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Waste elimination for manufacturing sustainability

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Abstract

The continuous improvement in manufacturing using waste elimination has been recognized as one of the most important tasks of socially responsible organizations. The capability to eliminate waste can lead to attaining environmental gains. Waste in any organizations is ranging from non-value adding activities to workplace hazards which can further lead to customers, employees and organizations dissatisfaction as well as environmental destruction. In this paper, nine waste types have been identified. Waste identification tools have been revisited. A waste elimination framework has been suggested as an approach for sustainability in manufacturing environment. The framework contains three consecutive phases: waste documentation, waste analysis, and waste removal.

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Keywords: Value stream mapping; Sustaianbility; Waste types; Waste root causes; Root cause analysis; Waste elimination process

1. Introduction

In many countries, the manufacturing sector is one of the vital sectors to national economic development. The sector generally develops a close connection with other sectors such as agricultural, engineering and service sectors. Any ineffectiveness and inefficacy in manufacturing performance can be predicted to generate negative consequences in other related sectors. An example of this chain impact can be seen from waste production in manufacturing sector that has caused a global concern on green environment and sustainability. Waste elimination in manufacturing is a main concept in this paper to ensure that the manufacturing sector progresses towards eco-efficient production processes and hazard-free workplace environment. The paper entails background of waste types

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and sustainability concepts as well as proposes waste identification tools, waste elimination processes and future directions towards sustainability in manufacturing systems.

2. Value and Waste

Manufacturing is surrounded by the concept of continuous improvement to maintain value-added activities which customers are willing to pay for. Value is perceived by customers through an activity, process or operation that delivers a product based on customer specifications and satisfaction. The key drivers to customer value or end-user value of a product or service can be further identified using the total value metric (Fig. 1) as below.

Quality • Meeting the customer requirements • Eliminate of waste • Continuous improvement • Minimum variances	Service level • Customer support • Product service • Product support • Flexibility to meet customer demands • Flexibility to meet market changes
Lead time • Time to market • Concept to delivery • Order entry to delivery • Response to market forces • Lead time • Materials • inventory	Cost • Design and engineering • Conversion • Quality assurance • Distribution • Administration • Inventory • Materials

Fig. 1. Total value metric (modified from Naylor, Naim [1])

Waste is defined as an activity in a process that adds costs and time but not value to product/service from customers' view [2]. In production, three types of value-associated activities are generally implemented [3]. A Value Adding (VA) activity is an activity of changing or processing raw materials towards what customers want [4]. A Necessary but Non-Value Adding (NNVA) activity is wasteful but unavoidable under the existing operation processes. A Non-Value Adding (NVA) activity is obvious waste that should be entirely eliminated. However, any production systems do not only contain activities, but also inputs, tools, and outputs. As a result, effective waste elimination should not focus solely on NA activities. A broader spectrum of waste elimination covering the entire manufacturing processes should be introduced. In this paper, waste in manufacturing is classified into nine types in which the first seven types were initially identified by the Toyota Production System (TPS) [5] consisting of: 1) overproduction, 2) waiting, 3) unnecessary transport, 4) incorrect processing, 5) excess inventory, 6) unnecessary movement, and 7) defects. The eighth waste type was identified by Womack and Jones [6] as unused employee creativity whereas the ninth type as seen in Khan et al. [7] is environmental waste. This latest waste type includes any activities that cause harm to human and/or environmental health such as excessive substances released to air, water, or land [8, 9].

3. Sustainability

The term sustainability has been used interchangeably with sustainable development. It is referred to meeting the needs of the present generation without compromising the ability of future generations [10]. The extended scope of sustainability has included economic, social and environmental performance reflecting the components of profit, planet and people [11]. Sustainability in manufacturing has placed its focuses on producing completely recyclable products, eco-friendly or green production processes, and completely disassemble products at the end of their functional life [12]. It is evident that waste removal is firmly related to sustainability [13]. Therefore, removing waste can lead to environmental gains. For example, efficient transportation of manufacturing materials results in lower CO_2 emissions. Another example is less defective products save raw materials and energy consumed as well as save recycling energy consumption. Waste removal is a significant contribution to environmental protection and improvement as well as maximization of customers and organizations satisfaction.

4. Waste identification tools

A number of waste identification tools can be used to detect the location of NVA activities within manufacturing processes. In this paper, the focus is on two types of value stream mapping: 1) Traditional Value Stream Mapping (TVSM) and 2) Dynamic Value Stream Mapping (DVSM) as they have capacity to produce visualization of the information, material flows and all activities within a production.

4.1. Traditional Value Stream Mapping (TVSM)

TVSM is generally used for visualizing and analyzing the current state of information and material flows of a production [14]. Benefits of TVSM are also designing and improving future processes, highlighting deficiencies in the process, planning and transformation, and cost saving [15]. Hines and Rich [4] introduced seven TVSM tools including process activity mapping, supply-chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis and physical structure mapping. Nevertheless, weaknesses of the VSM tools has been stated in Ramesh et al. [16] and Lian and Van Landeghem [17] for inabilities to capture the impact of variability and the dynamic interactions within the process as well as limitations of hand-drawn mapping.

4.2. Dynamic Value Stream Mapping (DVSM)

DVSM refers to real-time VSMs such as Radio Frequency Identification (RFID) and simulation-based VSM are the tools claimed to overcome the limitations of traditional VSM. RFID is capable in tracking and tracing products regardless impeding environmental conditions through microchip embedded technology. It allows accurate processing time and location to be recorded for the RFID tags. Nevertheless, RFID creates concerns over its technology cost, tag reliability and limited application in some form of products such as metal and fluid [18]. In more complex manufacturing systems whereas traditional VSM or RFID cannot be utilized, simulation-based VSM such as the Discrete Event Simulation (DES) is a suitable alternative. With the computerized technology, the real system is mimicked. The time variable can be adjusted to predict future results. Effective simulation-based VSM, however, requires programming and simulation knowledge, high setup cost and extensive data acquisition [19].

5. Waste elimination process

Having waste identification tools alone without an appropriate waste elimination process cannot guarantee the attainment of sustainability in manufacturing. A three-phase framework of waste elimination process is proposed in this paper for the purpose of sustainability enhancement in manufacturing (Fig.2).

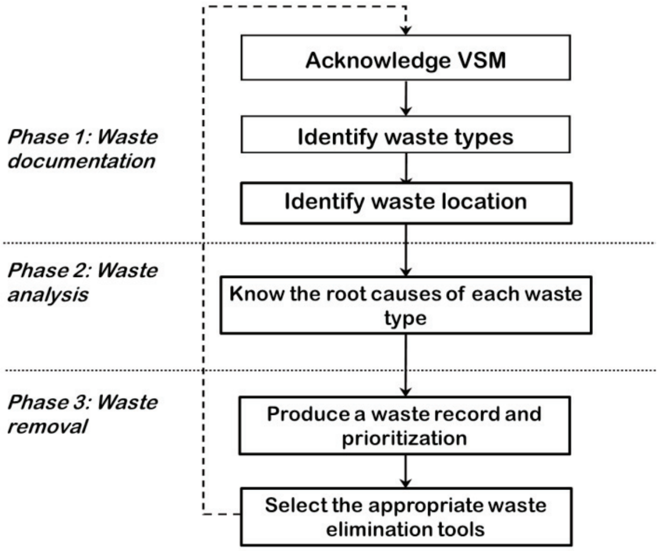

Fig. 2. Framework of waste elimination process.

5.1. Phase 1: Waste documentation

Phase 1 consists of three key waste documentation activities. First, VSM is acknowledged through identifying where customer value lies. The value stream contains all processes of producing and delivering products/services to the end-users. Acknowledging the value stream is important as it assists organizations in grouping products/services according to their manufacturing processes. Second, it is essential for the organizations to understand waste and enable to identify waste types. All nine types of waste should be examined within this activity. The nature of waste depends on the activities of an organization. Waste may be categorized into three major types: (1) unobvious waste; (2) less obvious waste; and (3) obvious waste. Hopp and Spearman [20] gave examples of the obvious waste as excessive inventory, unneeded processes, excessive setup times, unreliable machines, and rework. They argue that less obvious waste is associated with variability in process times, delivery times, yield rates, staffing level, and demand rates that create buffering costs. This type of waste also includes anything in the system that is not absolutely regular and predictable exhibits variability. Third, locations of the identified waste in the value stream need to be flagged. This activity can utilize any of waste identification tools as mentioned in the previous section.

5.2. Phase 2: Waste analysis

Only an activity needs to be completed within this phase i.e. waste root cause analysis. The phase requires outputs of *Phase 1* as inputs into this phase. Root Cause Analysis (RCA) can be simply performed using the brainstorming technique among expert within the organizations. Alternatively, a cause-effect diagram can be used to demonstrate the root causes of each waste type. The root causes discovered within this analysis process can be grouped further into five categories or 5M's: manpower, machine, method, material and measurement.

5.3. Phase 3: Waste removal

The phase contains two activities on waste removal. First, a production of waste record must be conducted in order to record and rank the significant waste types. The record can be constructed using concepts of Failure Mode and Effect Analysis (FMEA). In this case, waste is hypothesized as failure to optimize resources utilization. The modes of failure or waste are the root causes of each waste. The root causes can be assessed on the basis of five criteria: cost of cause removal, ease of cause removal, impact of cause removal, cause occurrence and detection. The organizations, therefore, should consider the cost and ease of root cause removal as the primary elements in the waste removal process as the criteria represent the organizational investment and capability in waste handling. To prioritize the root causes, this paper proposes the following formulae. The waste priority number (WPN) represents the addition of COR, EOR and RPN of each root cause under the same waste category (Equations 1 and 2).

$$RPN_i = I_i \times O_i \times D_i \qquad (1)$$

$$WPN_j = \sum_{j=1}^{9}\sum_{i=1}^{m} COR_{i,j} + \sum_{j=1}^{9}\sum_{i=1}^{m} EOR_{i,j} + RPN_i \qquad (2)$$

Where,

$COR_{i,j}$	:	Cost of removing cause *i* of waste type *j*
$EOR_{i,j}$	:	Ease of removing cause *i* of waste type *j*
I_i	:	Impact of cause *i* on other causes
O_i	:	Occurrence of cause *i*
D_i	:	Detection of cause *i*
RPN_i	:	Risk priority number of cause *i*
WPN_j	:	Waste priority number of type *j*
n	:	Number of waste types
m	:	Number of root causes under each waste type
i	:	Refers to root causes, *i=1, 2, ……………,m*
j	:	Refers to waste types, *j=1, 2, 3,…………..,9*

Note: COR ranks from Low (1), Medium (5) and High (10)
EOR ranks from Easy (10) and Difficult (1)

Second, selection of appropriate waste elimination tools is performed. The selection process can rely on any available lean tools equipped within the organizations. However, it is reminded that a single lean tool cannot eliminate all waste types. The selection of lean tool can follow a lean toolbox guide and framework [21, 22]. The selection process may include, but not limited to, decision making tools such as analytic hierarchy process (AHP), analytic network process (ANP) data and envelopment analysis (DEA).

6. Conclusion

This paper has identified nine types of waste in manufacturing processes. Overcoming all waste types can lead to the enhancement of manufacturing sustainability. Being able to spot waste, the organizations need to distinguish between value adding and non-value adding activities. VSM is considered as a common tool to visualize the activities flow. For non-complex manufacturing, traditional VSM could be sufficient to capture non-value adding activities. However, when the manufacturing systems become more sophisticated, dynamic tools such as RFID and simulation-based VSM can be more effective. Having only waste identification tools may not provide a complete waste removal process. To ensure that all waste types are eliminated, this paper has proposed a waste removal framework consisting of three consecutive phases that can be adjustable further to fit manufacturing types and scales. To enhance the process, formulae for waste prioritization have been structured. For the future research, it is recommended that pre- and post-measurement should be conducted in order to conclude the effectiveness of waste removal in relation to manufacturing sustainability.

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