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Transformative Impact of Industry 4.0 Technologies on the UK Manufacturing Sector

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Table of Contents

1. Introduction

The introduction of Industry 4.0 has brought a revolution not in the IT industry but in the manufacturing sector and in the society. The impact of Industry is so huge that even the concept of smart cities has been formulated based in Industry 4.0 technologies. The motivation of the study is driven from the significance of the Industry 4.0 technologies. In the manufacturing sector, there are various domains that are being affected by the Industry 4.0. However, this study decided to focus on the variables of OEE and competitiveness in context with the size of the organization. In the research domain of operations and production management, the research interest is being developed to study the impact of Industry 4.0 technologies on the manufacturing sector. The research focuses on OEE and competitiveness as these are also relevant topics within this research domain. The study aims to explore the significance of the Industry 4.0 technologies on the above mentioned areas of the interest. This will help us to understand the

nature of the relationship among them and will give us the insight to investigate the impact of the Industry 4.0 on the manufacturing sector.

This thesis is focussed on the factors that are involved in the decision-making process of flexible product development. Organisations need to be innovative and competitive while designing and launching flexible products into the market as competition can force the companies for continuous R&D to produce new products constantly keep up with the market forces. Sometimes, organizations are not sure what might be the right strategy for product development due to rapid changes in the consumer preferences. Organisations develop flexible products in terms of their functionality to reduce uncertainty to cater the wide range of consumer preferences. Products that can be used in multiple variations and can be reconfigured into different settings so that consumers can use them according to their need and desire are called flexible products. For example, electric shavers come with different trimmer sizes. This

option gives consumers multiple choices to use the electric shaver. Nes et al. (2005) argue that flexible products last longer because they cannot be replaced by any other product so it might give companies a level of certainty in consumer market in terms of consumer preferences.

2. Purpose of this study

The purpose of the study is to determine the effects of the implementation of Industry 4.0 technologies on the manufacturing sector. The implementation of Industry 4.0 technologies is being assessed based on organizational size, OEE and competitiveness. The scientific literature available related to these topics have shown evidence that there is a connection between them and the implementation of the Industry 4.0 technologies. In the light of the literature, the below mentioned hypothesis are being developed to be tested against the data which will be collected. The hypotheses are divided into different sections. The analysis of these hypotheses will tell us how the implementation of Industry 4.0 affects them and whether these variables play a significant role in it or not.

Organizational Size

H1: There is a positive influence of organizational size on the time since Industry 4.0 technologies been implemented.

H2: There is a positive influence of organizational size on the implementation of Industry 4.0 technologies.

H3: There is a positive influence of organizational size on the organizational readiness for Industry 4.0 technologies.

OEE

H4: There is a positive relationship between OEE and the Industry 4.0 technologies.

H4.1: There is an inverse relationship between Industry 4.0 technologies and downtime.

H4.2: There is an inverse relationship between Industry 4.0 technologies and setup time.

H4.3: There is an inverse relationship between Industry 4.0 technologies and defective products.

H4.4: There is an inverse relationship between Industry 4.0 technologies and performance loss.

H4.5: There is an inverse relationship between Industry 4.0 technologies and speed losses.

H4.6: There is an inverse relationship between Industry 4.0 technologies and planned/unplanned stoppages.

Competitiveness

H5: There is a significant impact of Industry 4.0 technologies on competitiveness

H5.1: There is a significant impact of Industry 4.0 technologies on reduction in resource usage

H5.2: There is a significant impact of Industry 4.0 technologies on reduction in production cost

H5.3: There is a significant impact of Industry 4.0 technologies on increased manufacturing capabilities

H5.4: There is a significant impact of Industry 4.0 technologies on increased R &D

H5.5: There is a significant impact of Industry 4.0 technologies on increased product quality

H5.6: There is a significant impact of Industry 4.0 technologies on increase mass customization

H5.7: There is a significant impact of Industry 4.0 technologies on increased operational efficiency

H5.8: There is a significant impact of Industry 4.0 technologies on flexible manufacturing process

H5.9: There is a significant impact of Industry 4.0 technologies on more flexible product design

3. Theoretical Aspects

The concept of Industry 4.0 has been discussed in an extensive detail along with its beginning from the digital transformation and how organizations make their decisions towards it. The literature has also discussed the complete implementation process of the Industry 4.0 technologies along with its prerequisites. The concept of manufacturing performance is also being reviewed in thoroughly in the context of OEE. The different dimensions of competitiveness are also being debated in the study in the relation with the Industry 4.0 technologies.

According to Abdirad et al. (2020), Duan & Da Xu (2021), Sigov et al. (2022), Xu (2020), Sony & Aithal (2020), Castelo-Branco et al. (2019), Gorkhali (2022), King et al. (2020) and Kumar et al. (2022) Industry 4.0 plan was announced by German government in Hannover fair in 2011. Initially, it was aimed to boost the competitiveness in the national manufacturing but it

triggered a revolution in the manufacturing sector all over the world. According to Mariani et al. (2019) originally Industry 4.0 was defined as “Industry 4.0 involves the technical integration of cyber-physical systems (CPSs) into manufacturing and logistics and the use of internet of things and Services in the industrial processes.” Abdirad et al. (2020) have defined Industry 4.0 as “a comprehensive introduction of information and communication technology (ICT) as well as their connection to IoT, services and data, which enables real time production”. King et al. (2020) argue that it is a next evolution of the industrial automation with increasing levels of communication and information available of the devices. Mateo & Redchuk (2022) have defined CPS as “a system with integrated computational and physical capabilities that can be interfaced in different ways”. Kim (2017) states that CPS is an integration of cyber systems with physical equipment. According to Li (2018) and Dalenogare et al. (2018) Industry 4.0 focuses on smart manufacturing and CPS that helps in the integration of digital technologies like

3D printing, Cloud Computing and IoT. According to Gorkhali (2022) Industry 4.0 has three stages of implementation. First stage is the introduction of smart technologies that take control over usage of resources and the whole manufacturing process. At the second level, smart technologies are being integrated together to form a CPS which helps to carry out the transition phase from conventional manufacturing to smart manufacturing. At the third stage, CPS integrates with humans to create human-machine work environment. It will assist human operators to control, monitor and perform all the manufacturing functions. This platform will establish a collaborative manufacturing ecosystem that can help to design sustainable digital manufacturing entities. Lu (2017) argue that CPS functions as an infrastructure that provides a foundation for integration of physical manufacturing facilities with internet and computer applications to form a system that relies on networking and information processing technologies. Industry 4.0 advocates a new phase of industrial revolution which is technology and innovation driven.

However, the term Industry 4.0 is described as “fourth generation of industrialization” but the term “revolution” is also being used in academic literature. Some other terms are also used in the academic literature but the most common term is “smart manufacturing.” The word smart means an object with additional features and enhanced capabilities; when it is coupled with manufacturing then it means a connected manufacturing environment with the help of internet and other communication tools (Culot et al. 2020, p. 12).

According to Culot et al. (2020) the idea of Industry 4.0 is originally focused on the impact of evolving technologies in the world of manufacturing. Zhang & Chen (2020) and Mateo & Redchuk (2022) have termed Industry 4.0 as a significant change in the manufacturing sector as it enhances manufacturing system efficiency and performance. However, now the concept of Industry 4.0 is in relation with the transformation of consumer behaviours and society on the whole. The horizon of industry 4.0 is so vast and heterogeneous that it cannot

be called a single technological breakthrough as it consists of several technologies. A combination of these technologies which are still evolving and function as enabling technologies is called Industry 4.0. Xu (2020) and Lasi et al. (2014) advocate that Industry 4.0 is comprised of theoretical concepts, technologies and organizational processes. It means that not only manufacturing system needs to be integrated but also the organizational units.

3.1 Conceptual Framework for Industry 4.0

Frank et al., (2019) have proposed a conceptual framework of Industry 4.0 which is based on two categories. These categories include baseline technologies and frontline technologies. One approach is smart factory which provides smart and intelligent production. Others include management, supply chain and consumer handling. The frontline technologies are *smart manufacturing, smart working, smart supply chain and smart products.* These are called frontline

technologies because they offer a transformation of traditional manufacturing into advanced manufacturing which is known as smart manufacturing in the literature. On the other hand, Kumar et al. (2022) argue that in Industry 4.0, machines are connected and integrated through sophisticated baseline technologies which include CPS, IoT, BDA and etc.

According to Duan & Da Xu (2021) and Zhang & Chen (2020) CPS plays a critical part in the implementation of Industry 4.0. Choudhary & Mishra (2021) state that implementation of Industry 4.0 is a challenge as it not only requires money or government support but also requires technical education and skillset. CPS can be termed as an architecture to integrate all the components. If CPS is poorly designed then Industry 4.0 will not perform. CPS helps to integrate all the enabling technologies within the framework of Industry 4.0. These baseline technologies are also known as Industry 4.0 enablers and without them it is not possible to lay down the foundation of Industry 4.0 enabled smart

manufacturing. These Industry 4.0 enabling technologies are further categorized and discussed in detail in the next section. This study uses a modified conceptual framework in the light of available literature. The modified conceptual framework can be seen in figure 1.

The research is focused on the aspect of smart manufacturing only as Industry 4.0 is a wide concept and this study has its own limitations. The motivation of choosing smart manufacturing is that it is related to the OEE and manufacturing competitiveness. The introduction of Industry 4.0 technologies in manufacturing can improve OEE, build competitiveness and help to achieve a closed loop manufacturing cycle. Frank et al. (2019) define smart manufacturing as a production system that can be adjusted automatically multiple times with flexible process lines to produce several products with different variations. It helps organizations to increase productivity, quality, flexibility, sustainability and mass production of customized products with better resource consumption.

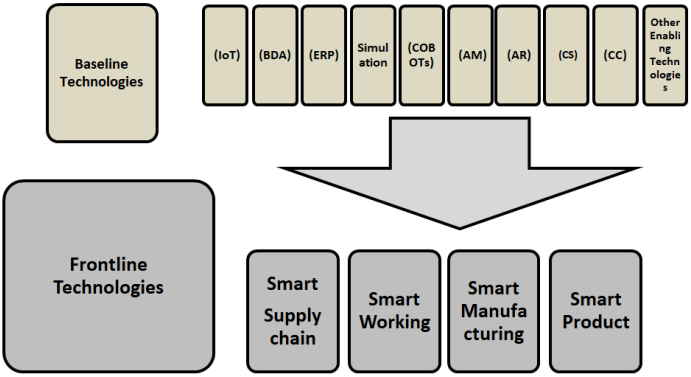

Figure 1: Industry 4.0 Conceptual Framework

Source: Frank et al. (2019)

4. Research Design & Methodology

The manufacturing industry faces growth and expansion challenges all the time. These challenges obviously require managerial attention and focus so that they can be addressed by improving the manufacturing processes. The activities in the manufacturing industry are rather complex and they require scientific solutions to the growing challenges of the time. According to Kumar (2014) research is not only a set of skills but it is also a way of thinking.

The impact of industry 4.0 technologies on the manufacturing industries is a truly relevant topic at this time. The impact contributes to the performance improvement on various grounds in the manufacturing sector. This scientific research aims to deliver a scientific study on the implementation of Industry 4.0 technologies and its impact on the performance. In this regards, individual researchers are always free to choose

the methods, techniques and procedures that best meet their need and purposes.

According to Zikmund et al. (2009) a research design includes a detailed, systematic outline of the research methodology. The process of data collection and analysis is defined in the quantitative exploratory research. For economical and time reasons, an online questionnaire has been designed supported by Microsoft forms platform. The questionnaire has been prepared in a professional manner and host website collects the data. The data can be downloaded in the form of MS Excel. The core of this research is primary data which was collected from manufacturing companies of all sizes located in United Kingdom. The instrument that is used for data analysis is SPSS.

Zikmund et al., (2009) argue that the design phase is like a master plan of a scientific research based on methods and procedures for the purpose of collection and analysis of data. The structured research approach is based on

data collection and analysis. Followed by general methodology, questionnaire design, pre-testing, final data collection and return ratios are discussed in the later stages.

The main purpose of scientific research is to evaluate the hypothesis against the gathered data. The impact of Industry 4.0 enabling technologies on the manufacturing sector will be tested and the hypothesis will be proved or disapproved accordingly. In the online survey approach, there are some advantages and there are some possible risks that are associated with this approach. For that purpose, a pre-test has been conducted to mitigate the possible risks in the data collection process. For the purpose of the research, the UK's manufacturing sector has been chosen to analyse how Industry 4.0 is affecting the UK's market and how UK's market is reacting to towards the industry 4.0 technologies.

4.1 Online Survey Conduction and Questionnaire Design

A written survey by means of an online questionnaire has been used for the purpose of research. The use of online questionnaires is a pragmatic approach when it is being compared to the interview. The advantages of an online questionnaire include lower cost and less consumption of time. These days' lots of Masters and PhD students are relying on internet to conduct their thesis due to the technological advancements. One major advantage that outweighs any other disadvantage is the low cost of setting up an online questionnaire. Once the online questionnaire is live, researcher can only count the number of participants until it reaches the required number of participants. One another advantage is anonymity. Participants and research do not need to know each other and participants do not have to feel pressure to participate, it increases the honesty. One of the major inevitable limitations to the online questionnaire is self-selection bias. It means that

respondents who are actually interested in the topic will fallout the questionnaire. This bias does not invalidate the results but requires careful interpretation of results (Dewaele, 2018). The questions are simple and specific in nature to avoid cognitive overload, so Likert scale questionnaires are preferred in the questionnaire to obtain maximum number of responses possible. On the downside, simple nature of questions may cause shallowness but it also can be avoided through mixed method approach by adding qualitative and quantitative data.

The method of choosing online questionnaire has been chosen for the following reasons.

- Evaluation of the results is anonymous as possible to ensure that all respondents have answered the questionnaire with honesty and openness as possible.
- An automated data collection tool is required to handle large numbers of respondents.

- The online questionnaire platform is easy to use; respondents can spend 5-10 minutes to fill out the questionnaire without any complicated steps.
- A hyperlink is being used to request the respondents to complete the questionnaire. It helps to avoid taking unnecessary storage space within the mailing system of the respondents.
- The online questionnaire has been made easy and convenient to use for the respondents in hope of attaining maximum number of participants possible.

It is also important to highlight any disadvantages of using online questionnaires for the purpose of research. Some of the disadvantages are listed below.

- It is a time consuming and difficult process to program an online questionnaire. A specialized online platform “Microsoft forms” has been used to design the online questionnaire.

- There are no high or specific IT skills required to formulate an online questionnaire on this platform. The hyperlink allows access to the participants to participate in the questionnaire in a digitally secure and protected way.
- Multiple participation in the online questionnaire can be avoided through built-in installed cookies.
- The identification problem can occur when it is not possible to make sure that the invited respondent is participating in the online questionnaire.
- The return-rate problem can arise when the respondent partially fills the questionnaire.
- Communication problems can arise from asynchrony in between the moment when questions arise and answered in the questionnaire. It is also mentioned that the clarification can only be asked upon the initiative of the survey respondent.

To mitigate the risks associated with the online questionnaire, the following measures has been taken apart from pre-testing.

- Participants were contacted through telephone/WhatsApp.
- Invitation emails were sent to the participants of the online questionnaire personally.
- Reminder emails were sent approx. after 2 weeks of the initial contact with the participants of the questionnaire.
- A valid email address was shared to all the participants via online questionnaire in case of any questions so that authenticity and validity of the survey can be maintained.

The online questionnaire only contained closed and selection type questions. It helped to increase the analysis process of the data collected. In selection type closed ended questions; respondents have a choice to select most suitable answer from the pre-defined options.

A multi-level Likert scale is being used in this research. In this method, possible answers can range from agree to disagree and from being neither agree/disagree or neutral. According to Wenderoth, (2013) Likert scale type questions are commonly asked and they are quite easy to analyze in regard with averages, mean values and standard deviations. Moreover, single option questions are also used with pre-defined answers where respondents could select best suitable answer from them.

5. Results & Analysis

H1: There is a positive influence of organizational size on the time since Industry 4.0 technologies been implemented.

The result shows a positive significant relationship between the organization size and the adoption time of Industry 4.0 technologies. Although the strength of the relationship is weak, the importance of organization's size cannot be ignored completely.

H2: There is a positive influence of organizational size on the implementation of Industry 4.0 technologies.

The positive relationship that has to be found in only 4 technologies is also positive weak while Internet of Things have shown negative relationship with respect to the organization size. It can be concluded by the results that organization size is likely to be the reason for the implementation of the Industry 4.0 technologies.

H3: There is a positive influence of organizational size on the organizational readiness for Industry 4.0 technologies.

The results indicates that prerequisites include Financial Capacity and Technical Capabilities have significant positive relationship with organization size independently while the strength is moderate. On the other hand, prerequisites include Installed Certified Hardware, Firewall Data Security, Awareness of Limitations, Manufacturing Knowledge SOPs and Production Ordering & Scheduling Capacity Software have a significant positive relationship with organization size independently but their relationship strength is weak. The prerequisites like System Integration for Interoperability has shown as negative relationship with the organization size. Whereas, Professionally Trained Workforce, High Speed Internet Networking and Thorough Mapping of Operational Processes have a no relationship with the organization size independently.

H4: There is a positive relationship between OEE and the Industry 4.0 technologies.

The results of H4 are given in the table 10a which shows that there is no relationship at all between the OEE and Industry 4.0 technologies.

H4.1: There is an inverse relationship between Industry 4.0 technologies and downtime.

H4.2: There is an inverse relationship between Industry 4.0 technologies and setup time.

H4.3: There is an inverse relationship between Industry 4.0 technologies and defective products.

H4.4: There is an inverse relationship between Industry 4.0 technologies and performance loss.

H4.5: There is an inverse relationship between Industry 4.0 technologies and speed losses.

H4.6: There is an inverse relationship between Industry 4.0 technologies and planned/unplanned stoppages.

It can be clearly seen from the table 10a that Industry 4.0 technologies have failed to establish any relationship with the any of the factors of the OEE independently however, this study manages to establish a weak positive relationship between Current OEE and the implementation of Industry 4.0 technologies. It appears to be inconclusive, so therefore, the research rejects the hypothesis from H4.1 to H4.6 as well.

H5: There is a significant impact of Industry 4.0 technologies on competitiveness

The results shows p-value = 0.05 so we accept H5 and conclude that Industry 4.o significantly impact competitiveness and it's dependent on the Industry 4.0 technologies.

H5.1: There is a significant impact of Industry 4.0 technologies on reduction in resource usage

H5.2: There is a significant impact of Industry 4.0 technologies on reduction in production cost

H5.3: There is a significant impact of Industry 4.0 technologies on increased manufacturing capabilities

H5.4: There is a significant impact of Industry 4.0 technologies on increased R &D

H5.5: There is a significant impact of Industry 4.0 technologies on increased product quality

H5.6: There is a significant impact of Industry 4.0 technologies on increase mass customization

H5.7: There is a significant impact of Industry 4.0 technologies on increased operational efficiency

H5.8: There is a significant impact of Industry 4.0 technologies on flexible manufacturing process

H5.9: There is a significant impact of Industry 4.0 technologies on more flexible product design

Based on the discussion and results, we can conclude that H5.4, H5.6, H5.8 and H5.9 are accepted.

6. List of Publications

1. Smart Manufacturing as a Management Strategy to Achieve Sustainable Competitiveness. (Not a Duplication)

Journal of the Knowledge Economy

https://doi.org/10.1007/s13132-023-01097-z

2. Designing a Conceptual Framework for Industry 4.0 Technologies to Enable Circular Economy Ecosystem

Managing Global Transitions: International Research Journal (Accepted and to be published in June 2023)

3. Implementation of Industry 4.0 Enabling Technologies from Smart Manufacturing Perspective Journal of Industrial Integration and Management

https://doi.org/10.1142/S242486222250021X

4. The Future of Flexible Products Manufacturing by Using Industry 4.0 Technologies in Regard with Consumer Preferences.

The Hungarian Journal of Marketing and Management Vol. 55 No. 03 (2021)

https://doi.org/10.15170/MM.2021.55.03.01

5. The Private Label Brands (PLBs): A National Brand Manufacturer-Retailer Relationship Perspective.

VI. International Winter Conference of Economics PhD Students and Researchers, Szent István University Gödöllő, Hungary, 2020

https://oszkdk.oszk.hu/DRJ/32826/cimkes

6. Smart manufacturing as a management strategy to achieve sustainable competitiveness. (Not a Duplication)

Farkas Ferenc II International Scientific Conference 2020

https://digitalia.lib.pte.hu/hu/pub/balogh-laszlo-sipos-farkas-f-ii-nemzetkozi-tud-konf-2020-ptektk-pecs-2020-4257.

7. The Relationship between Industry 4.0 & Circular Economy in the context of Sustainability.

IV. BBS International Sustainability Student Conference Proceeding. Budapest Business School, Hungary 2022

http://publikaciotar.repozitorium.uni-bge.hu/1865/