Using the Value Stream Mapping and Overall Equipment Effectiveness to Improve Productivity: A Literature Review

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**Abstract:** In the industries with high capital investment, the manufacturer has to spend a big amount of money for purchasing equipment. To overcome this imposed pressure the investor should utilize all the resources very efficiently for higher productivity and need to meet the customer’s ever increasing demands. This paper reviews both value stream mapping (VSM) and overall equipment effectiveness (OEE) system for optimizing the production efficiency which leads to gain high productivity. VSM is used to identify and eliminate the existing wastes and establishes a better material flow with a shorter lead time, cycle time, and faster product transfer. On the other hand, OEE contributes to reduce the losses in operating time, performance rate and quality. In this paper, the application of VSM and OEE is reviewed together with their advantages as well as their contribution to improve the dimensions of productivity. Besides, the review shows that limited research has been done to take the advantage of combined VSM and OEE system. Finally, a framework of using both VSM and OEE is developed to achieve the target of productivity improvement.

**Key words:** Value Stream Mapping (VSM), Overall Equipment Effectiveness (OEE), Productivity.

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**1- INTRODUCTION**

The increased competition in global market imposes high pressure on the enterprises to produce qualitative products at low cost with high efficiency to meet the customer’s ever changing demand. To meet the target productivity, a preferable way should be developed to utilize the resources of the company such as labor, equipments etc. Rother and Shook (1998) suggested a method named value stream mapping (VSM) to reorganize the resources for a better material flow and handling system. VSM was proved to be a useful tool to improve the productivity by reducing the wastes and increases the speed of production. In addition, Nakajima (1988) also proposed an effective tool called overall equipment effectiveness (OEE) to eliminate the losses for increasing the productivity. Both VSM and OEE can be used to improve the productivity. However, VSM focuses on wastes reduction in terms of time and rational material flow but does not address equipment utilization which is rather solved by OEE. Many researchers have worked on VSM and OEE but most of them focus only on VSM or only OEE. Therefore, this paper aims to review the use of VSM and OEE and the necessity to use both of them to improve the productivity.

A good number of research works based on VSM and OEE have been studied to investigate their implementation. Out of this work 33 journal papers are reported in this article to summarizing the use of VSM and OEE. Besides this, referring some books and other articles are also utilized to develop a different approach to explain the combination of VSM and OEE.

In the literature review section at sub-section 1, a brief description is presented on productivity concept. The application of VSM and OEE is given in sub-section 2 and 3 respectively. Then a short theory on productivity dimensions is presented and correlated with VSM and OEE in the sub-section 4. A literature review based on VSM and OEE is also included in the sub-section 4. The sub-section 5 presents a framework to improve productivity using both VSM and OEE. The discussion section then analysis the literature review to strengthen this article. The final section concludes with the inferences of the undertaken research.
2- LITERATURE REVIEW

In this paper, the concept of productivity, value stream mapping (VSM) and overall equipment effectiveness (OEE) is reviewed. Additionally, the advantages of VSM and OEE are also given to build a conceptual reasoning for using both VSM and OEE together. Besides, the necessity of this combination is strengthened by analyzing the contribution of VSM and OEE to improve the dimension of productivity. Moreover, a literature review is carried out on VSM and OEE to show their limitations. Therefore a framework is developed based on the combination of VSM and OEE for productivity improvement.

2.1. Productivity concept

Sakamoto (2010) defined productivity as “consumed management resources, such as time, number of workers, materials, money, and energy for producing management results; results can include sales volume and production volume”. And of course the parameters to improve the productivity and changing the productions or sales volume are not same and different management actions are required. In other words, productivity represents how resources such as, capital, labor, material and energy are used to produce a definite quantity of output. For example, in term of capital, the productivity can be shown by:

\[
\text{Productivity} = \frac{\text{output \times unit price}}{\text{input cost (material, labor, overhead)}}
\]

It is obvious that increasing productivity is one of the important targets for every company and any productivity improvement program should consider both technical factors and human issues. “Therefore, to improve productivity, operations managers should look at improving the technology, interface between departments, organizational aspect, supply chain as well as people management in a broad and systematic way” (Gunasekaran and Cecille, 1998). There are many tools to achieve higher productivity such as, just-in-time (JIT), value stream mapping (VSM), overall equipment effectiveness (OEE), kaizen (Continuous Improvement), etc. In this literature review, only two tools are focused which are very useful in production process called VSM and OEE.

2.2. Value Stream Mapping (VSM)

Value stream mapping is originated from the TPS which is also known as “material and information flow mapping.” This is a very important step in lean process before the task of waste elimination is divided. This is because, based on this step one can understand and organize rationally the work processes by using the lean tools and techniques. According to Rother and Shook (1999), VSM is “a pencil and paper tool that helps to see and understand the flow of material and information as a product makes its way through the value stream”. In this definition, a value stream is a collection of all value-added and non-value-added actions that are needed to transfer raw material through the flows to become a complete product and move to the customer (Rother and Shook, 1999).

![An example of Value Stream Map (VSM)](image_url)
VSM contributes some benefits in the production system which are listed below:

- Create a visualization of the whole process in more than just a single process level.
- Not only help the mapper to see the waste but also reveals the source that causes waste.
- Through VSM, the relation between manufacturing process, supply chain, distribution channels as well as information flows is established.
- VSM method improves several production parameters:
  - Idle time is decreased
  - Changeover time and total time cycle is reduced
  - Work-in-process inventory is lower
  - Lead time is decreased
  - Uptime is increased
  - Defects are eliminated
  - On time delivery is improved
  - Reduction in shop floor areas is achieved

2.3. Overall Equipment Effectiveness (OEE)

In the book “Introduction to TPM: total productive maintenance”, Nakajima (1988) developed the concept of overall equipment effectiveness (OEE) as a measure of TPM to evaluate the effectiveness of equipment. It was also said that the overall OEE measurement reveals the hidden costs that cause a considerable amount of production loss.

The OEE consists of three components: availability, performance and quality efficiency. It is the result of multiplying the percentage these three components together:

\[
OEE = (\text{Availability}) \times (\text{Performance}) \times (\text{Quality})
\]

- Availability - It represents the availability of a machine to operate against the total net available time.
- Performance – This records the production rate against the design or ideal rate.
- Quality Efficiency – A measure of the percentage of defects produced by the process.

Once the OEE calculation is done, the efficiency losses can be measured. There are six major losses which consume resources without adding any value to the final product (Dal et al., 2000): breakdown losses, setup time and adjustment, idling and minor stops, reduced speed losses, start-up losses, quality defect and rework.

The summary of six major losses and three elements of OEE are shown in the figure 02 below:

![Figure 02: The major losses and three elements of OEE.](image)

Advantages of OEE:

- After implementing OEE, the big losses can be eliminated
- Besides, the use of OEE brings following benefits (Dal et al., 2000):
  - Introduce a new level of production performance measurement.
  - Help the management and operators to be aware of the waste, concern about the reason of waste and the activities that can minimize waste more efficiently.
  - OEE not only motivates the production controlling and managing activities, but also contributes in encouraging the initiatives for the improvement of production. OEE also take part in combining practical management tools and techniques to obtain a balanced view of process availability, performance rate and quality.
  - Accuracy of the collected data is very important because OEE measurement is meaningless if the collected data is different from the practice.

2.4. Productivity dimensions and contribution of VSM and OEE

Total productivity improvement can be measured by multiplying three dimensions: Method (M), Performance (P) and Utilization (U).

\[
\text{Total productivity improvement} = M \times P \times U
\]
Methods dimension: Method (\(M\)) is the most dominant dimension and considered to be developed first for the productivity improvement (Sakamoto, 2010). The \(M\) factor can be classified into two types: hardware and software. Hardware, such as layout, tools, machines or the like, usually has long-lasting effects if any change is taken. Whereas changing in software, such as organization, motion patterns, training and support units, can create effects as long as the improvement is maintain, but the lasting effects do not come automatically.

Performance dimension (\(P\)): “\(P\), i.e., the motivation of the employees or the speed of the machines, is often emphasized as the means to increase productivity” (Sakamoto, 2010). The speed of machines can be raised by reducing the technical disruption and deficiency. \(P\) is formed by comparing the standard time and actual time.

Utilization dimension: “\(U\) is an expression, for both machines and humans, of the proportion of planned time that is used for activities and creates value” (Sakamoto, 2010). In order to increase \(U\), a better control of these activities is necessary. When \(U\) is improved, inventory, lead time and cycle time is reduced.

Each dimension has its own contribution on productivity. Therefore, “synergy of the three dimensions for improvement is ultimately the most effective goal” (Sakamoto, 2010). Table 01 shows some actions that should be done to improve \(M\), \(P\) and \(U\) which was given by Sakamoto. In addition, the possible contributions of VSM and OEE in each of action are also presented in Table 01.

Table 01: Activities to improve \(M\), \(P\), \(U\)

<table>
<thead>
<tr>
<th>Factors</th>
<th>VSM</th>
<th>OEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods ((M))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic function time (main run time to produce product) should be reached to the cycle time.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Movement of elements in machines should be arranged in parallel for simultaneous movement.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Moving distance of non-added value item should be narrowed (especially empty movement)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cycle time of workstations should be classified as dynamic line balancing rather than static line balancing</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Setting the speed of machines should be as maximum as possible concerning logical and reasonable speed.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Performance ((P))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocate the suitable job to each operators as well as other divisions</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Communicate directly between two shifts</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Measurement of (P) for the comparison between engineered standard time and improvement points.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Training of standard work methods for the workers should be done carefully and methodically.</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Supervisors should be available on the shop floors for the whole shift to observe the workers and give instructions.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Utilization ((U))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All kinds of tools and materials should be arranged in a fixed suitable place and should be used organizationally.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Periodical maintenance of tools and equipment must be carried out seriously. In addition, the machines should be set and kept in good conditions.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Unavoidable disturbance should be accepted and should be prepared rational maintenance activities.</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Inspection for coming components should be carried out before assembly.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Practical scheduling is based on current production conditions</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

The Table 01 indicates that each of VSM and OEE has their own and common contributions for improving the productivity. This means that there is an opportunity to increase the productivity by using both VSM and OEE rather than implementing only one of them.

Moreover, the Table 02 shows that very few researches carried out their research to combine both
VSM and OEE in order to take the advantage from both of them. That is also the motivation for this research.

Table 02: List of researches on VSM and OEE

<table>
<thead>
<tr>
<th>No</th>
<th>Authors</th>
<th>Content</th>
<th>Industry application</th>
<th>Country application</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hines et al., 1999</td>
<td>x</td>
<td>Electronic</td>
<td>England</td>
<td>VSM for supply chain</td>
</tr>
<tr>
<td>2</td>
<td>Sullivan, et al., 2002</td>
<td>x</td>
<td>Natural</td>
<td>America</td>
<td>Use of VSM for making decision for replacing equipment</td>
</tr>
<tr>
<td>3</td>
<td>Emiliani and Stec, 2004</td>
<td>x</td>
<td>Steel</td>
<td>America</td>
<td>VSM enhance beliefs, behaviors and competencies</td>
</tr>
<tr>
<td>4</td>
<td>Abdulmalekand Raigopa, 2006</td>
<td>x</td>
<td>Steel</td>
<td>America</td>
<td>VSM was used with simulation to prove the benefits of lean manufacturing</td>
</tr>
<tr>
<td>5</td>
<td>Braglia, M. et al., 2005</td>
<td>x</td>
<td>Electronic</td>
<td>Italy</td>
<td>Developed A new framework: “Improved VSM”</td>
</tr>
<tr>
<td>6</td>
<td>Grewal, and Singh, 2006</td>
<td>x</td>
<td>Medical</td>
<td>India</td>
<td>Use of VSM to increase productivity</td>
</tr>
<tr>
<td>7</td>
<td>Lummus et al., 2006</td>
<td>x</td>
<td>Health care</td>
<td>America</td>
<td>Based on VSM to optimize the time for scheduled appointment</td>
</tr>
<tr>
<td>8</td>
<td>Domingo et al., 2007</td>
<td>x</td>
<td>Valve</td>
<td>Spain</td>
<td>Logistic method to improve lean metrics without changing layout</td>
</tr>
<tr>
<td>9</td>
<td>Seth et al., 2007</td>
<td>x</td>
<td>Cotton-seed oil</td>
<td>India</td>
<td>Using VSM to improve productivity and capacity utilization</td>
</tr>
<tr>
<td>10</td>
<td>Grewal, 2008</td>
<td>x</td>
<td>Bicycle</td>
<td>Canada</td>
<td>Usefulness of VSM in small company</td>
</tr>
<tr>
<td>11</td>
<td>Lasa et al., 2008</td>
<td>x</td>
<td>Telephone</td>
<td>Spain</td>
<td>VSM used to redesign the productive system according to the lean system</td>
</tr>
<tr>
<td>12</td>
<td>Melvin, and Baglee, 2008</td>
<td>x</td>
<td>Dairy</td>
<td>England</td>
<td>Used VSM for rapidly cooling palletized products</td>
</tr>
<tr>
<td>13</td>
<td>Gurumurthy, and Kodali, 2009</td>
<td>x</td>
<td>Doors and windows</td>
<td>India</td>
<td>VSM + Simulation</td>
</tr>
<tr>
<td>14</td>
<td>Solding, and Gullander, 2009</td>
<td>x</td>
<td>Sweden</td>
<td></td>
<td>Creating dynamic VSM using simulation</td>
</tr>
<tr>
<td>15</td>
<td>Singh and Sharma, 2009</td>
<td>x</td>
<td>Crankshaft</td>
<td>India</td>
<td>Developed a VSM approach in an Indian company.</td>
</tr>
<tr>
<td>16</td>
<td>Torres and Gati, 2009</td>
<td>x</td>
<td>Alcohol and sugar</td>
<td>Brazil</td>
<td>Developed a environmental VSM or EVSM</td>
</tr>
<tr>
<td>17</td>
<td>Vinodh et al., 2009</td>
<td>x</td>
<td>Camshaft</td>
<td>India</td>
<td>Applying VSM in an Indian industry</td>
</tr>
<tr>
<td>18</td>
<td>Kuhlang, 2011</td>
<td>x</td>
<td>Camshaft</td>
<td>Austria</td>
<td>Increased productivity by using VSM and Methods-Time Measurement</td>
</tr>
<tr>
<td>19</td>
<td>Giegling et al., 1997</td>
<td>x</td>
<td>Semiconductor</td>
<td>America</td>
<td>Developed a system to automatically calculate the capacity and OEE</td>
</tr>
<tr>
<td>20</td>
<td>Pomorski, 1997</td>
<td>x</td>
<td>Semiconductor</td>
<td>America</td>
<td>Justification of OEE management to improve manufacturing performance</td>
</tr>
<tr>
<td>21</td>
<td>Ljungberg, 1998</td>
<td>x</td>
<td>Metal profiles</td>
<td>Sweden</td>
<td>Suggested a method for collecting disturbance data.</td>
</tr>
<tr>
<td>22</td>
<td>Jonsson and Lesshammar, 1999</td>
<td>x</td>
<td>Metal profiles</td>
<td>Sweden</td>
<td>Linking OEE to four dimensions and two characteristic of overall manufacturing performance</td>
</tr>
<tr>
<td>23</td>
<td>Dal, 2000</td>
<td>x</td>
<td>Airbag safety devices</td>
<td>England</td>
<td>Proved the role of OEE as an operational measure.</td>
</tr>
<tr>
<td>24</td>
<td>Jeong and Philips 2001</td>
<td>x</td>
<td>Semiconductor</td>
<td>America</td>
<td>Develop total productivity improvement visibility system (TPIS) methodology to compare OEE of multiple equipment</td>
</tr>
<tr>
<td>25</td>
<td>Huang et al, 2002</td>
<td>x</td>
<td>Glass</td>
<td>America</td>
<td>OEE was developed to model the productivity of a manufacturing system</td>
</tr>
<tr>
<td>26</td>
<td>Nachiappan and Anantharaman, 2005</td>
<td>x</td>
<td>Glass</td>
<td>India</td>
<td>OLE can be used to monitor and manage the improvement in continuous product line.</td>
</tr>
<tr>
<td>27</td>
<td>Ron and Rooda, 2008</td>
<td>x</td>
<td>Natural</td>
<td>Netherlands</td>
<td>Difference between OEE and E.</td>
</tr>
</tbody>
</table>
2.5. Framework for improving productivity using both VSM and OEE.

The purpose of Lean Manufacturing in general and of VSM in particular is to build a process that produce only what the next process needs when it needs (Rother and Shook, 1999). Similarly, in fact it is not anytime the company has to produce as much as they can. The company should produce what the customers need. Thus, choosing the method to improve productivity also should base on the demand of the market and the cost of the method. Implementing VSM may require a big change in the factory, it might cost much. While OEE is only applied in the bottleneck machine and the target is not to buy a new equipment, so it will cost much lower than VSM. Therefore, in the Figure 03 below we suggest a framework to implement both VSM and OEE based on the market demand.

From the framework, OEE is first considered. Then if the demand is achieved, it is not necessary to implement VSM. If not, VSM should be considered to gain the target. If after implementing VSM, the demand is achieved, it is not necessary to increase productivity anymore. If not, OEE should be continued because of a new bottleneck can be made after VSM implementation. 

3. DISCUSSION

From the literature review, there are some strong evidences to believe that the use of VSM and OEE is necessary:

Firstly, from the review of VSM and OEE, it can be seen that implementation of VSM provides a better material flow, eliminates the wastes, shortened the lead time and cycle time. Accordingly, the cycle time of each process is reduced because of rearrangement of workstations and optimization of movements. However VSM does not consider time losses due to breakdown, planned and unplanned downtime, speed and quality losses which are taken into account by using OEE. Therefore it is necessary to use both VSM and OEE to have a higher productivity. Besides, the order of implementing VSM and OEE should follow the framework above that depend on the customer demand.
Secondly, the Table 01 listed several activities that can be done to improve the dimensions of productivity. In addition, when implementing VSM and OEE, these activities are also included. This leads to the strong belief that both VSM and OEE would play their own and common role to improve the productivity.

Finally, from Table 02 it is seen that most of the previous works was done only on VSM or OEE which is another reason to combine VSM and OEE under the same topic. Besides, it can be seen that limited research have done based on VSM and OEE in some developing countries such as Vietnam, Laos,Cambodia, etc. Therefore this topic also has a great opportunity to apply in developing countries.

4. CONCLUSION

The paper demonstrates two very effective tools for improving the productivity; those are value stream mapping (VSM) and overall equipment effectiveness (OEE). Using VSM helps the manager to see the current situation and realize the existing waste in his factory and also help to imagine the effect of the implementation of lean tool. Besides, OEE is used to identify and eliminate the losses. Therefore, using both VSM and OEE is believed to achieve higher productivity than using one alone. Moreover, since implementing OEE is require lower cost than VSM, therefore OEE should be considered first, after that if the demand is not reached, VSM needs to be implemented. After VSM is done, OEE needs to be considered again if the demand is still not achieved.

REFERENCE


