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AN APPROACH TO INTEGRATING SUSTAINABILITY MANAGEMENT PARAMETERS AND INDICATORS INTO VALUE STREAM MAPPING

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ABSTRACT

Sustainability is addressed in many ways in production research, and it is often coupled with Value Stream Mapping (VSM), a widely used technique for optimizing production systems utilizing lean concepts. The majority of writers in scientific literature offer systems for rating manufacturing processes (e.g. ratios, benchmarks). These methods are designed to decrease the quantity of (material) input required to produce a given number of products. As a result, better value stream goal conditions may be created to boost ecological efficiency and, as a result, lower costs. The primary goal of this work, however, is to provide a method for combining widely recognized sustainability metrics and indicators with VSM. Process-oriented accounting of resource consumption through buffers, transports, and processes along value streams underpins this method. This approach of incorporating sustainability into VSM adheres to internationally recognized standards for preventing input resource disposal via reuse, recycling, and recovery. On the one hand, this approach can be used for sustainability reporting by following international guidelines and frameworks, such as calculating emitted solvents per produced part, kilogram carbon dioxide equivalents per produced part (with units [kgCDE] or [kgCO2eq]), kilogram disposals per produced part, and so on. Companies, on the other side, will be able to assess the expenses and profits of sustainable value streams, allowing them to monetize their efforts and benefits. As a result, it is essential to get immersed in material flows in the value stream, material consumptions at processes, transportation energy consumption, buffers and processes in the value stream, process linkage with scrap rates, waste generation, and so on. To express the characteristics and indicators of sustainability, new data lines in VSM must be established. A use case from the automobile sector will be used to demonstrate the study results.

KEYWORDS: *Manufacturing, Sustainable Development, Value Stream Mapping.*

1. INTRODUCTION

Manufacturers may utilize this information to benchmark their processes. Water, raw material, and energy consumption indicators should be incorporated in all industrial operations to guarantee use. Traditional/traditional techniques in manufacturing and service sectors are replaced by lean methods in lean production, established in the 1950s and 1960s by Eiji Toyoda and Taiichi Ohno for Toyota. The goal of lean is to reduce and eliminate waste while putting a strong emphasis on the customer.

To achieve a lean condition/process, methods such as Value Stream Mapping (VSM), 5S, and Kaizen are employed. The latter was popularized in the western industry mostly via the published work of Imai. Womack et al. bloom's "The Machine That Changed the World" popularized the idea of "lean production" outside of Japan, owing to substantial potentials for lowering manufacturing costs via organizational elements. The addition of sustainability to lean may be seen as a progression from the conventional short-term (e.g. annual) viewpoint. Quality, customer satisfaction, cost reduction, and lead time reduction have all been demonstrated using this combination [1] of lean manufacturing and sustainable development. The increasing number of published articles on lean management and sustainability indicates that the actual application of lean principles and scientific debate has become extremely popular. However, according to many research, lean methods do not always enhance environmental performance. The methodology described in this article is based on the foundations of value stream analysis and the many methods and practices in sustainability management that have been published so far. Value Stream Mapping Value Stream Mapping was initially created as a technique inside the Toyota Production System, then Rother & Shook presented it as a separate approach. Value Stream Mapping is a basic but efficient technique for gaining a comprehensive picture of the state of an organization's value streams. Flow-oriented target value streams (target-conditions) are designed and executed based on the current-condition analysis [2].

A value stream is made up of all actions that are required to produce a product (or provide a service) and make it accessible to the consumer, including value-adding, non-value-adding, and supporting activities. This covers all operational operations, material movement between processes, all control and steering activities, and information flow. Value Stream Mapping analyzes the whole operating time in comparison to the overall lead time in order to determine any improvement possibilities. The larger the difference between operating and lead time, the greater the opportunity for improvement. This method, like a prior published approach in which we coupled Value Stream Mapping with Methods-Time Measurement (MTM), delves into the details of processes in a value stream in the context of sustainability management. The combination of [3] Value Stream Mapping and MTM at various degrees of detail consideration helps identify, eliminate, and prevent waste, resulting in the design of efficient and successful operations.

1.1. Literature On Combined Sustainable Management And Value Stream Mapping Methods

Several methods to value stream sustainability have been proposed in the literature:

a) Green [4] VSM (GVSM) , focusing on office operations and indicators such as energy, water, materials, waste, transportation, emissions, and biodiversity. The graphic depiction options are restricted.

b) Environmental VSM (EVSM), which focuses on water usage. It's difficult to tell whether someone is squandering water by looking at it. Only the water resource has a full study available.

c) Energy Value Stream analyzes each manufacturing stage for energy waste with an emphasis on energy savings. Reach's work is feasible, but the examination of other resources (such as trash) is lacking.

d) Process energy usage is taken into account in the Energy and Environment VSM (EE-

VSM). However, energy consumption due to transportation or storage often overlooked

e) Lean Sustainable Production Assessment Tool, a development of EE-VSM that includes metrics for energy, water, material, and CO2 emissions. There is no mention of social indicators or visual representations of several indicators.

f) Sustainable Manufacturing Mapping (SMM) uses VSM, Life Cycle Assessment (LCA), and Discrete Event Simulation to evaluate chosen sustainability metrics (DES). VSM is utilized as a foundation; however, there is no comprehensive display of the data.

g) Sustainable VSM (SVSM) ,[5] which examines GHG emissions. The social indicators are thought to be integrated indirectly through beneficial impacts on the economy and the environment.

h) The lean and environmental toolkit of the United States Environmental Protection Agency (EPA) is utilized to identify possible waste considerations. It assists lean users in identifying energy waste and improving/reducing environmental impact.

1.2. Indicators And Criteria Of Sustainability

Several organizations and academics have defined sustainability metrics in their publications, but no uniform standard has yet been established. There is room for improvement in terms of sustainability reporting in the manufacturing process. This necessitated the development of criteria to aid in the assessment and improvement of sustainability plans. Provide a set of metrics for use in a Sustainable Manufacturing Mapping. The next sections describe commonly used indicators, such as those included in the GRI standard. These indications are also included in this method.

a) Waste as a result of the utilization of a resource called "material": The legal EU definition of waste is “any substance or item that the holder discards, wants to discard, or is obliged to trash” in this case. Material291 waste refers to any non-productive output (NPO), including solid and fluid waste , as defined by Thomas Edtmayr / Procedia CIRP 41 289–294 The “DIRECTIVE 2008/98/EC OF THE EUROPEAN [1]PARLIAMENT AND OF THE COUNCIL” , which ranks the “R” methods of reuse, recycle, recovery, and disposal in order of priority , provides a well-established classification for generated trash. As a result, waste reduction starts with prevention, followed by reuse, recycling, and thermal recovery. The output-to-input ratio is used to determine a manufacturing system's efficiency. According to Despeisse et al., a system that uses produced trash internally and sees it as a resource is more efficient than one that does not. Other methods, such as redesign and remanufacture [14], are not addressed in this article since they are not used in VSM.

b) Solvents: Solvents are utilized in paints and adhesives depending on the production method. Solvents have been utilized as sustainability indicators in the literature.

c) Water: water is often utilized in manufacturing processes for cooling, heating, and cleaning. Water is the primary emphasis of E-VSM.

d) Energy: Because non-renewable energy has a direct effect on greenhouse gas emissions, energy must be considered a key indicator for long-term sustainability.

e) Electricity, natural gas, and compressed air are common energy and material forms in manufacturing that are utilized as sustainability indicators. It is also possible to add diesel or district heating.

f) CO_2: In the United States, the EPA grid provides emission factors with which [kWh] may be converted to [kg] of CO_2. Consumer demand for products with a known CO_2 balance is gradually increasing. The total greenhouse gas (GHG) emissions from a particular product are calculated in terms of carbon equivalence (i.e., tons of carbon dioxide equivalent [tCO_2e] or grams of CO_2 equivalent per kilowatt hour of production [gCO_2eq/kWh]) using the technique "carbon footprint analysis" Identifying difficulties in long-term value streams The methods presented in the literature address sustainability in value streams, but only very briefly and without a thorough examination of resource use and cycle, and particularly without an underlying, universal model for calculating sustainability indicators. Furthermore, neither the waste pyramid categories of reuse, recycle, recovery, or disposal, nor their monetary worth, are taken into account. This article outlines a strategy for bridging the gap. The value stream viewpoint is utilized to look at the entire system, similar to a previously published method (Value Stream and MTM), while the process assessment looks at and assesses the particular and may therefore be changed afterwards. This technique takes into consideration the requirement for methods for display of the chosen metrics in a complete Sus-VSM. Documented methods to waste reduction, namely waste avoidance, are not taken into account. Despite the existence of previously published "case studies" describing the evolution of the present state of Sustainable Value Streams (i.e. Sus-VSM), further study is required. Model-based Value Stream Mapping for Long-Term Sustainability An "ideal-typical re-utilization cycle" is presented in this work. It serves as the foundation for assessing sustainability metrics. An ideal-typical re-utilization cycle is underlined in each step in the value stream, and all ideal-typical re-utilization cycles practically comprise the categories reuse, recycle, recovery, and disposal. However, in most cases, more material is needed during manufacturing. Each ideal-typical re-utilization cycle of a process is given a waste of material resources. Depending on the process technique, waste may arise [4].

2. DISCUSSION

The methods mentioned in the literature deal with value stream sustainability — but only very briefly. And without taking into account the usage and cycle of resources particularly in the absence of an underlying, universal paradigm for the Sustainability indicators are calculated. Furthermore, neither the waste pyramid's categories the monetary value of reuse, recycling, recovery, nor dispos Values are taken into account. This article outlines a method for close the chasm this method is similar to one that was previously published. The value stream viewpoint (Value Stream and MTM) is utilized to look at everything, while the procedure was being [6] evaluated examines and measures the particular, allowing it to be improved. Subsequently. Because a complete Sus-VSM must have this is a technique for visualizing the chosen metrics. This method takes this into co the methods mentioned in the literature deal with value stream sustainability — but only very briefly stream sedation as well. Documented methods that place a strong emphasis on waste reduction, Waste avoidance, in particular, is not taken into account. Regardless of "Case studies" that explain the situation have already been published. The current state of Sustainable Value Streams is being developed. Further research (i.e. Sus-VSM) is required. Model-based Value Stream Mapping for Long-Term Sustainability.

An "ideal-typical re-utilization cycle" is described in this paper. Introduced. It serves as the foundation for assessing sustainability. Indicators. An ideal-typical process exists in each value stream process. The re-utilization cycle is underappreciated, and all ideal-typical re-utilization cycles include the following categories. Reuse, recycling, recovery, and disposal are all options. However, in most cases, additional materials are required. Production. Each person is responsible for the waste of material resources. A process's ideal-typical re-utilization cycle. There is waste. Depends on the technology used in the procedure this trash may be in two forms: partial waste and full waste– reused, recycled, reclaimed, or sent to a landfill However, before diving into the ideal-typical re-use scenario, cycle, as well as the determination of sustainability metrics, A value stream's processes must be connected.discussed.4.1. Scrap rate in total with a value stream's serial series of processes and the scrap rates that occur in processes, each upstream process must generate more in order to meet the necessary quantity the consumer in the opposite direction of material flow, For each value-added step, the total scrap rate rises. Stream in the appropriate manner as a result, the cumulated calculation is no longer possible. Each process in a serial sequence has a scrap rate of1in assistive you're looking for a unique (1) x scum... scrap rate over time in a value stream [percent] x si... process scrap rate I [percentage]Starting with Dnet's actual customer demand, As a consequence of consumer demand per procedure Inept Netcom D Dx Dent's I an increase in net demand per process as a result of I [parts per time period] cumulated scrap rate procedure Dnet... consumer net demand [pieces per time period]x scum.... scrap rate cumulative [percent]. This formula is required for total waste computation. throughout the value chain [8] The cumulative scrap rate has another impact that isn't obvious. Although not discussed in this article, it is worth mentioning because of Value Stream Mapping's practical relevance: The accumulated The necessary net demand per scrap rate rises as the scrap rate rises process the value stream that is being evaluated upstream Consequently, the For each client, customer tact time is not expected to remain constant. Process. In a strict sense, each touch moment is unique. Due to an increasing net need, the procedure must be sped up. Demand while maintaining a consistent networking time Waste calculation in single operations each step in the manufacturing process wastes material resources. As previously stated, the value stream is linked to the ideal typical re-utilization cycle. This trash may be found in a variety of places. There are three methods to do it; see Formulas 3, 4, and 5.x Wnok... waste as a result of the cumulative scrap rate [kg per timex Dnet increased consumer net demand [parts per time periodic Dnet.... consumer net demand [pieces per time period dn... input resource net weight [kg per component Wnok is a waste since it does not meet quality standards. Stipulations such as faulty or incorrectly constructed parts. dg is the gross material input. Because of the selection,

Extra resource input in the production process Wok is often used. Required and computed in the following manner: . ( ) W D dd ok net (4)x Wok... waste owing to variation in material input [kg per time]period]period]x dg.... input resource gross weight [kg per component]x dn... Input resource net weight [kg per component] the net material input is denoted by dn, for example. The difference between gross and net injections is sprue. In the painting process, molding or paint sludge may occur. Wb(i) is a third type of waste caused by set-ups. Introduced. Batches of this waste are commonly produced. Models based on production or models based on discontinuous shifts. The precedin the proportions of all waste vary depending on the time period under consideration the percentage of waste generated by set-up is usually not in the positive. The same period of observation as the required amount of the net, the client As a result, the following proportionality is used. Presented [7] a biff you're looking for a unique (5)x Wset-up... set-up waste [kg per time period]x Dnet.p... a rise in net demand per process as a result of [Parts per time period] accumulated scrap rate Wb... per batch waste [kg per batch]batch size x b [number of pieces per batch] The average waste per batch is represented by Wb. The letter B is referred to as batch-size. The total amount of trash generated over a certain observation time - for example, shift – is computed in the following way's W... total waste [kg per period of time]x Wnok... waste as a result of the cumulative scrap rate [kg per time period]x Wok... waste owing to variation in material input [kg per time period]x West-up... set-up waste [kg per time period]To convert the waste per unit, multiply the computed waste per unit by the number of units. It is necessary to divide the observation time by the observation period. As a result, the waste per component for each procedure is as follows (7)x w(i)... total waste per acceptable component [kg per acceptable part]x dg.... input resource gross weight [kg per component]x scum.... scrap rate cumulative [percent]x dn... input resource net weight [kg per compose Wb... per batch waste [kg per batch]batch size x b [number of pieces per batch]For each procedure, the waste per unit may be determined. each resource that is used This squandering of natural resources are provided to and evaluated by the ideal-typical usage procedure. When a resource is evaluated, it does not include process water. Packing or solvents4.3. For each process, ideal-typical re-utilization cycles the ideal-typical re-utilization cycle is discussed in this chapter. Introduced. Each process's three kinds of waste are identified. Allocated to the previously mentioned categories of reuse, recycling, and recovery as well as disposal Material is utilized in all categories except disposa Disposals, on the other hand, are transferred somewhere else. The reutilization categories are divided into layers for each step in a value stream (see Figure 1). Five transport actions, three reutilization activities, and five reutilization activities make up one particular reutilization cycle. To create an ideal typical re-utilization cycle, buffers and the re-utilization process itself must be combined. This ideal-typical repurposing cycle may be used in any kind of manufacturing or assembly. Processes. Injection molding is a good illustration of this process.

Spree and scrap rate waste are produced as a result [9]of set-ups.80 percent of total trash is recycled to meet consumer needs to make other items (such as a linoleum-covered floor) answer have two layers since disposal accounts for 20% of the total. The operator of the machine disposes of all trash in one or more containers, which are then recycled. Carried to a silo for shredding by forklift after shredding, the ready-to-recycle material is stored in bags on a conveyor belt. Pallet. All efforts, including space, transportation distance, and time, are made fore-utilization may be evaluated in the same way as traditional VSM. Furthermore, several resources may be separated. To differentiate kinds of disposals, use types in the value stream. On the other hands On the one hand, this resource flow modeling at processes seems to be a good idea. When sketching value streams on paper, it's impossible to replication the other hand, it may be represented in a Vs [1]. Software application the limits and levels of the system are shown in Figure 1an ideal-typical process re-utilization cycle in a value chain stream

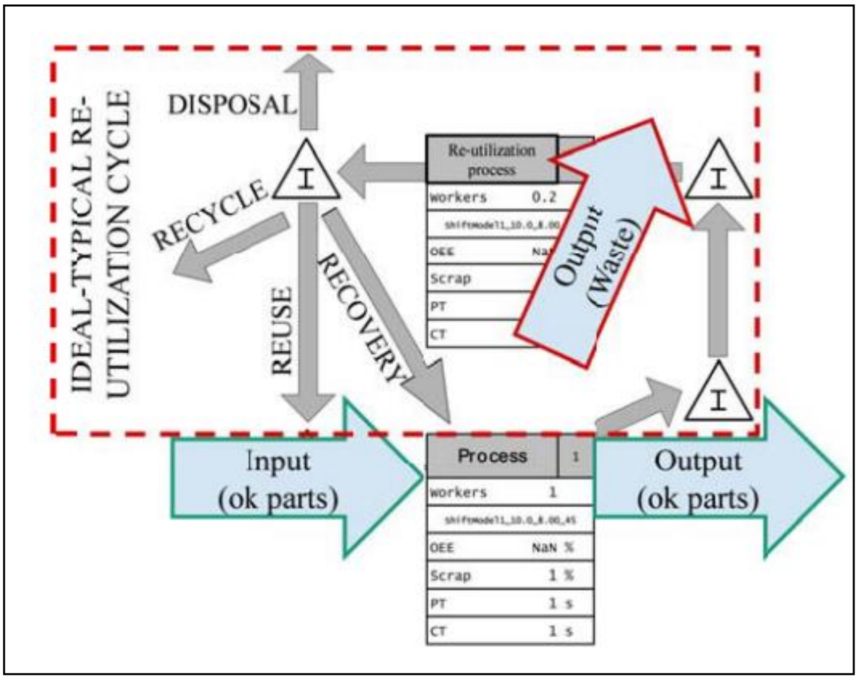

Figure 1: Principle of Ideal Typical Reutilization Cycle.

3. CONCLUSION

When calculating waiting periods in any operation. These are sum an example of our serial pro action mold peps of dispose athletics, coati gram per p boss water an athletics of pa theories of did her and/or alto lee stream. The data line in Figure rt to be coma also.

When a hen combines aping, it's called hen combining aping. In the future, the monetary sets and revenues, as well as the proc gram carob educing custom es in the same sources, are s aging material and/or customer it the present acting total le n buffers are mime with ad e two values y end of a v e disposals d mimed up to ca o illustrate, processes and ding, painting sales of primer in and part Other read coating pro packaging mat supposals may be b manner. G sustainability urea functions, was appropriately, and quantity use of sustain less-oriented an on dioxide mar demand. Drink ls and practice solvents. Finally, there is a ca ted model for all reporting. Data line. ead time of an added; same ding up all are represented value stream. All process g, assembling rye input redo ts from bill-o sources may odes as well terial at asset be totaled u display the did salsa data line We will provide y to classic v active paramet nobility action accounting o equivalents al examples n king water, pr criterion need to be calculated as a value stream e when calculating process Tim end in the time We utilize v e stream cons technologies to dispose of many kinds of waste. Apart from disposals of a w of a value strew s are compute nt and value s nt how to ass value streams tars/indicators, g and sequin urges are the of-material in y be solvents l as cardboard embay process up [10].

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