ICMIEE-PI-140244

Green Lean Approach to Minimize the Environmental Wastes of Cement Industry

Ashma Ahmed[1,*], *Md. Abdul Quddus*[2]
Department of Industrial Engineering & Management, Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH

ABSTRACT
The objective of this paper is to identify, assess and minimize the environmental wastes produced from processing side of a cement industry using value stream mapping (VSM).The usage of energy, workspace and material and air emission are considered as environmental factors derived from a hierarchy that is developed by EPA. The values of these environmental factors are incorporated in lean metrics and also in VSM which is called Environmental value stream mapping (EVSM). The paper addresses the various environmental wastes or non-value added activities in the processing side of the cement industry, using VSM approach to make the existing process greener. Finally, Future state of the map is drawn with Kaizen opportunities which minimize the environmental wastes.

Keywords: lean, VSM, environmental waste, cement industry, green manufacturing

1. Introduction

In today's competitive world, companies focus on eliminating wastes to increase their profit, growth and ensure customer satisfaction. Lean is a powerful and well-known tool for waste minimization. Products with superior environmental performance attract new customers. That's why organizations must comply with the federal rules and regulations towards environmentally friendly manufacturing. Lean manufacturing provides opportunities for improving the environmental performance along a production line.
Cement industry is one of the fastest growing sectors of Bangladesh. Due to huge local demand cement sector is developing rapidly. Cement industry produces lots of environmental waste. Therefore, it is categorized as red according to Environmental act, 1997. Environmental performance improvement is thus crucial for gaining competitive advantages.

2. Literature review

There are different techniques to measure environmental performance as there is no standard technique available: Green Productivity Index (GPI), Air Pollution Index (API), Ozone depletion Index, Global warming Index [8-10]. Most methods for assessing environmental impacts mentioned are not suitable for a company to implement [2] and lack in integration and assimilation of the traditional waste management approaches with that of the lean manufacturing approach to waste [14]. This is particularly apparent with respect to environmental mapping, as there has been relatively little exploration of Environmental Value Stream Mapping (EVSM).
EPA developed Lean and environment toolkit that draws heavily from the experience of the EPA's partners and organizations who have pioneered integrated approaches to lean and environmental decision making while at the same time delivering world class performance, exerting market leadership, and achieving bottom line results [15]. In this paper, the environmental wastes are identified, assessed and minimized applying a lean tool named Value Stream Mapping (VSM) as it is the simplest, easiest and more convenient and effective to implement in a company.

3. Concept of Lean Manufacturing, VSM and Environmental wastes

Lean manufacturing is a business model and collection of tactical methods that emphasize eliminating non-value added activities (waste) while delivering quality products on time at least cost with greater efficiency. Lean is practiced to eliminate waste, inconsistency and reduce the workload [11].There are seven types of waste in lean production and they are: a) defects, b) overproduction, c) unnecessary inventory, d) inappropriate processing, e) unnecessary motions, f) transport and g)waiting [3]. Five basic principles of lean manufacturing are: defining value, identifying value stream, work flow, pull the work and pursue to perfection [4].
VSM is the simple process of directly observing the flows of information and materials as they now occur, summarizing them visually and then envisioning a future state with much better performance [4]. A VSM gives a pictorial representation of activities, cycle time, lead time, information flow and material flow. Initial step for creating a VSM is to prepare current state map. The immediate step is to analyze the VSM and identify the areas of improvement. The final step is to draw future state map with the improvement ideas along the value stream map [13].
Environmental waste is any unnecessary use of resources or a substance released into the air, water, or land that could harm human health or the environment [5].

4. Objectives of the study

a) Getting an insight on the cement production process for the current state map.
b) To identify environmental factors of the manufacturing system from the hierarchy.

* Corresponding author. Tel.: +88-01731893146
E-mail address:sorna69cutee@gmail.com

c) Measuring environmental factors and incorporating them in a VSM.
d) Analyzing data to identify improvement areas.
e) Drawing future state map with the recommendations.

5. Methodology

The data presented in this paper were obtained from Bashundhara Cement Mills Ltd., Mongla. Data about the process at large were collected over one month from critical observations and conducting interviews. After that, environmental wastes were identified from hierarchy of environmental factors. Current state VSM was drawn based on the data collected. The environmental metrics were incorporated in the VSM which is called environmental value stream mapping (EVSM).Eventually future state map was drawn according to recommendations.

5.1 Hierarchy of environmental factors

The hierarchy of environmental factors in a manufacturing system shown in table1 was developed from a list obtained from EPA. These environmental factors help to document cost-benefits, resource quantities and environmental opportunities which form the basis of improving the environmental performance of an organization. Among the measures, only energy use, material use, workspace use and air emission are considered for incorporating environmental factors in a VSM in this paper.

Environmental measures			
Input measures	Non-product measures	Downstream product measures	Other measures
Energy use Land use Materials use Water use Hazardous materials use	Air emissions Water pollution Solid waste	Product impacts	Money saved Qualitative measures

Table **1** Hierarchy of environmental factors

5.2 Environmental VSM

There are different ways followed by EPA to address environmental values in a VSM:
a) Environmental data in a VSM
b) Comparison of resources needed with usage data.

The study is based on some assumptions:
a) Only Portland Composite Cement (PCC) is produced in the cement industry
b) The collected information and the results are reliable and accurate and were taken from the production activities
c) The top level of the organization was committed to identify the waste of its activities and develop the improvements.
d) The suggestions and improvement are reachable for the industry.
e) Only the material and process flow is analyzed,, information flow is not shown in the map to avoid complications.

6. Current state map

6.1Cement production process

In this case study, cement production means the finish grinding process. Clinker, Gypsum and blast furnace slag are assumed to be used as raw material. No clinker burning and processing is done here. All the raw materials are imported and unloaded at jetty area. Then they are stored in their respective silos and sheds. Production of cement involves following steps:

6.1.1 Grinding

At first processed clinker which is used as the main raw material is ground. Raw clinker is fed from silo through conveyor belt to the VRM feed building. Feed is given in two ways:
a) Main feed system
b) Reject feed system
Then clinker is transported to the Vertical Roller Mill (VRM) mill through enclosed belt conveyor. From the VRM mill, ground clinker is collected by dust collector and then sent to clinker silo for storage. Gypsum and slag is ground in the same way from gypsum shed and slag shed. Then they are also stored in different silos

6.1.2 Mixing

Normally mixing is done in two steps:
a) Ordinary Portland Cement (OPC) mixing: Only clinker and gypsum is mixed in mixing house at 95:5 proportions. OPC is then sent to OPC silos for storage.
b) Portland Composite Cement (PCC) mixing: OPC, slag and other materials (limestone, fly ash, moisture) in very small proportion is mixed to produce Portland Composite Cement (PCC).
Mixing is done in either ball mill or by a screw conveyor.

6.1.3 Packing

After mixing, PCC is stored in silos. Then it is sent to pack house for bagging. The bags are transported for final storage and shipping.

6.2 Process attributes

6.2.1 Blaine number

It is the measure of fineness of the cement particles, expressed in units of cm^2/g [1]. Normally, it ranges from (3000-5000) cm^2/g for Portland cement.

6.2.2 Re-circulation or rework rate

It is the percentage of raw feed mill that is fed back to be ground for obtaining desired fineness of the cement particles. Current state map is shown in fig.1.

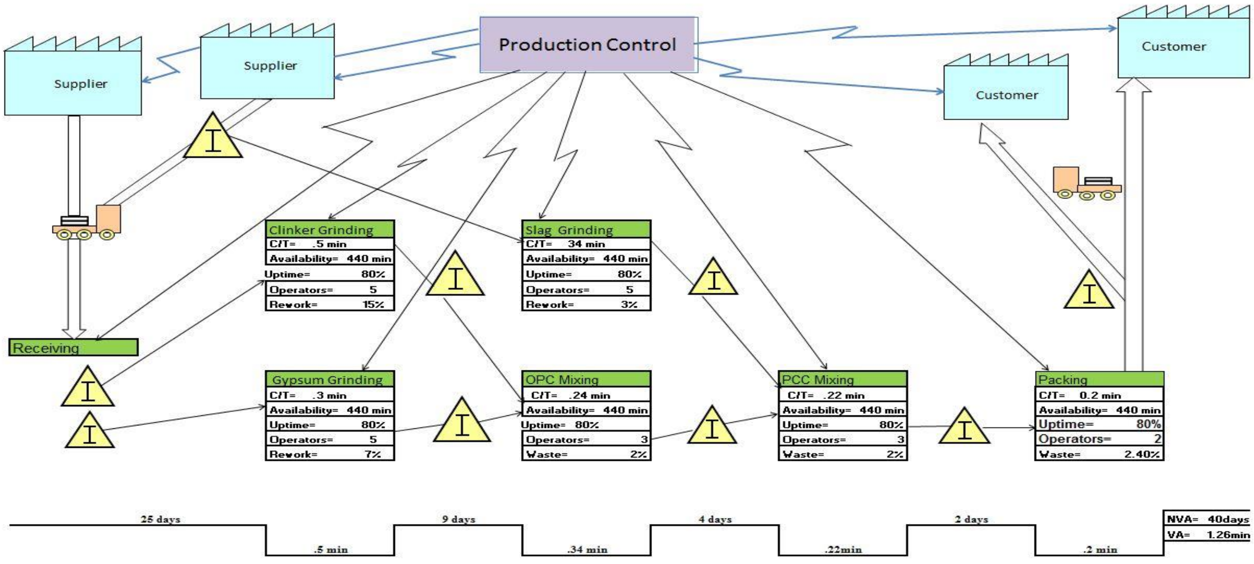

Fig.1 Current state map of the cement industry

6.3 Incorporating Environmental values in VSM

As discussed, the above input measures like energy used, workspace used and materials used and non-product measure like air (dust) emission from the hierarchy shown in figure are utilized for incorporating the environmental factors in a VSM.

6.3.1 Energy use

Assessment of energy use with a VSM helps to identify areas of improvement in environmental performance, safety and productivity and decreasing operating cost of an organization. Measuring energy consumption for each process will identify where excess energy is utilized. Measure energy can be used as a basis for minimizing energy consumption and maximizing energy efficiency for reducing costs and improving environmental quality.

6.3.2 Workspace used

Assessment of workspace use using a VSM gives an opportunity to improve space utilization and reduce energy use in those areas which indirectly reduces environmental impacts. The workspace used for inventory storage is shown below the inventory symbol. The workspace used for a machine is known as value-added workspace and the workspace used for storage of raw materials, inventory, tools and other substances are known as non-value added workspace.

6.3.3 Material use

Assessment of material use with a VSM gives an idea of how much material is used for each process. Material usage can also be minimized by comparing usage data with materials required data. Measurement of material usage gives an idea of how much material is wasted for each and every process.

6.3.4 Air emission

Only SPM emission from each process is considered here. Suspended particulate matter (SPM) refers to particles in the air of all sizes. SPM is a complex mixture of organic substances, present in the atmosphere both as solid particles and liquid droplets. Health impacts of PM vary depending on the size and the concentration of particles.

The incorporation of environmental values in a VSM is shown in fig.2 and summarized in the table 2.

Table 2 Incorporating environmental values in a VSM

Serial no	Process	Energy used in kWh/t		Workspace used in square feet		Material used in ton/day		SPM emission in μg/m3
		VA	NVA	VA	NVA	used	needed	
1	Receiving		0.2		40000			
2	Clinker grinding	50	0.2	24800	23000	7801.92	7224	153.24
3	Gypsum grinding	43	0.2	24800	5000	520	516	114.33
4	BFS grinding	40	0.2	24800	20000	2657.4	2580	94.73
5	OPC mixing	20	0.2	11450	25000			156.13
6	PCC mixing	20	0.2	11450	37000			148.21
7	Packing	15	0.2	10000	40000			288.8

* Corresponding author. Tel.: +88-01731893146
E-mail address:sorna69cutee@gmail.com

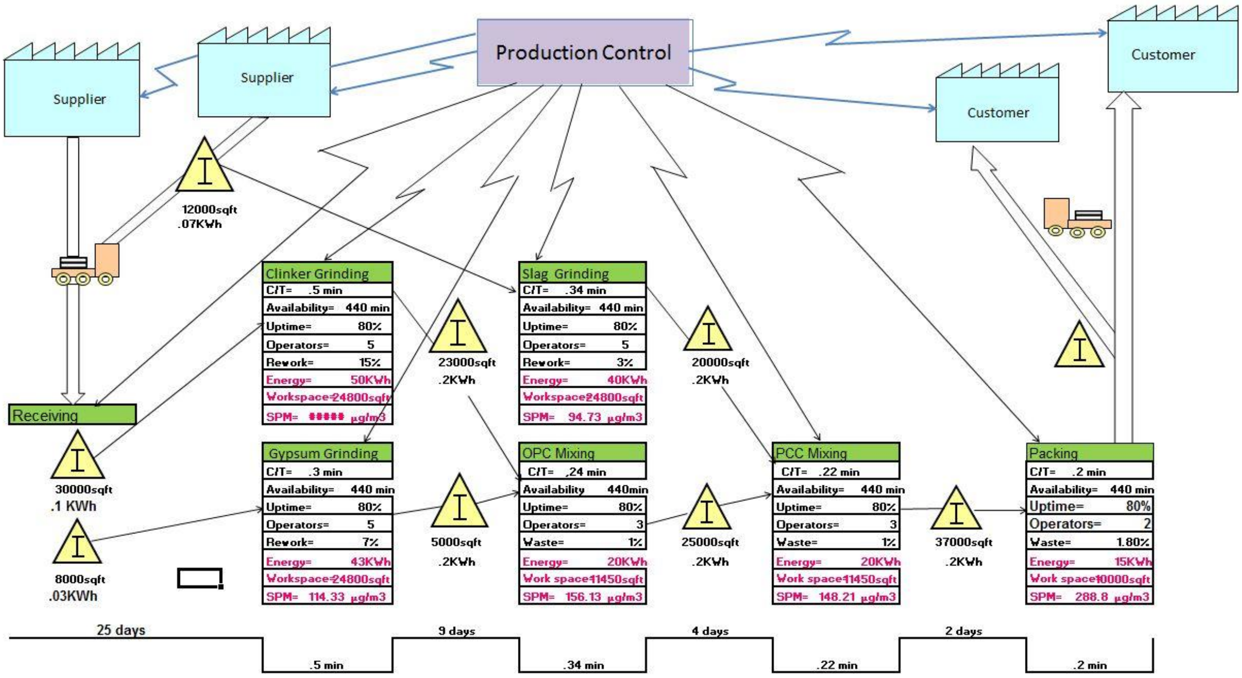

Fig.2: Incorporating environmental values in VSM

7. Future state mapping

Some proposed steps for future state mapping is suggested below. The first step is to reduce variability in blaine number of cement particles and recirculation rate. The higher the blaine number, the better the quality of cement, but it costs high in terms of time and energy as particles are re-circulated to obtain desired number. So, reducing and maintaining a standard range of blaine number results in less time and energy required with standard quality. Second step is to develop pull production system instead of push system with implementing JIT and Kanban production system. The Kanban system is used to inform each company, the production necessity, changing the too each forecast made with enormous forecasts antecedence for each agent. By implementing pull system, Kanban and JIT, overproduction and excess inventory can be reduced.

Suspended Particulate Matter (SPM) is a special concern of cement industry as it is harmful for human beings. Strategies stated below should be incorporated in the production system to control and minimize hazards.

Use of alternative source of energy and clinker substitutes can improve product quality economically and environmentally.

The proposed future state map and data are shown in fig.3 and table 2.

Table 2 Future state data (proposed)

Serial no	Process	Energy used in KWh/t		Workspace used in square feet		Material used in ton/day		SPM emission in μg/m3
		VA	NVA	VA	NVA	used	needed	
1	Receiving		0.2		30000			
2	Clinker grinding	45	0.2	24800	20000	6500	6300	145
3	Gypsum grinding	38	0.2	24800	5000	454	450	114.13
4	BFS grinding	35	0.2	24800	15000	2378	2250	94.73
5	OPC mixing	20	0.2	11450	20000			150
6	PCC mixing	20	0.2	11450	30000			140
7	Packing	15	0.2	10000	30000			180

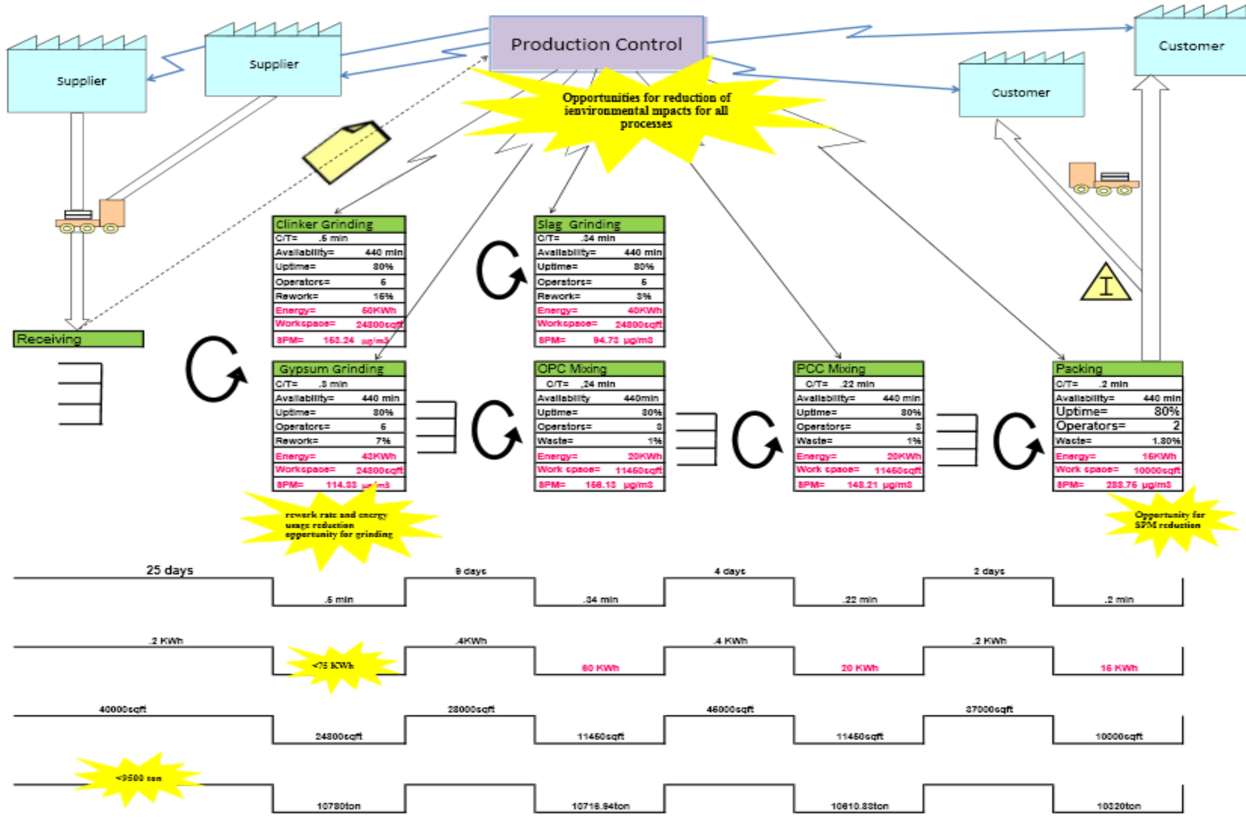

Fig.3 Future state of VSM (proposed)

The energy use can be reduced to 1% non-value added workspace use can be reduced to 20% by implementing JIT, Kanban and pull system. Material usage can be reduced to 1646 ton per day. Waste of materials due to scrap, rework or recirculation, spillage, emissions and other wastes can be reduced from 8% to 3.55%. Also air emission can be reduced specially in packing by adopting proposed measures.

8. Action plans

Following suggestions or recommendations can be applied to improve the current state of the cement industry:

a) Reduction of the variability in blaine number of cement particles.

b) Reduction of recirculation or rework rate of about 50% to reduce energy consumption.

c) Inventory reduction by implementing JIT (Just In Time) methodology.

d) Adoption of pulled production through supermarket.

e) Fostering communication and co-ordination between upstream and downstream of the production process to increase flexibility.

f) Incorporating sufficient safety measures to control and reduce SPM. Environment Management plan for minimizing dust is shown in table 3.

g) Change in facility layout to minimize workspace usage.

h) Adoption of 6S (5S+safety) to create and maintain a clean, orderly, and safe work environment.

i) Use of alternate sources of energy like biofuels, biomass; clinker substitutes such as pozzolans, fly ash [7].

Table 3 Environmental Management Plan for minimizing dust

Srl. no.	Activity/process	location	hazards	Strategies to minimize hazards
1	Transportation	Jetty area, sheds	Dust pollution, landscape and forest degradation	Sprinkle of water, minimum travel of transport, smaller speed limit of vehicles, use of pallets.
2	Grinding	Grinding mill	Dust pollution	Enclosed material handling system, ESP, bag dust collectors, masks for workers.
3	Cement production	Mixing plant	Dust pollution	Enclosed material handling system, ESP, bag dust collectors, mask for workers
4	packing	Packing plant	Dust pollution	Mask for workers

9. Limitations

The study has some limitations:

a) Monetary value of the waste reduction is not calculated.
b) Only SPM is considered as the air emission;PM10, PM2.5 and other particulate matters are not considered.
c) SPM data is collected for processing steps only; air emission due to transportation, vehicles, free flow are not considered.
d) Workspace is not measured in terms of volume other environmental factors from the hierarchy is not assessed.
e) Kaizen events are not considered.

10. Conclusion

It is rightly argued that whenever there is a product for a customer, there is a value stream. The challenge lies in seeing and working on it. VSM can be done in the same way for practically any business activity and expanded upstream or downstream. Cement Industry has a huge potential due to fast rising commercial and residential in Bangladesh. Use of inappropriate methods of processing, scarcity of raw materials and excess inventory is causing production losses and wastes as well as adverse effects in the environment. Minimizing production wastes as well as environmental wastes result in green organization and more customer satisfaction.

With the above action plans being in practice, the cement industry might look into the future with a positive outlook to be greener and of course lean. The future scope of work lies in exploiting other powerful tools of value stream to attack wastes and take appropriate actions to minimize those wastes. The concepts can be replicated for other cement industries to capture various scenarios and attack wastes in processing and distribution chains. Similarly, studies can be used to compare value streams in the context to the country specific situation.

NOMENCLATURE.

VSM : Value Stream Map
EVSM : Environmental Value Stream Map
SPM : Suspended Particulate Matter, µg/m3
kWh : Kilowatt hour
BFS : Blast Furnace Slag
OPC : Ordinary Portland Cement
PCC : Portland Composite Cement
EPA : Environmental Protection Agency
VA : Value added
N-VA : Non-Value Added

REFERENCES

[1] Alain Blasco, Particle size analysis reduces cement manufacturing cost, Engineerlive Magazine, (2013).

[2] Gavindarajulu, A.P., Using a value stream map to assess environmental impacts, Wichita State University, (2009).

[3] Ohno, T., The Toyota production system: beyond large scale production, *productivity press*, Portland, Oregon,(1998)

[4] Womack, K., D. Jones, Lean Thinking, Simon and Schuster, New york,(1996)

[5] U.S. Environmental Protection Agency (EPA), Lean and environment toolkit, Washington, D.C., USA, (2011).

[6] Tourki, T. Implementation of lean within the cement industry, De Montfort University, (2010).

[7] ClimateTechWiki, Clinker substitute, (2011).

[8] Gandhi, N. M., Selladurai, V. and Santhi, P. Green productivity indexing: A practical step towards integrating environmental protection into corporate performance, *International Journal of Productivity and Performance Management*, Vol. 55 Iss: 7, pp.594 – 606, (2006).

[9] Basu, D., Srivastava, R.K.and Vaishya, R.C., An assessment of air pollution impact for an Indian highway project: A GIS based approach, *Management of Environmental Quality: An International Journal*, Vol. 19 Iss: 5, pp.510 – 519, (2008).

[10] Bare, C.J., Norris, G.A., Pennington, D.W. and Mckone, T., The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts Issue, *Journal of Industrial Ecology*, Volume 6, Iss: 3-4, pp.49–78,(2008).

[11] Wu, Y.C., Lean Manufacturing: a perspective of lean suppliers, *International Journal of Operations and Production Management*, Vol. 23 Iss: 11, pp.1349 – 1376, (2003).

[12] U.S. Department of Energy, 2003. Energy and Emission Reduction Opportunities for the Cement Industry, Washington, D.C., USA.

[13] Braglia, M., Carmignani, G. & Zammori, F., A new value stream mapping approach for complex production systems, *International Journal of Production Research*, Vol. 44, Iss: 18-19,(2006).

[14] Roosen, T.J., Reducing Lean and Environmental Wastes: The Integration of Value Stream Mapping with Environmental Wastes to Improve Production, Performance, Efficiency and Process Flow, University of Canterbury, (2013).

[15] U.S. Environmental Protection Agency (EPA), Best practices and case studies, (2011).

* Corresponding author. Tel.: +88-01731893146
E-mail address:sorna69cutee@gmail.com