wastes visually, with the help of the E-VSM method.
[20]	Environment and transport supply chain evaluation with Sustainable Value Stream Mapping	SVSM	Enhancing the sustainability of the manufacturing process by estimating the GHG and CO_2 emission. They have indirectly assumed that the societal metrics are incorporated. This notion considering the economic or the environmental benefit would be accompanied by the social benefit, hence, incorporating the sustainability.
[21- 22]	Sustainable Value Stream Mapping in the Food Industry	SVCM	Combination of the SVSM by Simons and Mason with the sustainability metrics by Norton [34]. Created an SVCM for obtaining relevant information flow between the food retailers and the food manufacturers in the UK.
[23]	Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards	SVCM	Validation of the SVCM method using the case study involving the sourcing and the packing of the cherry tomatoes. Estimating the energy consumption is a difficult process; hence, measured the energy consumption metric using the life cycle analysis.
[24]	Framework and Indicators for the Sustainable Manufacturin g Mapping Methodology	SMM	Proposed a novel methodology termed Sustainable Manufacturing Mapping (SMM) that includes Life Cycle Analysis (LCA), Discrete Event Simulation (DES), with the VSM technique. This goal-oriented technique uses the commercially-available Life Cycle Inventories (LCI) data and combines it with the DES and VSM. This process is simple and more visual. In spite of a huge array of sustainability metrics that are available, it is unclear how to properly visualise the VSM metrics properly.

[25]	Visualising Sustainability Performance of the Manufacturing Systems with the help of a Sustainable Value Stream Mapping (Sus-VSM)	(Sus-VSM)	Proposed the process for visualising and estimating the sustainability at manufacturing line levels. Sus-VSM maintains the functioning of a conventional VSM, but also added the Metrics which identify the societal and environmental aspects regarding sustainability.

2.0 METHODOLOGY

Like the conventional VSM approach for identifying the Kaizen effort opportunities, the extended VSM technique should incorporate the sustainability metrics for visualising the sustainability performances and also identify the improvement opportunities. For analysing the process sustainability using VSM, this study has adopted the similar framework proposed by [25]. Also, this model would be used in combination with the Lean and Environmental Toolkits by USEPA along with being re-engineered with the Guidelines for the Green Industry Audit, by the Department of Environment Malaysia, which act as a standard for the formulation of the CO2 quantification. This model [25] is also called as the Sus-VSM, and it possesses a precise set of Economic, Environmental, and Societal metrics which determine every suggested study areas. In this study, we have performed 5 major steps for ensuring a minimal environmental waste generation and a hazard potential. Hence, we obtain the information flow in the process, engine specification, recovery capacity, water use, raw material and fuel information. Moreover, information regarding waste, like solid wastes, wastewater, and toxic wastes, is also considered and refined with the economic wastes using the comprehensive CSM steps described in Figure 1.

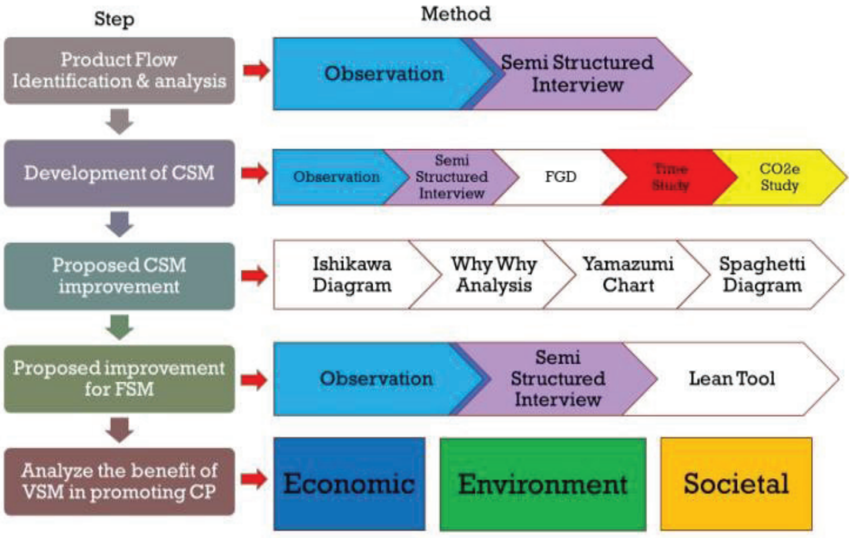

Figure 1: Research methodology

Depending on the collected data that is given by the company's production management team, our team would determine the different Economic, Environmental, and Societal metric subsets, which are mentioned in the above-mentioned studies, and identify the subsets for including them in the CSM method. Thereafter, an FSM would be established and appropriate Lean tools would be used for the Kaizen activities. Lastly, the CP implementation in the E-recovery plant would be assessed with the help of the enhanced VSM technique. A case study was carried out at the E-Waste Recovery Plant and it discussed the different implementation steps for creating a CSM survey and determining waste (Environmental, Economic, and Societal) after analysing the CSM along with the above metrics at the Copper and Fibre Recovery Line. Figure 2 illustrates the simplified concept used in this study, based on the CPVSM technique which includes the sustainability metrics used for identifying the various CSM of a recovery process.

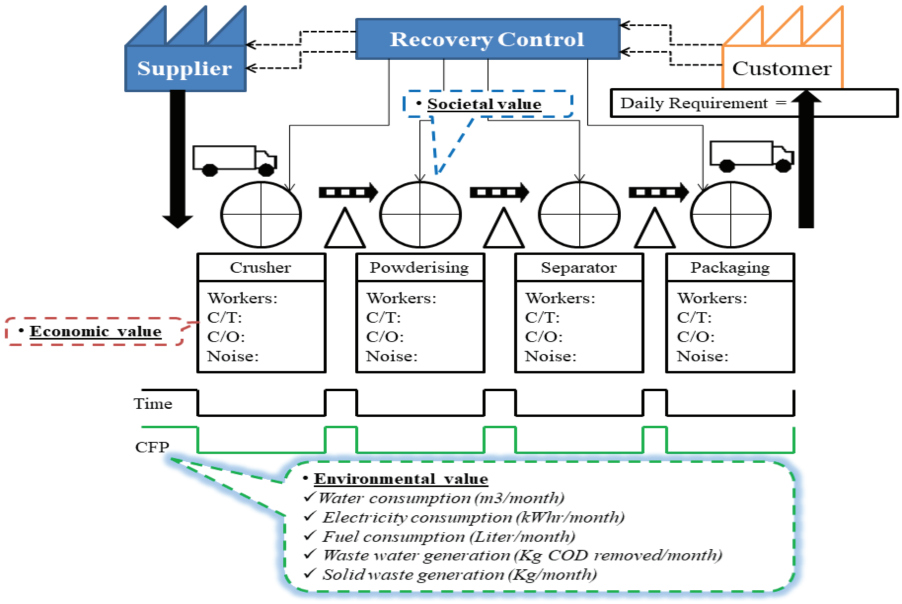

Figure 2: Conceptual of CPVSM

3.0 RESULTS AND DISCUSSION

In investigating the manner the CP sustainability measures are embedded in the VSM, a case study was carried out in a local SME E-Waste recovery facility that focused primarily on the Copper and Fibre Recovery Process. Figure 2 presents the Recovery Process steps with a maximal recovery capacity of 10 MT per day. Figure 3 illustrates the extended CPVSM for this study to identify the economic, environment and social metrics. It is confirmed that the NVA activities was contributing more than 98.95% to the PLCB recovery process due to not enough raw materials for processing the waste. The machine is set idle until it is economical to run optimally. Due to distance location of suppliers and inconsistent delivery of raw materials, it requires 10 days on average before the recovery process commences. Detail observation concludes that on average the recovery plant can manage only to receive 43.48 MT/month of raw material and capable to process around 40.46MT/month from June 2015 to July 2016. This fact approves that the running capacity of the recovery plant was only at 40% from their optimal design basis.

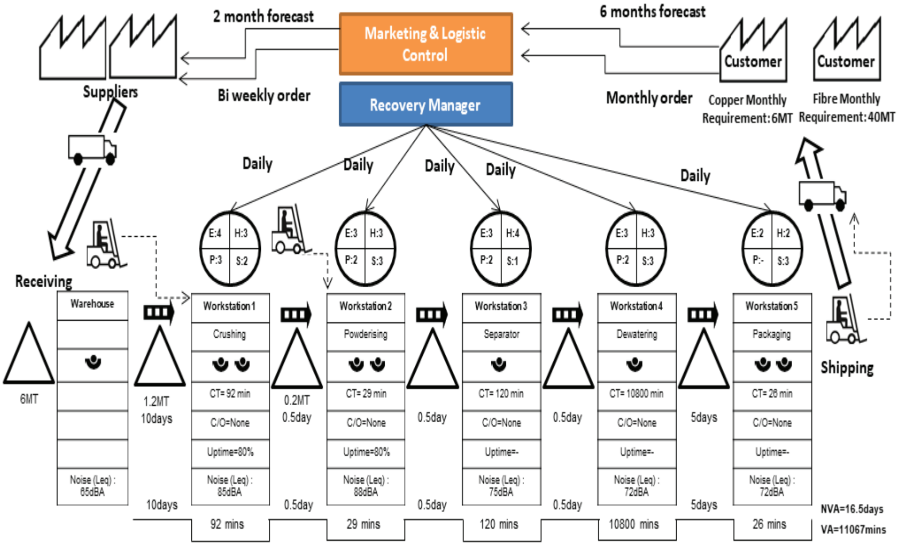

Figure 3: Economic & Socio Metrics at CPVSM from E-Waste Recovery Process

The environmental metric shown in Table 2, Figures 4 and 5 were able to construct the Carbon Dioxide Equivalent (CO2e) generation from the recovery process. Figure 4 reveals that the electricity consumes more than 92% of CO2e in the recovery process. In this case, the crushing and powderising process contribute high electricity usage in the plant, as was illustrated in Figure 5. Technical modification has to be made to suit low and inconsistency supply of raw material. Small capacity with high energy efficiencies motor and pump with inverter regulator might be the best choice for future improvements. This study manages to count the amount of CO2e and almost 12.67 MTCO2e/MT of PLCB recovered.

Table 2: Summary of Carbon Dioxide Equivalent from CPVSM

Process / Entity	Water Usage	Electricity	Fuel	Waste Water	Solid Waste
Unit	KgCO2e				
Crushing	15.52	9752.52	814.69	NV	42.92
Powderising	46.24	2211.40		NV	NV
Separator	139.36	334.20		0.03	NV
Dewatering	NV	41.81		0.00003	NV
Packaging	NV	NV		NV	71.04

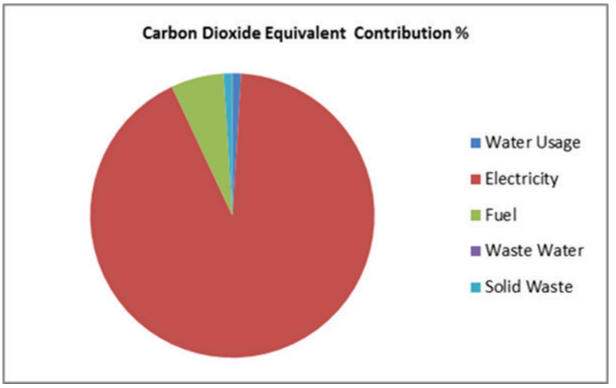

Figure 4: Summary of carbon dioxide equivalent from CPVSM

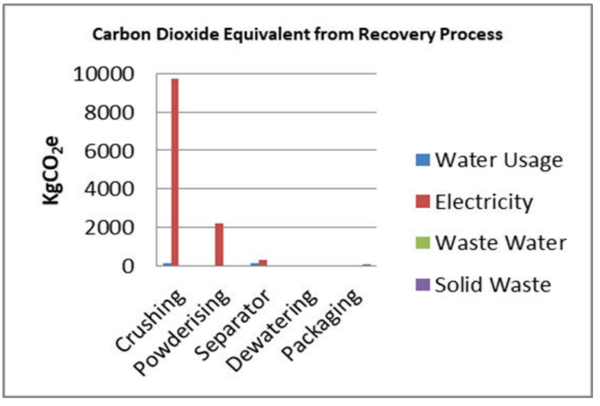

Figure 5: Summary of carbon dioxide equivalent for each process

Meanwhile, Table 3 provides the summary of work environment risk for social metric found at the crushing and powderising process, and potentially dangerous with low risk for Electrical System [E], Hazardous Material [H] and High Speed Components [S]. Continuous training and proper PPE are the best option to mitigate the accident happen at the recovery floor.

Table 3: Summary of Work Environment (Socio Metric) from CPVSM

Work Environment/ Process	Electrical [C]	Hazard Material [H]	Pressurized System [S]	High Speed [S]
Crushing	2	2	-	2
Powderising	2	2	-	2
Separator	1	1	-	1
Dewatering	1	1	-	-
Packaging	1	1	-	2

4.0 CONCLUSION

In this paper, we have demonstrated that the CPVSM can measure the sustainability in the manufacturing line. It provides an easy visualisation of the economic, environmental waste and risk hazards will supports the Kaizen activities at the same time. This paper further confirms that implementing the CPVSM will enhance the economic performance, and promotes the environmental and the societal benefits, requiring minimal costs and efforts from the Lean practitioners and the CP teams. This paper will serve as the basis for future works for determining the CPVSM technique application for helping the local SME e-waste recovery facility maintains their business.

ACKNOWLEDGMENTS

The authors are grateful to the Malaysian Government and Universiti Teknikal Malaysia Melaka (UTeM) for funding this research via Grant (PJP/2014/FKP/ (9C)/S013262).

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