

Are Welsh Manufacturers Ready for the Adoption of Industry 4.0 into Existing Lean Processes?

A Research Proposal

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1. Introduction

Industry 4.0 is considered to be the change in industries from traditional manufacturing to advanced smart manufacturing through the use of modern technologies such as Cyber-Physical Systems (CPS), Artificial Intelligence, Internet of Things (IoT), Big Data and Robotics (Pereira & Sachidananda, 2021). According to Schwab (2016), this is the first time in the history of industry that such a paradigm shift is occurring at an unprecedented pace, creating the so called 'Fourth Industrial Revolution'. With Industry 4.0 upon us, alignment with its requirements is unavoidable for manufacturers if they are to remain competitive and ultimately survive (Maisiri & Van Dyk, 2019).

Lean Manufacturing, a term popularised in 1990 by Womack et al, has been the go-to production system for manufacturers for many years. The popularity of Lean has consistently grown due to the expected benefits that Lean can bring, such as consistent quality, improved efficiency and customer satisfaction, made possible through the elimination of waste (Womack, et al., 1990). Becoming a Lean manufacturer is not an overnight occurrence, organisations devote years of investment and training to obtain a Lean culture, it is more than processes and systems; it is a way of life where employees at all levels are engaged (Ohno & Bodek, 1988).

The emergence of Industry 4.0 has led to Lean manufacturers questioning the compatibility of Lean and Industry 4.0, with many fearing that the Lean culture they have invested so much in may become obsolete and replaced by Industry 4.0 (Pereira & Sachidananda, 2021). Previous studies (Sanders, et al., 2016; Roy, et al., 2015) recognised this was not the case. One report by Roy, et al., (2015) stated that the adoption of Industry 4.0 will not eliminate lean manufacturing but will help to increase the maturity of the firm's lean programme, as the two philosophies are not that different to each other and are capable of complimenting one another when used together. Kolberg, et al., (2017), wrote that Lean manufacturing has a huge potential to adopt Industry 4.0 technologies in manufacturing and together they can improve productivity and decrease waste. Industry 4.0 can also assist Lean manufacturers with keeping up with customer demands, a necessity since customisation has become a major trend (Rossini, et al., 2019).

Tortorella, et al., 2019 amongst others, see Lean adoption as a necessity prior to adopting industry 4.0 if an organisation is to experience the full benefit. However, many Lean manufacturers who are recognising the opportunities Industry 4.0 can provide are still unsure if they are ready for it and if in fact, it will provide the expected benefits.

Manufacturing in Wales is the largest contributor of Gross-Value Added (GVA) to the Welsh economy (Welsh Government , 2021), it is therefore essential that the industry keeps up with technological advances provided through Industry 4.0 to provide a competitive edge against other countries. Additionally, the rise of Welsh independence from the United Kingdom is on the increase; therefore, if Wales pursue becoming an independent country, Welsh industries need to succeed.

The objective of the proposed research is to understand the current state of Lean and Industry 4.0 adoption in Wales while determining if Lean Welsh manufacturers considering Industry 4.0 adoption are ready to do so.

While reviewing current literature, it was evident that no studies have taken place that solely focus on Industry 4.0 readiness for Welsh manufacturers. Therefore, this study will aim to close this gap by tackling the following research question (RQ):

RQ: Are Welsh manufacturers ready for the adoption of Industry 4.0 technologies into existing Lean Processes?

The study aims to benefit manufacturers by benchmarking the Industry 4.0 situation in Wales. Additionally, the study can be beneficial to the Welsh Government in understanding the current situation in Wales and the mind-set of manufacturers, ultimately enabling the government to determine if Wales is moving in the right direction.

2. Literature Review

2.1. Industry 4.0

To understand the significance of Industry 4.0 and what it means for Wales, it is necessary to understand the definition of the term and what it has to offer.

Industry 4.0, also referred to as ‘The Fourth Industrial Revolution’ is considered to be the change in industries from traditional manufacturing to advanced smart manufacturing through the use of modern technologies such as Cyber-Physical Systems (CPS), artificial intelligence, internet of things (IOT), big data and robotics (Pereira & Sachidananda, 2021).

The term Industry 4.0 was first used in Hannover, Germany in 2011. It referred to an ongoing project involving the government, private sector and academia. The objective of the joint venture was to initiate and enhance Germany’s competitiveness in the manufacturing sector (Kang, et al., 2016). Similar approaches have since been applied in other countries, in the USA they announced the ‘Advanced Manufacturing Partnership’, China launched ‘Made in China 2025’ and the UK’s response was the ‘Smart Factory’ project, to name just a few (Kumar, et al., 2020).

According to Moeuf, et al., (2018), there are as many as 100 different definitions of Industry 4.0 identified during their research. This supports Buer’s, et al. 2018 observation that over time, the Industry 4.0 term has evolved into a label for describing the next era of manufacturing, where during this process the term has become a “poorly defined buzzword for the future of production”. Since Buer, et al’s. (2018) paper, Kumar, et al., (2020) ‘*Industry 4.0: Complex, Disruptive but Inevitable*’ article presented a definition that frequently appeared during the literature review which is a popular choice for the definition of Industry 4.0;

Industry 4.0 is a generic term used for complex and automated manufacturing systems, services, and processes where devices are self-aware, communicating with each other and humans. Further, they can be accessed remotely and take remedial actions and apt decisions instantly according to situation with the use of artificial intelligence, prior experience and data available in the network and cloud” (Kumar, et al., 2020).

2.2. Lean Manufacturing

The term Lean manufacturing was made popular through the book ‘The Machine that Changed the World’ by Womack, et al. (1990). The first use of the term is accredited John Krafcik in 1988 to provide his own definition of the Toyota Production System (TPS). The TPS began its life in 1945, after Toyota founder Kiichiro Toyoda challenged his company to catch up with its Western competitors. With limited resource and finances, a different approach was needed (Poppendieck & Poppendieck, 2007). This new approach came in the form of then assembly shop supervisor Taiichi Ohno. Tasked with turning Toyoda’s vision into reality, Ohno would go onto develop what would become the Toyota Production System (TPS), (Vanguard, 2020).

The TPS philosophy represents a culture of continuous improvement (Kaizen), by setting standards with one clear objective in mind; eliminate waste (Muda).

Defined as any task that does not add value to the product or the customer, seven waste categories were identified by Ohno: Transportation, Inventory, Motion, Waiting, Over-Processing, Over-Production and Defects, or commonly referred to as the acronym ‘TIMWOOD’ (Neuwirth, 2019). Eliminating these wastes can significantly reduce the time taken to deliver an order to the customer while keeping costs to a minimum without affecting the overall quality of the product (Smalley, 2000).

Using the TPS as their foundation, Womack, et al. (1990) popularised the Lean ideology through their ‘Five Lean Thinking Principles’: pull production, value stream, value, flow and pursuit perfection (continuous improvement). The five Lean principles mentioned are considered the main drivers towards the adoption of Lean Manufacturing, providing a baseline for a ‘change-promoting work environment’ where workers are encouraged and motivated to think, look for problems and to go and solve those problems (Womack, et al., 1990).

2.3. Lean 4.0

The concept of ‘Lean 4.0’ where Lean meets Industry 4.0 is increasingly discussed in recent literature (Buer, et al., 2018). From the review, two perspectives, regarding how the two can interrelate with each other emerged. One perspective is that Industry 4.0 is an essential compliment to Lean (Tortorella, et al., 2019, Kolberg, et al., 2017). With customer demands and products becoming more complex and personalised, many believe Lean principles by itself will struggle to remain effective. Sanders, et al., (2016) amongst others state that Industry 4.0 and Lean can work together to ensure organisations keep up with the pace of customisation, whereby Lean can use Industry 4.0 as a portal to adapt to new manufacturing trends while ensuring the robustness of Lean processes are preserved (Ciano, et al., 2020).

The second perspective refers to lean as a foundation for Industry 4.0 adoption (Kümmel, et al., 2017). With the main focus of Lean aimed at waste reduction along the entire process (Womack, et al., 1990), a process that is already stream lined and under control can help achieve the full benefits when digitalising (Buer, et al., 2018). Rossini et al., (2019) adds that organisations with a significant level of Lean adoption will benefit the most from Industry 4.0.

Ciano, et al., (2020) summarises that Lean is not a ‘binary prerequisite’, yet it ‘amplifies the positive effects of digitalization’.

2.3.1. Lean 4.0 in Practice

Just-in-Time (JIT) in a Digital Supply Chain

Just in Time (JIT) first established by Toyota, is one of the pillars of the TPS (Sugimori, et al., 1977). For the JIT principle to work, it is essential that inventory information is accurate and timely to prevent large buffer and safety stocks (waste). The digitalisation of supply chains can improve this through the use of real-time data, providing transparency and accurate tracking of inventory throughout the organisations.

Jidoka and Cyber-physical Systems

Another of the TPS pillars, Jidoka or loosely translated as ‘Automation with a Human Touch’ (Hinkley, 2007), refers to the ability of machines to detect issues. From an Industry 4.0 perspective, Cyber-Physical Systems (CPS) can do just that through its capability to provide intelligence to machines, facilitating and enhancing automation (Ohno & Bodek, 1988) by reporting issues instantaneously, initiating root cause analysis and corrective actions, resulting in little to no down-time during the manufacturing process.

Value Stream Mapping (VSM) and the Internet of Things (IoT)

VSM, regarded as one of the most significant Lean tools, is widely used by companies to identify waste (Muda) within its processes. However, Garza-Reyes (2020) states that the VSM only provides a snapshot of a process at a specific point in time. Industry 4.0, through technology such as the Internet of Things (IoT) and Radio Frequency Identification RFID, can enhance the VSM by collecting and providing real-time and accurate data.

2.4. Wales 4.0

With its long history in Wales, manufacturing, the largest contributor of Gross-Value Added (GVA) to the Welsh economy, provides essential employment to thousands of people and scores of communities throughout the country. However, manufacturing is in the midst of one of the most intense periods of change in its history, where a combination of issues such as Brexit, the COVID-19 pandemic, climate change, the increasing pace of globalisation and the eruption of new technologies affecting customer choices are all playing a significant part (Welsh Government, 2021). As a response to the future challenges in Wales, the Welsh Government announced their Manufacturing Action Plan (MAP) – ‘A Manufacturing Future for Wales’ in February 2021. The plan aims to tackle six over-arching issues:

1). Equality and Diversity 2). Language & Culture 3). Research, development and innovation 4). Data, information and knowledge 5). Public sector procurement 6). Business support.
Industry 4.0 will have a significant part to play within the MAP as the array of technology it can offer will be a key ingredient to tackling each of these issues and ensuring Welsh manufacturing remains ahead of the curve (MADE, 2021), as in the words of the Welsh Government, ‘Business as usual’ is not an option (Welsh Government, 2019).

2.5. Industry 4.0 Readiness Models

Companies can gain an understanding of their Industry 4.0 readiness level by using an Industry 4.0 readiness assessment model. Such models can be used to measure readiness and map out a company's direction to ensure a successful digital transformation is achieved. Using an Industry 4.0 readiness model can help to identify focus areas that require attention prior to introducing new technology (Maisiri & Van Dyk, 2019). Assessments can be carried out in a variety of settings, such as an entire company, a department within a company or even at a national level (Basl & Kopp, 2017).

To answer the research question 'Are Welsh Manufacturers Ready for the Adoption of Industry 4.0 into Existing Lean Processes?' it is necessary to apply an Industry 4.0 readiness model that is suitable for manufacturing companies of various sizes across a broad spectrum of manufacturing industries throughout Wales.

Within the current literature, it was evident that many Industry 4.0 readiness models exist, some created by academics and others created by organisations (Sony & Naik, 2019). A literature review carried out by Mohd, et al., (2020), recognised as many as 30 readiness models. The authors analysed each of the models and identified six recurring dimensions; Technology, People, Leadership, Process, Strategy and Innovation. However, Sony & Naik, (2019) state that not all readiness models are applicable or equally relevant, for example, some models are designed for all industries and sizes, while others have a much narrower scope, specific to a particular sized enterprise or sector.

In practice, readiness models come in the format of a questionnaire and can usually be completed electronically, either through an email link or website, such as that of the popular recurring model within the literature, 'IMPULS'. The IMPULS Industry 4.0 Readiness model, a joint venture between the German Engineering Federation (VDMA) and the Cologne Institute for Economic Research, can be easily accessed through the VDMA IMPULS website. The readiness self-check questionnaire allows companies to calculate their very own Industry 4.0 scorecard to determine where they are already well prepared for Industry 4.0 and where they still have room for improvement. The model is built upon six dimensions; employees, organisational strategy, smart operations, smart factory, smart products and data-driven services. On completion of the readiness assessment, companies will be categorised into one of the six levels providing a measurement of their Industry 4.0 readiness. Each readiness level (0 to 5) includes a minimum requirement that must be met in order to complete the level. In terms of the scoring, Level 0 would be classed as 'the outsiders', the companies that have carried out little or no planning/adopting in regards to Industry 4.0 activities. At the opposite end of the scale is Level 5, this is where the top performers would be found, the companies that have successfully implemented all Industry 4.0 activities (IMPULS, 2021).

The IMPULS model is a well-grounded tool (Maisiri & Van Dyk, 2019) recommended by many researchers as the go-to tool for performing assessments of Industry 4.0 readiness that can be applied to companies of all sizes within any industry (Rajnai & Kocsis, 2019; Basl & Kopp, 2017). It is for these reasons that the IMPULS model will be used as the foundation in assessing the readiness of Welsh manufacturers.

3. Methods

The proposed study sets out to research, investigate and assess the readiness of Welsh manufacturers for the adoption of Industry 4.0 technologies into existing lean processes, as per the aforementioned research question. To do so, two research methods will be applied;

- 1). A survey of Welsh Manufacturers to establish readiness for Industry 4.0 adoption into existing Lean Processes
- 2). A case study within a Welsh manufacturing company to determine their readiness for Industry 4.0 and validate the survey

3.1. Survey

The foundation of the survey will be that of the IMPULS Industry 4.0 readiness model discussed in the literature review of the current paper. The model consists of a questionnaire covering six dimensions; Employees, organisational strategy, smart operations, smart factory, smart products and data-driven services through a series of closed-ended questions, providing quantitative data for analysis. A quantitative research method is recommended for calculating Industry 4.0 readiness levels as it requires chosen indicators to be scored (Maisiri & Van Dyk, 2019).

To determine the Lean levels of Welsh manufacturers, additional questions focusing on Lean will be added to the survey. Additionally, a few questions will be modified to suit manufacturing companies within Wales.

Once the survey is finalised, the researcher will seek validation from academics and Industry experts within Wales to ensure the survey is fit for Welsh companies. According to Tsang, et al., 2017, the validity of a questionnaire is determined by analysing if it actually measures what it is intended to measure. In other words, are the conclusions that are based on the results of the questionnaire valid? (Tsang, et al., 2017).

Prior to distribution, and as part of a case study within an aerospace manufacturer in South Wales, a survey pilot test will be launched to further validate the survey in practice. This is discussed in more detail in section 3.2. Once validation is complete, the survey is to be electronically distributed using the online tool 'Survey Monkey' to senior managers within Welsh manufacturing companies. According to Wright (2005), there are many advantages to using an online survey tool compared to methods such as paper based or face-to-face surveys. For example, they can provide access to unique populations, save time and cost less. Wright (2005) also acknowledges some disadvantages to using digital methods, such as sampling issues and access issues. These issues can be addressed by providing clear communication with the participants and providing them with contact details of the researchers (Wright, 2005).

3.1.1. Survey Sample Size

The first step in conducting a survey is to determine a sample size that will ensure the chosen sample accurately estimates the population, in this case, Welsh manufacturing companies. According to Survey Monkey (2022), the sample size can be determined by understanding the total population size, the accuracy required and how responsive the researcher believes people will be.

According to Caldeira-Pereira (2019), there were approximately 5,650 manufacturing companies in Wales in 2017. Using an online calculator (Survey Monkey, 2022) the recommended sample size (number of completed surveys) required for the proposed research is 96 companies, based on a confidence level of 95% and a 10% error margin. Not all companies approached will respond to the survey, therefore, it is necessary to estimate a response rate that can be factored in to the calculation to ensure the required sample size (96 companies) is obtained. Response rates do vary and can be affected by a number of factors such as the survey length, complexity, incentives and the topic of the survey. Where there is no prior relationship with the target audience, a response rate of between 20-30% is considered to be very successful. However, a response rate of 10-15% is a more conservative estimate if the researcher has not surveyed the population before (Survey Monkey, 2022). On this basis a 10% response rate will be factored in to the required sample size for the proposed research. Hence, to obtain a minimum of 96 completed surveys 960 Welsh manufacturers will be approached to participate through the online survey tool 'Survey Monkey'. To satisfy the research question; Are Welsh Manufacturers Ready for the Adoption of Industry 4.0 into Existing Lean Processes? The survey results must produce a minimum of 96 respondents that have existing Lean processes in their business, the additional questions on Lean that will be added to the IMPULS model will capture this.

3.1.2. Survey Sampling Method

Once the sample size has been determined, it is then necessary to select a sample that represents Welsh manufacturers as a population. There are two types of sampling methods that can be used for this purpose; Probability sampling and Non-probability sampling (McCombes, 2022). Selecting the type of sampling method for a study depends on the nature, type and purpose of the study (Etikan, et al., 2016).

The convenience sampling technique, which falls into the non-probability category, will be the chosen sampling method for the proposed survey. Convenience sampling can be applied to both qualitative and quantitative studies, although it is most often used in quantitative studies (Etikan, et al., 2016). The focus of the proposed research is to obtain primary data from a general group of Welsh manufacturers, which makes convenience sampling suitable for this type of study (Constantiou, et al., 2002). Additionally, convenience sampling is a common technique used in areas of research that are fundamentally new, Industry 4.0 for example (Maisiri & Van Dyk, 2019). According to Etikan, et al., (2016), convenience sampling identifies a group that meets practical criteria, such as accessibility, and those that are eager to engage in the research. Easy accessibility, can be interpreted as the method of identifying and accessing the survey recipients.

Etikan, et al., (2016) acknowledge a disadvantage in using convenience sampling, in that it can be biased, as the technique does not usually represent the whole population. Duerr & Skowronek (2009), state that bias can be removed from convenience sampling by ensuring the sample is 'significantly representative', increasing the diversity by the way in which the survey is distributed and incorporating as much data as possible.

For the proposed research survey, a list of Welsh manufacturers will be compiled from a number of Welsh manufacturing networking organisations and directories such as 'Industry Wales' and 'Manufacturing Wales'. To satisfy the minimum required response rate of 96 manufacturers, 960

manufacturers from the supplied list of manufacturers will be selected and approached to complete the survey.

3.2. Case Study

The second method to be applied in the proposed research will be a case study within an aircraft seat manufacturer based in Cwmbran, South Wales.

The objective of the case study is to determine the organisations readiness for Industry 4.0 adoption into their existing Lean processes through a pilot test of the proposed survey prior to distributing it to a wider audience. The pilot test will involve 20 managers, each completing the survey to test its functionality and format. Once complete, the managers will be invited to a workshop to discuss the survey and provide feedback to the researcher.

Additionally, the case study will involve interviews with employees representing various functions, including operations, supply chain, quality, engineering, IT etc. This will provide insight into the culture of the company and may provide some interesting results that may be significant to the overall study.

Case studies are beneficial as they provide a holistic review. Unlike other research methods such as a survey, which only offer a snapshot of a research topic, case studies allow the researcher to use a selection of methods, providing more time to obtain a more detailed understanding of the topic in a practical setting (Salmon, 2017). Case studies can also reduce bias in research by gaining a greater understanding of the subject in hand. Salmon (2017) states that one of the challenges with case studies is that they are time consuming. Conducting multiple interviews, collecting data, organising workshops etc. takes up a considerable amount of time. Time challenges can be overcome by planning the case study activities well in advance and outlining what is required from participants from the outset and being assertive with deadlines (Salmon, 2017).

3.3. Ethics

When carrying out such research it is essential that the proposed methods are ethically responsible. To ensure the study conforms to this, the anonymity and privacy of the participants will be respected at all times. Additionally, communication of the purpose and full content of the study is essential to ensure the participants can make an informed judgement before deciding to participate (Fisher, 2020). In regards to using the IMPULS readiness model as a foundation for the survey, it is common courtesy that the researcher seeks approval from the creators (VDMA) beforehand.

4. Results

In applying the two research methods, survey and case study, there will be a mixture of quantitative and qualitative data collected to answer the research question '*Are Welsh Manufacturers Ready for the Adoption of Industry 4.0 into Existing Lean Processes?*.'

The survey will provide the largest data set and all responses will be quantitative in nature. Qualitative data will be collected through interviews within the case company.

To analyse the quantitative data obtained from the surveys, descriptive statistics and inferential statistics will be used. Descriptive statistics is a recommended approach when using a convenience sampling method as proposed in this paper (Price, 2013). However, Etikan, et al., (2016), state that statistical analysis results obtained from convenience sampling data are not usually generalised beyond the sample to the population. Thus, inferential statistics will be used to determine whether there is significant difference between the readiness models six dimensions, in their contribution to the overall readiness level.

Using online survey tools such as Survey Monkey enables the researcher to view the data via a dashboard where depending on the researchers requirements, the data can reviewed in a variety of ways and statistical analysis techniques changed with the push of a button, making the digital survey tools an effective way of handling data. This could save the researcher a significant amount of time and effort in comparison to more traditional statistical analysis (Nagalakhmi & Trivedi, 2015).

As previously discussed, interviews will also be conducted at the case study company to gather qualitative data. Interviews are useful tools to gain some context of the company culture, working conditions and any other concerns that are specific to the research or company. Interviews also provide an opportunity to ask follow-up questions, read body language and notice anything that a quantitative research method may not. However, qualitative studies usually consist of a small group of people, therefore the data is limited to only describing something, rather than helping the researcher to make a decision or draw a conclusion (Survey Monkey, 2022). This is acceptable for the researcher, as the case study interviews will be used primarily to support the survey outcome.

5. Evaluation

The research proposed in this paper has the potential to make a positive impact within the manufacturing community and the economy in Wales. Currently, there is a gap in the research as there are no studies within the literature that focus on Industry 4.0 readiness in Wales. The literature review identified the many opportunities Industry 4.0 can provide and ultimately enhance Lean processes and systems. However, many Lean manufacturers are still yet to make the jump towards Industry 4.0 adoption, many do not understand if their organisation is ready to embrace the opportunities available through the fourth industrial revolution that can ensure they stay ahead of the curve.

The proposed research will help to close this gap and answer the research question: Are Welsh Manufacturers Ready for the Adoption of Industry 4.0 into Existing Lean Processes?

Applying the tried and tested readiness model (IMPULS), modified and validated to remain relevant to manufacturing in Wales along with a case study within a Welsh manufacturing company will paint a significant picture of the current state of Industry 4.0 readiness for adoption into Lean manufacturers in Wales. This will be beneficial to manufacturers and the Welsh government alike, enabling them to understand if and where additional investment or resource is required to keep them on track, ensuring Wales is not left behind.

One of the most significant limitations to the proposed research is the issue of time. Although the sample size required for the survey is only 96 respondents, it will require 960 surveys to be sent to ensure the minimum sample is achieved. Distributing this many surveys is a significant amount of work and will need to be strictly managed with a solid plan in place. To keep track of the research progress, a project timeline in the form of a Gantt chart will be created, highlighting the actions that need to be completed against the timeline.

The quality of the survey will also depend on the number and the quality of responses, as without the researchers present, individuals may not understand the questions fully, only to select an inaccurate answer. This can be minimised by ensuring the companies have been provided with contact details for the researchers and providing clear and concise instructions to aid with completion of the survey.

In regards to financial constraints, the only financial concern would be subscribing to the Survey Monkey tool. For the level required for the proposed survey that includes the advanced statistical analysis tools, the only option is to purchase an annual subscription at a cost of approximately £364.

On completion of the proposed study, it will open the door for further research into determining what the next steps are for Welsh manufacturers once they have determined their level of readiness in adopting Industry 4.0. Additionally, the readiness survey created for the study could also be applied outside of Welsh manufacturing to support businesses on their own Industry 4.0 journey.

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