Proceedings of the International Engineering Research Symposium (IERS 2023), pp[xx-xx], 2023.

Review on the application of circular economic principles in the automobile sector

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Abstract

A Successful Business climate is the prominent requirement of any manufacturing sector. The competitive advantage over the manufacturing process is backboned by several theoretical concepts. Sustainable manufacturing principles have been identified as the best option for process optimization. The automobile manufacturing remains the major sector throughout the world. The notable drop in the productivity has been observed in the automobile industry due to the limited application of sustainable concepts. The Focus has been initiated to identify the involvement of circular economical aspects in the automobile sector with the clear screening of gaps of research interests. Several literatures highlighted the application of lean manufacturing thoughts and presented their outcomes, where the concepts concerning the 6R principles remained unnoticed. A conceptual framework had been build based on the review-based study with the available literature on the application of several sustainable manufacturing concepts to automobile industry. The constraints were identified and an appropriate means to overcome those constraints have been discussed in detail. Thus, the literature opens the way for the analysis on several tracks for process optimization in the automobile industry.

Keywords: *sustainable Manufacturing, 6R Principles, Circular Economy, Automobile Industry*

1. Introduction

The world is moving towards achieving the best in business activities. This achievement should be a sustainable achievement. In order to succeed, the current manufacturing sector is more rely on the three major pillars of sustainability, which can create the competitive advantage for the organization [1]. As per the, annual reports of a manufacturing firm, they insist more towards social and environmental development which are the pioneers for the business activities [2]. Industries gain their competitive advantages by means of globalization, market growth and absorption of new product techniques. Thus, the future of the industrial sector is wholly depended on the dramatic improvement in the productivity while meeting the customer expectations through quality-based product manufacturing process. This rises the importance of rethinking of any manufacturing environment for the successful survival [3].

On the other hand, it has been proven that business activities prevail the main reason for environmental pollution. According to the previous statistical analysis, manufacturing sector holds the third position in the rank of activities which generates more CO_2 where electricity and heat production leads the list around the world [3]. This creates the attention of the sustainable business activities for all scale of manufacturing industries. As a solution, the circular economy has received the attention as the potential solution for most of the sustainability issues in industries [4]. The

strategic implementation of Circular Economical practices has shown the drastic improvement in the business-related issues in the current world.

To study that, the concept of 6R principles has been selected for the process optimization in the automobile industries. The idea behind this selection is to implement the 6R principles which is a branch of Circular Economy, which leads to process optimization. It has been shown that 6R principles are convenient, scalable, and it is not only restricted for an automotive industry, while having the capability to implement throughout the whole manufacturing sector. Thus, it is believed, that this might create a bridging for the automobile industry between lean manufacturing and circular economy.

2. Methodology

The aim of this study is to identify the Potential needs for the Implementation of 6R Principles in the Automobile Industry and assess the Process Optimization through Sustainable Manufacturing. To serve the purpose, a few objectives have been identified.

- Study, the importance of circular economic principles for the automobile industry.
- Determine the gap for the improvement and combine the concepts of circular economy to the selected industry.
- Formulate the framework for the assessment of the impact of process optimization in the sustainability of Automobile Sector.

In order to accomplish this review, a detailed study has been adopted from the top to bottom approach. The initial study highlighted the overview on the surface topics which further narrowed the topics to a circular economic principle in specific. This review data was used to identify the gap between the application of the circular economic principles in the automotive sector.

3. Review results

3.1. Sustainable Manufacturing

From the base definition for sustainability, it is defined "as meeting the needs of the present without compromising the ability of future generations to meet their own needs" [1]. It can be further explained as the process of creating manufactured products with reduced negative environmental issues, preserving the energy and natural resources while not damaging for the future usage, with the intention of safeguarding the employees, communities and consumers [5]. The sustainability is focused on three main aspects, namely, environmental, economic and social directions. Each of its pillars have specific objectives which has to be achieved for the successful implementation of sustainability. As an example, the environmental pillar is to achieve clean environment in terms of air, soil and water, implementation of regulations and ecological balance. The economical sustainability is encouraged to achieve financial benefits and economic growth. The process and product development, business enhancement and employment opportunities are few parameters of it. The later pillar, is concerned with the health and safety of employees, their lifestyle and quality of life. [4]

The sustainability concepts can be analyzed under three major levels, namely, process, product and system levels. These three levels have an interaction and provides the expected sustainability targets in an organization. These three integrated interacting levels provides the basis for the definition of sustainability and value creation for economic growth [5].

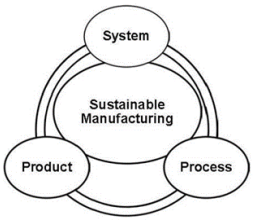

Figure 3-1 Integrated elements of sustainability

For example, previous literature has identified six sustainability elements for a manufacturing process. They are Manufacturing costs, energy consumption, personal health, operational safety, eco friendliness and waste management. This creates the interconnection between sustainable manufacturing and circular economy[5].

The figure below shows the interconnection between each of these elements.

Figure 3-2 Sustainability elements of Manufacturing processes

An open literature suggests that the implementation of the mentioned sustainability aspects can be done in three stages namely, research, development and commercialization. The research phase is important for identification of potential needs, thereby developing sustainable requirements. The development stage is concerned with improving the environmental performance by means of various tools while the later phase is to communicate and refine the follow-up processes in terms of sustainability. This establishes the relationship between the stake holders and the manufacturing company[2].

There are few parameters need to be considered for the improvement of the performance of manufacturing sustainability. They are, Concepts, that provides the comprehensive analysis of the three pillars, Methods and tools for adaption of smart tools and techniques, Data for clarified analysis, Manufacturing practices for assessment and value creation, government policies for legal documentation and governmental supports, Research, which incorporates the academics and researchers into the field of sustainability and finally integration, which coordinates all the above parameters. These parameters will entertain the improvement in the manufacturing sustainability with the identified needs and concepts of sustainable manufacturing[2], [3].

When we study the evolution of sustainable manufacturing, it can be stated that sustainable manufacturing has gone through various generations, way from traditional manufacturing, lean manufacturing and green manufacturing[6]. In the most developed phase, it has been identified as an integrated approach with the 6R principles as well[2]. The figure below explains its evolution against stake holder's value.

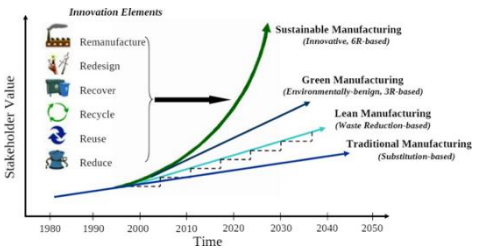

Figure 3-3 Evolution of Sustainable Manufacturing

In the flow, the design for manufacturing is also a major concern in terms of organizational sustainability. A closed loop has been observed in a manufacturing environment which covers the life cycle stages of a product. It starts from manufacturing, use, inverse manufacturing and finally inverse use. The following

diagram taken from a paper, shows this clearly[1].

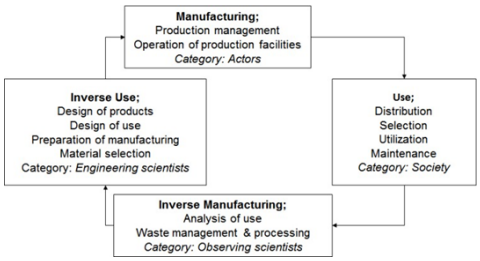

Figure 3-4 Life cycle Stages and design for manufacturing

3.2. Circular Economy

From the past, the linear economy has been identified and applied worldwide which focused as "Take – Make - Dispose" approach or "gain-gain" principles [7]. But this model failed in many aspects, especially for sustainability that targets in economic growth, environmental protection and societal wellbeing, thus, circular economy concept is combining resourcefulness, design thinking and much more for sustainable manufacturing [8]. In 2021, the European Parliament defined "The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended".[9] The circular economy establishes the balance between the economy and environment. It has been proven that the application of circular economical aspects throughout the life cycle has gained the benefit of transition in terms of environmental sustainability [10]. Thus, the circular economy has gained the attention of many stakeholders and researchers as a potential to way to overcome the current model of consumption and production.

Studies have shown the application of Circular economy concepts in Asia for the business production. Few examples can be cited from the globe as well. The manufacturing perspectives of Nike, BSH, Philips and Adidas are few of them[7].

The ultimate goal due to the implementation of circular economy is to create values in sustainability. This is achieved by 6R principles and further supported by innovation, education and training, novel methodology and visionary thinking. Unfortunately, historically the circular economy is relied on 3Rs: Reduce, Reuse and Recycle[11]. Sustainability and the circular economy, both have a separate track of applications. But both of them go together and being quite distinct. Sustainability remains the umbrella for the concepts under circular economy. Therefore, both has been linked with the intention of reducing the impacts on the environment, closing the economic and ecological links in terms of resources[12].

The figure below shows the concepts that govern the circular economy.

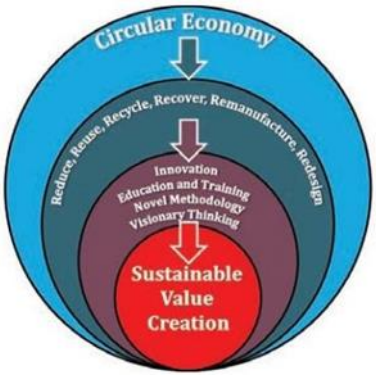

Figure 3-5 concepts under circular economy

A paper presented by Andrew[13] states that circular economy incorporates biomimetics – "an approach to innovation that seeks sustainable solutions to human challenges, emulating the patterns and strategies tested by nature's time". It is coordinated with bio-geochemical cycles. Lieder and his team[10] shown that the circular economy can be discussed under

three different perspectives such s scarcity of resources, environmental impacts and economic benefits. Damato [14] has introduced the concepts like green economy and bio economy in relation to the circular economy. Korhonen and his colleagues [15] presented a theme on a collaborative economy based on the three dimensions of the circular economy. In another research work [16], the circular economy is explained as an essentially contested economy.

3.3. 3R and 6R Principles

3R and 6R approaches are innovative based solutions for sustainable manufacturing. It can be used over multiple life cycles of a product. Initially, 3R concept is developed focusing the Reduce, Reuse and Recycle aspects of manufacturing. But, for the certified sustainable product, the important of explaining the 6R concept is fairly concentrated as it assists all the aspects of life- cycle to support the sustainable manufacturing [17]. In a product manufacturing process, four major stages have been identified, namely, pre-manufacturing, manufacturing, use and post use[17]. The 6R approach is applicable for all these stages with the intention of transferring the traditional manufacturing to sustainable manufacturing.

The 6Rs can be explained as shown in the table.

Table 1 - Explanation of 6R Approach

6R principles	Definition
Reduce	Focuses on sustainable consumption of resources and energy at the design, construction, and operation stage
Reuse	Involves the reuse of components after their first life cycle or other subsequent life cycles to reduce the use of virgin materials in the production of a new component
Recycle	Process of converting components that cannot be restored into their original state into new materials or components
Recover	Involves the process of collecting materials at the end-of-life stage and then disassembling, sorting, and cleaning for use
Remanufacture	Involves the re-processing of already used components for restoration to their original state or a like-new form through the reuse of as many parts as possible without loss of functionality
Redesign	Involves manufacturing or remanufacturing next-generation components using materials recovered from the previous life cycle or previous generation of components

In a paper presented by Jawahir [18], he has clearly provided the background for establishing the interconnection between 6R and material flow and 6R and product value. In that analysis, a clear mapping is shown with the application of lean concepts and sustainability concepts. It shows the interaction between 3R with the strategies mentioned. Below glimpses from the literature adds value.

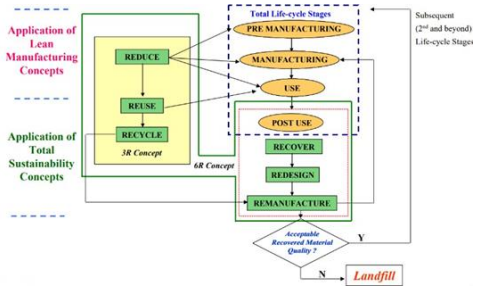

Figure 3-6 Material flow and 6R approach

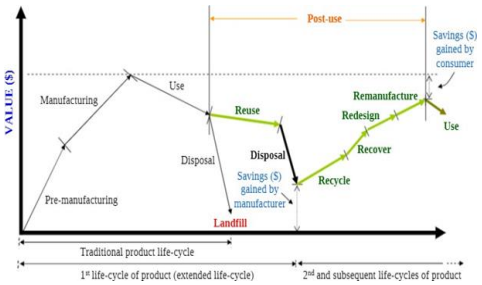

Figure 3-7 Product value and 6R approach

3.4. Process Optimization

Process optimization is a development achieved in the manufacturing process that is targeted to minimize the waste while consuming raw materials and reuse of waste materials. There are few sustainable manufacturing implementation stages have been identified as shown in the figure below. Among them, Process Optimization approach is a simplest means for the implementation of sustainability[19]. Few examples can be sighted for this application such as alteration of steps in the specific manufacturing process, optimal settings for operations, relocation of machines and

rearrangements and use of efficient energy usage technologies are few of them [20].
Previous studies have proven the application of process optimization principles for a manufacturing sector. A study has been conducted in a construction sector for the enhancement of waste recycling using the 6R approach and waste management techniques. The application of

additive manufacturing and nano-technology concepts for the printing process also adds value to the process optimization [19].

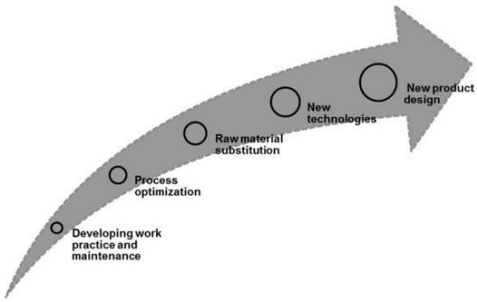

Figure 3-8 Process Optimization in Circular Economy

An assessment methodology for the process optimization was presented by Hossam and his team[1]. They have presented the idea under quantitative and qualitative frameworks. An integrated model was developed and optimization methodology has been adapted. The authors discussed the system constraints as well. It has been clearly stated that there is no appropriate means to measure the effectiveness. So that, they have focused on the product, the process and the system level assessments. An assessment criterion was also presented in terms of manufacturing costs, personal health and safety, energy consumption, wastage management and environmental impacts which ultimately focused the product and system levels while three pillars of sustainability has been used for process level assessment[2].

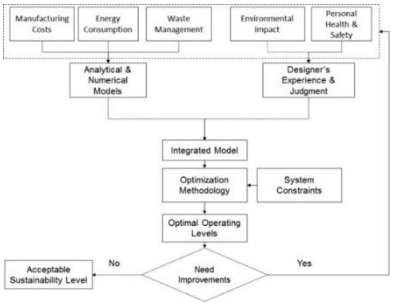

Figure 3-9 Process Optimization framework

There are several means of process optimization methodologies have been explained in the literature. The authors have given priorities for 5S principles, OEE (overall Equipment Effectiveness), Pareto Analysis, Elimination of waste strategy, Kaizen, setup time reduction methods, process mapping, Value stream mapping and Eight steps practical problem-solving methods[21]. Among them, the high level of interest is shown towards value stream mapping approach. Authors have pointed out the specific property of value stream mapping for the application in the process optimization as it helps to visualize the value added and non-value-added activities in the production line[22].

In a cross sectional case study presented by Helleno and his mate[23], referred to an application of VSM for the improvement of resource efficiency. They mentioned that their model discusses about the disposal process effect in sustainable management. Thus, the model provides the basis for the calculation of resource wastage and prevention of disposal by 3R approach. Paju and his team[24] effectively did a literature review in order to integrate the traditional VSM and environmental performance. This model provides the background for the visualization of three pillars in the production process. Cherrafi[25] has presented the relationship between value stream mapping and life cycle assessment. Pampenelli and his mates[26] related the

integrated sustainability metrics with the traditional VSM taking the automotive industry as an example. It has been stated that this model is appropriate for the measurement of three pillars thus needed further investigation.

It can be summarized that, there are few process optimization measurement tools have been identified. Authors suggest the effective application of Six Sigma approach for lean manufacturing aspects in the manufacturing industry. DMAIC approach is also suggested which is a branch of Six Sigma[5]. The next suggested methodology is a quality control aspect with the use of control charts and visual inspection methods.

3.5. Automobile Industry

Today, we cannot imagine a life without a machine called Automobile. It has been developed over a long time and now we are in a world of electrical vehicles and much more. The automobile industry remains the highest manufacturing industry throughout the world with almost 70 million in 2021[27]. It has generated the revenue of 2.95 trillion US Dollars in the fiscal year 2022 and still on rising[28]. But when compared to 2019 records, it is a slow recovery as many external parameters had their influence. The Cost and the quality are the paramount factors for the automobile industry to survive in the competitive market[29]. Therefore, it requires new tools and technology to produce goods to compete and survive in the market. Previous statistics has shown that the automobile industry strongly influence the economic development thus, it requires rethinking in terms of business models that will reduce environmental impacts[30].

Organizational Sustainability is gaining the concern in the companies due to its impact on the process efficiency. It is also based on the three pillars of sustainability. The economic pillar is aimed to address the issues with financial stability, organizational efficiency, production time reduction and developed partnerships. The KPIs of environmental pillars are waste management and greenhouse gas reduction. The social pillars focus on communication and human resources. It has been proven that the organizational sustainability practices can differ according to the size of the organization and it helps to refine the organizational structure, business processes and operational and strategic planning. But it is a difficult task to interconnect the automobile industry and organizational sustainability. The solution has been found using the sustainability goals which can be used to interrelate them. The following table taken from a literature shows this interaction with the SDGs[19].

Many researchers have implemented the lean principles in the automobile industry. Azevado and his mates[31] proposed the framework combining VSM and LCA in the automobile industry. A goal-oriented approach is proposed for the process mapping and this is hypothetical in nature and requires further analysis. Jabbour and his team[32] suggested a framework on four pillars for the purpose of integrating lean and green. This questionnaire-based survey is only applicable for the foundries only. Jadhav[33] have mentioned the effect of lean tools in the environmental performance. It has been confirmed that this application is in terms of identification and reduction of environmental impacts. The major drawback of this study is that is applicable only for motorcycle manufacturing industries and diversified analysis is required for various industries as well.

A cross-sectional case study has been proposed by Wang[34] suggests that energy efficiency can be measured in the automobile manufacturing industry through sustainable VSM. Also, the water usage, raw material usage, social aspects and environmental hazards can also be evaluated. Vinodh [35]evaluated the lean, green and carbon-value efficiency concepts to an automotive sector. This approach has shown its benefits in improved cycle time and continuous flow processing. Stoycheva and his mates[36] presented research with integrated green and lean six sigma. This approach has supported in analyzing the weaknesses and strengths with the intention of reduced resource consumption.

Table 2 Organizational sustainability and Automobile Industry

No.	Principle	Implication	Goal
S1	Interests of stakeholders	Putting into operation activities that are in line with stakeholders' strategic plans.	SDG1, SDG12
S2	Reduction of toxicity	Reducing the toxic impact of the workplace on employees.	SDG4, SDG5
S3	Reducing operator overload	Reducing operator overload on production jobs	
S4	Reducing resources	Reducing process losses contributes to improving financial results.	SDG9, SDG12
S5	Time efficiency	Increasing production capacity as a result of reducing activities time	SDG9, SDG12
S6	Reducing waiting time	The company has to reduce its waiting time to improve its production capacity.	SDG9, SDG12
S7	Monitoring fixed costs	Reducing fixed costs contributes to the efficiency of the production activities	SDG12, SDG17
S8	Stakeholder engagement in strategic decisions	Strategic planning should take into account the functions of sustainable development	SDG6, SDG8, SDG17
S9	Supporting community activities	Company involvement in society contributes to improving living conditions	SDG2, SDG3, SDG16
S10	Training human resources	By training human resources, the company's performance level is improved.	SDG4, SDG5
S11	Corporate Social Responsibility (CSR)	CSR actions improve employee wellbeing and improve public image	SDG 1, SDG10
S12	Increasing recycling capacity	Reducing the amount of waste generated contributes to reducing the organizational impact on the environment	SDG14, SDG15
S13	Increasing the capacity of the reuse, remanufacturing, reconditioning	Waste management functions generate added value for the organization	SDG7, SDG12
S14	Reducing energy consumption	Increasing the capacity to generate energy and reducing energy consumption contribute to protecting the environment	SDG9, SDG13
S15	Greenhouse gas reduction	The implication of the company in this activity leads to reducing pollution to the environment.	SDG11, SDG13

3.6. Process Capability

Process capability can be defined as a scientific and systematic approach that uses various control elements such as control charts to identify and eliminate the unnatural occurrences until the process control is achieved. It can be provided in terms of percentages and matrices. A case study has been presented by Rahul Raut and Attar which introduces the application DMAIC approach to automobile industry. The body shop production process has been thoroughly studied using the DMAIC approach and quality tools such as control charts and visual inspection methods have been used to present the data. The authors summarize that the process capability is the main driving parameter to increase the desired output[19].

A similar study has been presented by Manish Yadav and Manoj Kumar[37], with detailed process capability studies for the auto manual transmission brake plate using several statistical tools such as control charts, process capability analysis and fish bone diagram. A quantitative analysis has been presented using the MINITAB with the intense of showing the process is not adequate. This can be sighted as an example of a numerical analysis of process capability.

3.7. Industry 4.0 and sustainable manufacturing

An interesting topic has been discussed by Antonio Sartal and his team [2] on a literature study about the evolution of sustainable manufacturing concepts within the industry 4.0. it is a new paradigm to combine both aspect in an innovative thinking manner with the qualitative and inductive content analysis-based literature review. The authors present a framework for the basis of interrelation between three aspects: Sustainable manufacturing, 6R and Triple Bottom Line dimensions.

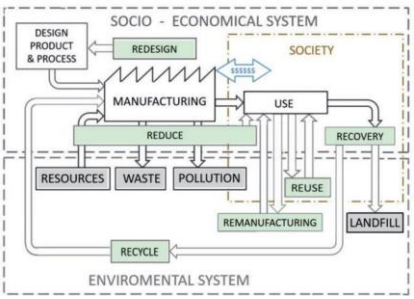

Figure 3-10 Interrelation between Sustainable manufacturing, 6R and Triple bottom line sequences

They typically provide the summary of their findings in Industrial Internet of Things, Autonomous and collaborative robots, simulation systems, system integration, virtualization, cloud computing and additive manufacturing. This shows the means of Industry 4.0 adapts the circular economical strategies in a more appropriate manner. At the end, they suggest the importance of digital transformation for the SMEs which will affect them in the transformation towards Industry 4.0 with sustainable manufacturing concepts [2].

3.8. Lean Manufacturing for Automobile Industry

Several researchers have described the application of lean tools in the automobile manufacturing industry from a different point of view. Arunagiri with his team[38] shown the high impact lean tool for automobile industry using weighted average method. They have shown that 5S is in the leading for the elimination of waste in the industry. Ratneshwar Singh and Ashish Gohil [39] depicted the implementation of TPM in the machine shop which led to the reduction in the break down time thus improved the performance efficiency. Santosh Kumar[40] applied the tools for a truck body assembly to show the reduction in cycle time. The authors have pointed out the importance of method time measurement and line balancing in the production line.

Manuela Ingaldi and Marta Jagusiak-Kocik [41]used the Yamazumi chart, Machine-motion analysis, MTM method and timing for a company which is a leading manufacturer of brake systems, seat belts, vehicle dynamics and driver assistance systems. They summarized that the movement of machinery is the key for the process optimization in the considered plant. They introduce the concept of Bottleneck and its implications for the process optimization. Mayank Agarwal and their team[28] presented a case study on improving the productivity and capacity enhancement in the automobile industry. The important has been given for Travelling Salesman Problem (TSP) along with other lean manufacturing tools like Kaizen, automation principles and MOST (Maynard Operation Sequence Technique) approach. The authors summarized that the process optimization is required in the welding robotic arms. They have shown that the results obtained are quite satisfactory. The improvements were suggested but the improved results were not presented.

A book chapter contributed by Tommaso Pardi[42] views the lean production in the automobile industry. It discusses in the employees' point of view and managerial decisions. As a conclusion, the author said that lean is not creating a value but it reduces the cost. An idea for the future research has been provided for the evaluation of inefficiency of lean production in the managerial level and in the public sector. In a paper provided by Nallusamy and Adil Ahamed[43] relates the case study on the application lean tools for the productivity enhancement in the automobile industry. The usage of Value stream mapping with the 5S and layout modification, the results shown that the remarkable amount of reduction in the cycle time and nonvalue-added time while increasing the productivity with the certain percentage. ARENA simulation has been used for the analysis for the detailed study.
A thesis work of Vinay Mohan[44] studies the application of lean methods in the automotive industry. He has presented the importance of Just-in Time manufacturing in relation with lean. The author provides the future direction to the application of same principles for the shipbuilding and aircraft industry. Patrick Garcia and John Drogosz [45] applied the lean practices at

Tenneco which is an American automotive component manufacturing company. They have pointed out few KPIs for better performance of Lean Practices in an automobile industry. They are training and communication, couple lean training and workshop implementation, active support from the senior management and support from the workforce are few to name them. MZM Ismail and his colleagues[46] evaluated the application of lean practices in the assembly line of an automobile manufacturing process. A special consideration has been given to 5S, VSM and work standardization. The tools like takt time, cycle time, lead time and processing time were used for the quantitative assessment. But the paper fails to discuss the validity of the effectiveness of the tools chosen. It has no idea about time study and observational survey.

Nesreen M. Ahmed with his team[47] evaluated the customer satisfaction due to an appropriate implementation of lean practices in the automobile service sector. The cause-and-effect diagram along with value stream mapping has been used extensively for the analysis and at the ends the customer satisfaction index has been increased by 74.1% as per the report. Moreover, there is a reduction in the takt time and lead time as well. This is an easy approach to consider a service sector with the application of 7 wastes concepts of lean manufacturing. Shyam Lal Sharma and their mates[48] did research at carrier wheel Pvt. Ltd using the lean practices. The important application of lean tools such as JIT, JIS, 5S, Six Sigma, FIFO, LIFO, continuous improvement and Kanban process were critically analyzed for the auto components. They have summarized that the application of those mentioned lean tools have aided them in achieving the product level which led to overall development. Carvalho and Reis [49] demonstrated the application of lean manufacturing system for an automobile component industry in the heavy vehicle segment. Kaizen and value stream mapping has been used for the evaluation. This resulted in the consistent improvement in the productive capacity. The major limitation is that they have focused on a single production line thus being an ideal situation. Moreover, the usage of non-simulation tools was also limiting the results they have obtained.

Manish Tiwari and Bhim Singh[50] evaluated the best tools that can be applied for the process optimization of Indian Automobile Manufacturing Sector. They have selected a company and carried out the detailed study. A project-based approach has been highlighted in the study. The importance of fuzzy and TOPSIS has been clearly defined throughout the paper. Isak Karabegović and his team[51] provided their contribution in terms of analysing the innovative automation of the production process especially in the automobile industry. An idea about intelligent manufacturing process in terms of lean manufacturing is focused throughout their research. It has been provided that China being the leader in industrial robots for automobile industry followed by North America, Japan, Germany and India. Suresh Kumar and Syath Abuthakeer [52] from India evaluated implementation of lean tools and techniques specifically SMED technique for an automobile industry. In the same research, it has been shown that SMED is more beneficial in terms of quick customer response and improved workers' safety. A drastic improvement in the production rate was observed.

Cristina Veres and few others [53] have applied the 5S concepts to analyze its impact in the automobile company in Romania. A positive correlation has been provided between the overall performance of production results. In a study about nut and bolt manufacturing process, the authors established the relationship between 6R and Lean manufacturing

process. Each and every stage of this manufacturing process, it has been clearly related to 6R. [17]

3.9. Research Gap and physical constraints

From the studied literature, few limitations and possible ways for the future improvements were able to identified. Most of the papers discussed the application of lean principles solely in the automobile industry. They haven't provided the base for the application of circular economy. The researchers have pointed out the various branches that comes under lean manufacturing and the importance have been given for such topics. No any researches have been identified with the establishment of the relationship between 6R and process optimization thus both are under circular economy. The previous studies shown that process optimization can lead to the application of circular economy. As mentioned previously, the researches focused on the product, for specific they have considered a single product in a cross-sectional analysis. And no any scalable parameters have been provided in the literature.

From there, it is possible to lead the research in which a process can be considered and evaluated using the 6R approach. Rather than limiting to Sri Lankan perspective, a model-based study can be formulated which can be accommodated for world wide application. With that knowledge, the research can be started with analysis of current trends of automobile industry in terms of organizational sustainability. Identifying the possible locations which require an optimization within the process and applying the 6R with the lean manufacturing practices. Compare the improvements else the changes that have occurred and finally presenting in a working model for the continuous usage of assessment.

There can be possible limitations from the disclosure of data by the industry. The actual data is required for analysis and it may consume some time for data collection. Similar to product-oriented study, a single process selection might be difficult and it has to be considered as an ideal operation. Focus group selection is another issue that can limit the research. The data may vary depending on the country's conditions. This might have an impact on the working model developed.

4. Conclusion

The automobile industry is facing ongoing challenges to improve its sustainability as it consists of complex and energy intense processes. The means to develop strategy to build up the sustainability principles becomes paramount important. Lean manufacturing combines with circular economy would be an advantageous path for this improvement. The current market is struggling to survive due to the vast development of competition with the sustainable manufacturing. The industry failed to optimize their manufacturing process which results in lengthy lead time and declined production rates.

The previous studies relating to the application of lean manufacturing lays the foundation for the application of circular economic approach to automobile industry. The result derived from this literature review shown that the application of lean in combination with circular economic is lacking in the automobile sector. Use of 6R remains the gap that needs to be filled. This triggers the interest towards lean manufacturing and 6R with the intension of optimizing the process in the manufacturing environment.

A base knowledge on process optimization has been obtained and a relationship has been established with circular economy. The selection of an appropriate process for analysis and the related KPIs would be challenging. It can be summarized that; the application would promote the hinges on the integration of lean manufacturing and circular economic techniques. Based on the favorable results shown in the previous studies, 6R method would be applicable to automobile industry.

An apparent tool has to be developed for the measurement of the results as no scalable methods have been explained in the literature. Process optimization is a way for the improvement in a manufacturing world. It is a part of circular economy of any industry. An effective implementation of the circular economy principles will automatically improve the process of automobile industry.

In this detailed study, the concepts like sustainable manufacturing, lean manufacturing, circular economy, 6R and process optimization are discussed in terms of their applications referred from various literature. At the end, the development of a framework is vital necessary where it can be applied worldwide. In the given literature, it has been confirmed that 60% of the researches suggested the application of lean tools alone for the process optimization. Only 20% of the study have witnessed the process optimization in automobile industry. Thus, no any literature combined the concepts of lean and circular economic principles for the process optimization in automobile industry. Apart from the original topic, supplementary analysis has also done to support the research from recent perspectives like industry 4.0. This sort of out-bounded study might enhance the learning for the purpose of developing the strategies applicable for current industries compared to conventional manufacturing environment.

Acknowledgment

I would like to acknowledge the assistance provided by Prof.Seeram Ramakrishna, National University of Singapore and Dr.L.U.Subasinghe, University of Moratuwa in compiling this review.

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