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Understanding the hidden cost and identifying the root causes of changeover impacts

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ABSTRACT

A Changeover is the set of operations required to switch from producing one product to another and it includes both setup and cleaning operations. Changeovers are especially critical for multi-product environments where flexibility, time and quality are key requirements of the manufacturing system. A range of environmental and economic impacts occur during changeover operations and quite frequently the magnitude and extend of these are not fully captured by manufacturing companies. However, information gathered from the literature and factories suggest that these impacts could drastically reduce the sustainability performance of companies through creating waste streams. Furthermore, reduced economic and environmental performance of the companies impairs social and industrial desire to achieve sustainable systems. This research focuses on how companies can develop capabilities to evaluate and monitor their changeover performance, as well as understanding the causes of these impacts and how can they be mitigated. In this paper, the underlying factors and root causes of changeover impacts will be discussed. Results from the case studies suggest that, it is possible to capture changeover losses by using a mass balance approach. In addition to this, twelve factors were identified as the main influencers of changeover performance and further analysis of these twelve factors provided three root causes that determines the changeover performance. Identification of these factors and causes was expected to help industry to improve their changeover performance by highlighting the key areas to focus on and hence improve firms' sustainability performance.

1. Introduction

As the concepts of sustainability and sustainable development find their place in today's world, from an academic perspective, they have also been some of the most covered, integrated and confronted subjects over the past years. Increasing demand on resources, changing patterns of resource consumptions and lack of environmental consciousness on design and operation of industrial and economic systems, have led to major environmental problems at global scale such as global warming, climate change, resource and water scarcity, air pollution, extinction of species. Moreover, global industry has been a major contributor of the impacts since the industrial revolution. Today, almost every product in our lives has either been manufactured or processed by industrial systems before reaching the customer use. World's current population of 7.3 billion is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100 according to a recent UN report (United Nations, 2015). Meanwhile, we are already facing shortages in critical resources such as materials, water and energy. All these considered, industry will have to quadruple its output by 2050 to meet the increasing demands of the society. In order to achieve this, companies will have to go through significant changes in the whole provision system, from obtaining resources to manufacturing them, from day to day decision making to business models. Today, it is well established that in order to survive radical changes have to be made at very different levels (Allwood et al., 2011; Hawken et al., 1999; Jackson et al., 2009; McDonough and Braungart, 2009; Meadows et al., 2005).

Increased Interest both from researchers and industry stakeholders has provided many improvements at almost any level from design to manufacturing, extraction of materials to providing service based business models. However, the many years' worth of accumulated knowledge and experience cannot be changed overnight and therefore transition to sustainable industrial systems is

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slow. Moreover, not every single aspect of industrial systems has been investigated yet and the transition to sustainable industrial systems requires addressing these knowledge gaps. Changeover operations were highlighted as from such topics that require more attention and research to reveal its relationship with industrial sustainability.

Changeover operations are a crucial aspect of the manufacturing environment. In most manufacturing firms, there is some kind of changeover operation which may range from a physical setup operation that requires replacement of the machine parts to intensive cleaning operations which involves the use of cleaning agents, or it may involve both types at the same time. Changeovers are critical for a wide range of industries, however, the environmental and economic impacts as a result of changeover operations (hereafter will be mentioned as changeover impacts) are not well understood yet. On one hand, changing market demands is pushing companies towards enriching their product portfolio and demanding more flexible production systems. On the other hand, the need for sustainable manufacturing systems requires companies to reduce the environmental footprint. In this complex system changeovers possess an important role as their impacts are frequently not well understood or left out.

So far the main interest on changeovers was due to the significant loss of production time. Therefore, the main objective was achieving faster changeovers. One of the largest step changes have been through the introduction of Single-Minute-Exchange-of-Die (SMED) methodology by Shigeo Shingo (1985). With the applications of SMED many companies have drastically reduced their changeover times. Whilst, this one dimensional approach has provided companies some benefits, both environmental and economic impacts started to stand out as the manufacturing companies are facing increased pressure to become more sustainable. This study addresses this issue by highlighting the hidden cost of changeover operations for manufacturing companies. By gathering information from both literature and case-studies this paper shows that changeover operations can cause significant burdens through product and time losses, additional water and energy use, creation of wastewater and solid waste streams as well as chemical use for cleaning purposes. In this research environmental impacts were described as the cost of these burdens to the nature, while economic impacts represent the cost to the company. Without the proper attention, these impacts can drastically reduce the sustainability performance of the companies by affecting both environmental and economic directions. Observations from case-studies suggest that the total cost of a changeover may reach to thousands of pounds and in manufacturing sites where dozens of changeovers happen every day, the annual cost grows very rapidly.

Last but not least, besides understanding the cost of changeover impacts, this research also tried to capture the root causes of changeover impacts to support the improvement process. Providing a better understanding of why changeover impacts occur to the companies was expected to highlight the aspects of changeover operations that companies need to focus in order to prevent and/or reduce environmental and economic impacts. To reveal the causes behind the changeover impacts, data was gathered and analysed from various manufacturing sites. This paper reports from a wider research investigating the root causes of environmental and economic impacts of changeover operations. It aims to help the reader understand the underlying causes of changeover impacts and guide companies towards achieving eco-effective changeover capabilities (Gungor and Evans, 2015). In this paper we will explain the influential factors that affect the changeover performance within the manufacturing environment and how do these factors are categorized around three root causes; changeover design, management and knowledge.

2. Literature review

Over the past years, significant amount of research was conducted within the fields of sustainability. Researchers have been focusing on various aspects both in theory and practice to reduce the negative impacts we have been causing at local and global levels. Furthermore, achieving industrial sustainability has become one of the key requirements of sustainable development as the manufacturing industry has become the largest consumer of energy and significant source of greenhouse gases. times (Jeswiet and Nava, 2009; Jovane et al., 2008). Furthermore, International Energy Agency (IEA) also published that manufacturing industry were responsible from majority of the energy related environmental pollution and for over a third of the global energy consumption (Iea, 2008).

Researchers and practitioners have been investigating ways to reduce the impacts that occur along the life-cycle of a product, from extraction of raw materials to end of life. In addition to that, environmental and economic impacts that occur as a result of the manufacturing of the goods has also been grabbing attention. Moreira et al. (2015) have holistically investigated the ways of utilizing the methods and approaches within the literature in collaboration with the green aircraft completion sector. Their proposed framework was expected to reduce the carbon footprint of the aeronautics industry and improve corporate social responsibility. On the other hand, some researchers have looked at the potential synergies between different factories through industrial symbiosis and tried to maximize the benefits. Their case example reflects the sustainability benefits of such relationship between different factories by providing a new decision support tool (Rosa and Beloborodko, 2014). Furthermore, Sproedt et al. (2015) have propose a new decision support approach for eco-efficiency, in which they integrate Life Cycle Analysis (LCA) and Discrete Event Simulation (DES) approaches and suggest that it could help companies to achieve eco-efficiency improvements which in return is likely to reduce the environmental impacts (Sproedt et al., 2015). Wang et al. (2009) argue that increasing the control measures by implementation of energy assessment and quota practice would improve environmental and economic performance for companies. On the other hand, researchers have reviewed the literature on sustainability practices such as eco-efficiency, eco-innovations and concluded that despite the abundance of such tools and practices the fragmentation among the literature reduces the benefits (Bocken et al., 2011). They offer 8 archetypes to bring together the defragmented contributions within the literature and increase overall benefits. In addition to that, Liu et al. (2015) have investigated impacts of what they defined as setup operation (the operation of turning off the idle machine and turning on it again) and developed a bi-objective optimization model to find the right balance between the total completion time and total carbon dioxide emissions. They argue that their results could support sustainable manufacturing by reducing the energy consumption.

Academic literature covering the environmental and economic impacts of changeover operations has yet to be developed. Current literature streams are clustered around setup time reduction and cleaning operations separately. However, considering the complexity of the problem, in order to make balanced decisions all aspects of changeovers should be jointly considered. Therefore, the literature review was focused on these two areas. Additionally, manufacturing strategies most related to changeover activities have been investigated.

Brand reputation and customer satisfaction are of crucial importance to all companies. It is so important that when cleaning systems are being designed, most of the time there are extra safety

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