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SUSTAINABILITY DRIVERS AND APPLICATIVE CASE STUDY WITH INDUSTRY4.0 IN A COMMERCIAL VEHICLE INDUSTRY

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Abstract

Industry 4.0 spans the entire gamut from automation to digitalization up to smart factory inclusive of sustainable measures. This paper details few of the sustainable development specific to commercial vehicle manufacturing with key focus on in-house facility development for mitigating product defects, an overview of progressive transformation of facilities and support mechanisms like energy management in a sustainable manner as well as the future course of sustainability on similar areas. The authors further provide practical approaches with examples in each area and the benefits observed.

Keywords – Industry 4.0, Sustainable facilities development, Energy management, Engine facilities transformation.

INTRODUCTION

Industry 4.0 being multifaceted spans the entire spectrum in manufacturing industry with multiple use cases and user stories. It is the springboard into the future of manufacturing wherein dependence on digital data based decision making approach is observed ie decision based on actual facts and numbers. As a start Manufacturing industries requires energy and in particular Electrical energy for its various energy needs like heating, ventilation, cooling, lighting, running mechanical devices through electric motors and drives. In this backdrop Commercial Vehicle(CV) manufacturing is no exception, as electricity is the primary requirement in CV industry to function. Additionally CV industry are continually evolving from mechanical to digital to smart across a time period in a progressive manner due to multiple factors like Capex(cost), technology, scale of adoption, resource constraints and methods. This paper explores with case studies on the nuances of adoption of industry 4.0 across the CV industry taking into consideration sustainability, Self-reliance and adoption of made in India products.

REVIEW OF LITERATURE

To start with a systematic review of literature was conducted to understand research already done, captured as below:

Claude et.al [1] conducted an empirical research in a south African multinational engineering company and the challenges faced by experienced area managers. Further deep dives into the meaning of organizational change and transformation applicable in South African business environment,also themes like speed, effectivity, and Broad-Based Black Economic Empowerment (BBBEE) are discussed. Julian et.al [2] examines i4.0 industrial relevance and related opportunities including challenges as drivers for implementation under sustainability. the study takes different perspective considering company sizes, industry sectors, and the company's role across nearly 746 German manufacturing companies spread across five industry sectors giving a positive outlook from strategic, operational, as well as environmental and social opportunities for i4.0 implementation, whereas challenges with regard to competitiveness and future viability as well as organizational and production fit impede its progress.

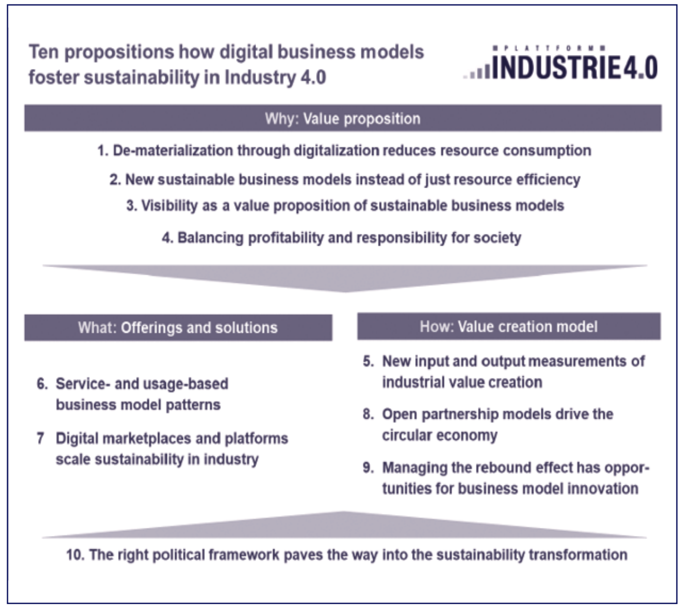
Mirjam et.al [3] has compiled the relation between i4.0 and sustainability based on descriptive and content analysis and presents a theoretical framework. Specific questions of "How does Industry 4.0 affect company sustainability practices and performance? How do sustainability goals affect Industry 4.0 adoption?" are analyzed. Further the impetus on positive aspects over negative aspects of i4.0 are discussed.

Judit et.al [4] discusses on 4 scenarios ie deployment, operation, integration and compliance with sustainable development goals in the long term. Negative relationship observed between production process flow , raw materials, different energy needs, information flow and disposal of waste and the environmental impact. Integrating i4.0 enhances environmental sustainability by creating ecological support system thereby ensuring higher environmental performance. LEONARDO et.al [5] observes an increasing trend between i4.0 and sustainability with its adoption as a pillar under the smart factories umbrella established via bibliometric performance and network analysis (BPNA) treated with Science Mapping Analysis Software Tool (SciMAT) resulting in 12 network structure clusters with patterns in a theoretical mode. Bhaveshkumar et.al [6] explores i4.0 understanding among the Indian manufacturing industries for finding out the motivating factor towards its implementation, assessing their sustainability and its impact on sustainability pillars. Krzysztof et.al [7] evaluates relation between i4.0 and sustainability through review of literatures using systematic literature network analysis and constructed a sustainable i4.0 depiction framework on SLNA. Neaga Irina [8] emphasizes the circular economy approach on sustainable usage of resources and energy. Additionally, advices to enhance the circularity or recycle of the resources and energy within industries based on the actuals with an understanding on the scarcity of natural resources and the waste at the end of life of products may retain some value. Ivic et.al [9] analyses and observes mining companies in Europe on their positive engagement on health, safety, air and water areas while an absence in utilization of renewable energy and waste recycling including gender diversity. Björn et.al[10] analyses the transformative change in accordance with Paris agreement 2030 and presents a comprehensive analysis of literature survey and deliberates on the transformations observed including sustainability. Breno et.al[11] studies the business strategic environmental decisions in a of a luxury car manufacturer based out of United kingdom and understands the basis of green adoption and further shares the benefits attained through green initiatives. Nabila et.al[12] presents a Life Cycle Costing method using different scales for comparing design options and materials used in automotive vehicle. Various Life Cycle Costs considerations were analyzed like environmental damage costs, fuel expenses and materials costs as well as brining in socio-technical vision for a French car manufacturing company. Hab et.al[13] using Lowell Center for Sustainable Production (LCSP) modelled towards analysis of sustainable production and assess automotive manufacturing companies in the European union for crucial key aspects. Empirical studies undertaken based on Corporate Social Responsibility/ Sustainability reports of car manufacturing companies and analyzed and observed that most of the sustainable production practices focusses on sustainability from environment perspective, the employee and social aspects are also present. Wanja et.al[14] focuses on interior development of premium automotive car manufacturers from lightweight construction and CO2 emission reduction and the influence of economical, ecological and social issues from sustainability based on quantitative study considering customer expectation. Caroline et.al[15] conducted a bibliometric analysis in Industrial engineering domain on Automotive sectors sustainability and innovation. The study concludes stating the need for radical innovations for conforming to existing environmental standards like reduction in greenhouse gas emission, life cycle assessment, reverse logistics and ecological innovation emphasizing the need for further empirical studies. Lucian et.al[16] presents a different automotive business model considering three dimensions of organizational sustainability such as Economic, social and environment and validates fifteen principles fo sustainability. The review of literature also observes the applicability in CV manufacturing industries is very limited and present tremendous scope for enhancements.

SUSTAINABILITY

Sustainability as per UN [a] is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Present generation engineers are accountable for sustainability as they engineer the tomorrow. Therefore, the impetus on the engineers are way much more in terms of bringing in efficiency into operations, planning of new / upgrading existing facilities thereby protecting the future generation from deprivation. Engineers in manufacturing industries tend to adopt industry 4.0 towards achieving sustainability as stated by Pillar et.al[17] in figure 1.

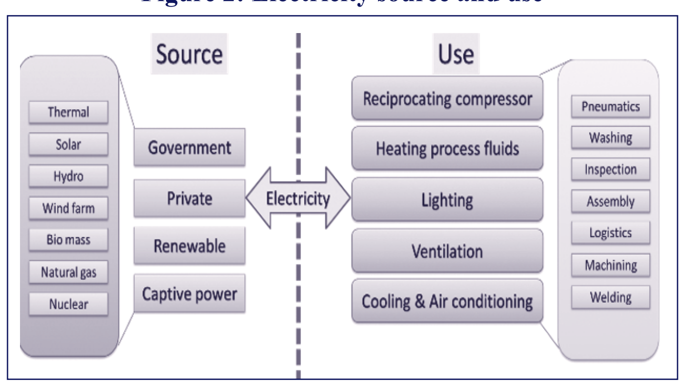
Figure 1: Ten propositions how digital business models foster sustainability in industry 4.0



Manufacturing industries of which CV also forms a part use many forms of resources of which Electricity (power) forms a major one.

Power in Manufacturing Industries:

Figure 2: Electricity source and use



Manufacturing industries rely heavily on usage of Electrical power (nearly 55% of operating expenses) for its various manufacturing requirements. Details are broadly summarized in Figure 1.

The usage of electrical power in CV industries especially in assembly lines are mostly towards compressed air generation which are used for operating pneumatic tightening tools used in assembly processes.

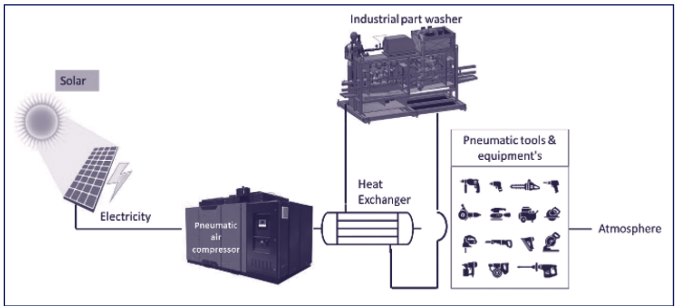


Figure 3: Heat recovery from pneumatic compressor

Case study 1:

The pneumatic compressors in addition to providing compressed air output also produces lots of heat which are vented to the open atmosphere as tabulated in table1. It can be observed that nearly 85% of input power get transformed into recoverable heat while 10% are un-recoverable and only 4% get converted into compressed air.

Table 1: Conversion of input power to compressed air

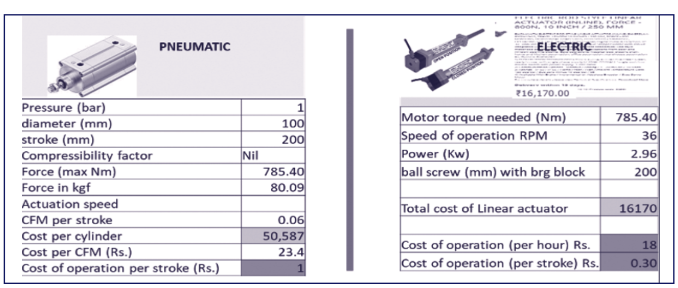
Electrical power 100%	Motor Losses – 8%	Compressed air – 4%
		Unrecoverable heat – 10%
	Hot air – 25%	Recoverable heat – 85%
	Hot Oil – 67%	

Through the usage of thermic fluid based heat recovery system given in Figure 2, the waste heat are captured and used for heating industrial part washers installed in machine shops, thereby the usage of heavy duty industrial grade dip type heaters needed for heating the alkaline degreasing solution in the bath of industrial part washers and the corresponding energy consumption reduced by 50Kw per air compressor of Atlas copco GA 90 model (reference data).

Case Study 2:

Compressed air is also used for operating multiple pneumatic devices like cylinders and actuators which are used in machine tools for operating doors, slides and multiple machine elements. Also pneumatic hoists are in use for material handling purposes. A theoretical study undertaken for one case of converting a pneumatic cylinder based application with electric slide equivalent is presented in Figure 3.

Figure 4: Substitution analysis of pneumatic cylinder with electric slide



PNEUMATIC

Pressure (bar)	1
diameter (mm)	100
stroke (mm)	200
Compressibility factor	Nil
Force (max Nm)	785.40
Force in kgf	80.09
Actuation speed	
CFM per stroke	0.06
Cost per cylinder	50,587
Cost per CFM (Rs.)	23.4
Cost of operation per stroke (Rs.)	1

ELECTRIC

₹16,170.00

Motor torque needed (Nm)	785.40
Speed of operation RPM	36
Power (Kw)	2.96
ball screw (mm) with brg block	200
Total cost of Linear actuator	16170
Cost of operation (per hour) Rs.	18
Cost of operation (per stroke) Rs.	0.30

It can be observed that the running cost per stroke of electric slide is 33% that of made in India Pneumatic slide which interprets in a savings of 67% of running cost for power alone. This switch / change in technology has enormous potential in reducing the variable manufacturing cost of the product being produced. Also the fixed cost of electric slide is less than 50% the total cost of pneumatic circuity, this has potential for CAPEX (Capital expenditure) reduction thereby potential for reduction in fixed cost of manufacturing. Engineers in manufacturing locations have the skill set needed to identify such cases and bring about savings and benefits to manufacturing organizations in a more sustainable manner.

Case study 3:

As stated in the beginning, nearly 55% of total operating cost is towards power. Therefore, adopting of renewable energy sources in manufacturing organizations have large benefits to the business operations and profitability. A south indian large CV manufacturing company have reported that the usage of Wind energy has reduced external power demand upto 23%. Similarly, Solar source of electricity generation has saved the company 37% of total energy consumption. In all about 60% of power consumption is met by renewable sources thereby paving way for more sustainable operations. Other sustainability initiatives like wood free operation (reduction by 15%), Carbon neutrality through tree plantation (~ 96,000 trees), Water conservation being water positive and recycling 60% of water needs also contribute to the company's profitability. These are being monitored through industry 4.0 tools. Additionally, various energy conservation measures like LED fication, optimization of cooling towers, usage of Energy efficient motors (EE3 classification), Interlocking hydraulic pump operations based on hibernation mode of main systems, Dust collection system interlock with main machines, Diesel to LPG conversion of ovens in foundry application are some of the initiatives taken up towards reduction of consumption and are also being monitored through IOT devices.

Case study 4:

Since CV manufacturing involves large manufacturing facilities due to the size of the product under manufacture, lots of components and sub assemblies needs to be aggregated and assembled in the right order with the right torque to specification. Operator errors results in high severity needing product recalls [b][c]. These were planned to be mitigated by engineers working in the manufacturing lines through a concept called 'Interlocking' wherein feedback based tools were interlocked with the assembly conveyor in such a manner that without operation completion the product does not index to the next stage of assembly. While the concept is fairly simple at the face of it, multiple challenges exists starting from the need for facility upgradation, procurement of feedback based tools, providing error proofing devices, establishing Communication with legacy systems, availability of budget and times. These were planned to be mitigated through a phased and frugal approach by engineers through enabling feedback from existing electric tools, upgrading selective pneumatic tools with feedback mechanism, upgrading the programmable logic controllers in the existing manufacturing setup and usage of Supervisory Control and Data Acquisition system at less than 10% the cost of new systems. Through the usage of such systems costly product recalls were reduced and products were produced in a more sustainable manner. ECRSO (Eliminate, Combine, Reduce, Simplify & Optimize) method were exclusively used for the above project towards bringing in frugality and cost savings for the company.

CONCLUSION

The paper can be taken as a reference for manufacturing industries on their journey towards reaching sustainable industry 4.0 in manufacturing. The case studies presented provide good references towards easy adoption in sustainability and ideation for more applicative developments across the manufacturing industry in a progressive manner.

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