Developing a managerial framework for digital manufacturing in the new normal era

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ABSTRACT

This study aimed to determine what a management framework for digital manufacturing in the new normal era will comprise of in the CPG industry in South Africa, and to establish what characteristics and requirements a managerial framework should constitute.

Due to the COVID-19 pandemic, most manufacturing businesses in South Africa had to adopt new technology at a rapid pace. This was done out of necessity, with an outward rippling effect on all associated processes, from cybersecurity to e-commerce.

Amidst the current crisis, global manufacturing and supply chain organisations are moving through a very distressing and disruptive stage. As we transition out of the current crisis, business leaders will need to make decisions and create a strategy that needs to be practically implemented to navigate to the "new normal." Significant acceleration in the use of technology, digitization, and new forms of working is going to be sustained.

This quantitative study aimed to assess what qualities and criteria a managerial framework should have to create a successful digital framework. The sample was limited to persons representing CPG firms with a manufacturing presence in South Africa and are publicly traded on the Johannesburg Stock Exchange (JSE).

In South Africa, digitalization is happening in a country where the economy has already seen premature deindustrialization. There is potential to develop, use, and perfect technology to drive value across the CPG value chain, particularly in the areas of product development, sales, distribution, manufacturing, procurement, and supply chain, as well as customer management, particularly in the context of the South African market.

The study concluded that the main challenges for digital manufacturing advancement in the CPG industry in South Africa today are a shortage of skilled resources, followed by financial or budgetary constraints. The main challenges for training or re-skilling are user adoption, fears of job losses caused by automation and robotics, and resistance to change from the current workforce. Technological challenges include an outdated IT- and OT stack, as well as the high cost of having a solid IT foundation to support manufacturers' digitization strategies.

KEY WORDS: Digital Manufacturing, Digitisation, Management Framework, Industry 5.0, Strategy, Disruption, Skills, Adoption, Automation, Robotics, Usefulness, Cyber Security, Artificial Intelligence.

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

A management framework for digital manufacturing in the new normal era

CHAPTER 1 – NATURE AND SCOPE OF THE STUDY

1.1 BACKGROUND

To be more productive and compete effectively on the local and global stage, with the same resources available, is as accurate for the South African economy as it is for most of the economies of the world (Hendrikse, 2013:18). At the core of increased productivity in the manufacturing industry, is digitalisation.

Digital manufacturing is the application of computer systems to manufacturing services, supply chains, products, and processes. Digital manufacturing technologies link systems and processes throughout all sectors of production, from design to production to product maintenance (TWI-global, 2020:1). Digital manufacturing is a promising set of technologies for reducing production time and cost, as well as for customisation, improved product quality, and a faster time to market (Chryssolouris *et al.*, 2009:451).

Since the outbreak of the COVID-19 pandemic, all economies in the world have been affected unlike any other in recent history. The world felt the seismic effects of the pandemic reverberating through everyday life. Most countries worldwide enforced a complete or partial lockdown, and the focus has shifted to a surge in demand for essential products and services. A decline in demand for certain non-essential products and services occurred as well.

Fundamentally, most things, such as working, shopping, paying, or getting around, have changed because of the COVID-19 pandemic, affecting our normal lives. Currently, most manufacturing and supply chain organisations are struggling to anticipate the negative consequences of COVID-19 (Kumar *et al.*, 2020). However, the current pandemic is only the start of more disruptive events that must be anticipated. Amidst the current crisis, global manufacturing and supply chain organisations are moving through a very distressing and disruptive stage. Emerging Infectious Diseases (EIDs) such as Ebola, influenza, SARS, MERS, and most recently, Coronavirus Disease (COVID-2019) cause enormous disruption in goods production, people's lives, transportation, and stimulate civil unrest (Kumar *et al.*, 2020). The Global Risks Report, 2021 highlights other notable risks that may impact the world economy: Among the highest impact risks of the next decade, infectious diseases are the highest, followed by climate failure and other environmental risks. Weapons of mass destruction, livelihood crises, debt crises, and IT infrastructure breakdown may pose further risks, as the current unrest between Russia and Ukraine has proved (McLennan). It is thus essential to discuss what the "new normal" will look like after the recent crisis regarding a sustainable manufacturing environment for the Consumer Packaged Goods industry in South Africa and worldwide. During the COVID-19 crisis, digitization has seen tremendous growth, from online customer service to remote working to supply-chain reinvention to using artificial intelligence (AI) and machine learning (ML) to improve operations (Sneader & Singhal, 2021). This means that the future of work and manufacturing, and a more robust supply chain arrived ahead of schedule. Digitization, in other words, the networking of people and things, and the convergence of the natural and virtual worlds enabled by information and communication technology (ICT), will be the most powerful driver of innovation over the next few decades. Enabled by information and communication technology (ICT), it will trigger the next wave of innovation (Kagermann, 2015:24). In the past, it has taken a decade or longer for game-changing technologies to evolve from cool new things to productivity drivers. The COVID-19 crisis accelerated the transition in areas such as AI and digitization by several years (Sneader & Singhal, 2021). The McKinsey Global Institute (MGI) estimated that more than twenty percent of the global workforce (in sectors such as finance, insurance, and IT) could work away from the office and be just as effective (Sneader & Singhal, 2021). Not only because of the COVID-19 crisis but also because we have seen advances and acceleration in automation and digitization. Microsoft CEO Satya Nadella noted in April 2020 that “we have seen two years’ worth of digital transformation in two months (Spataro).

In the months and years, as we transition out of the current crisis, business leaders will need to make decisions and create a strategy that needs to be practically implemented to navigate to the “new normal.” Methods may include working away from the primary place of work for certain roles and challenging the workforce to adapt to the requirements of automation, digitization, and other technologies (Sneader & Singhal, 2021). In 2018, the World Economic Forum estimated that more than half of employees would need significant reskilling or upskilling by 2022 (Sneader & Singhal, 2021). However, this was realised even before the COVID-19 crisis. In a McKinsey survey conducted in May 2019, almost 90 percent of the executives and managers surveyed, said their companies were faced with skill gaps or expect to in the next five years. Only a third said they were prepared to deal with the issue (Agrawal, De Smet, *et al.*, 2020).

Significant acceleration in the use of technology, digitization, and new forms of working is going to be sustained. Sustaining long-term productivity will not be known until the data for several more quarters are evaluated. It is worth noting that US productivity in the third quarter of 2020 rose 4.6 percent, following a 10.6 percent increase in the second quarter, which is the most significant six-month improvement since 1965 (Sneader & Singhal, 2021). The South African economy is projected to rebound by 3.8% in 2021 and 2.5% in 2022 (OECD, 2021). The general outlook is that the South African economy is recovering. Still, the recovery is uneven across sectors, and the manufacturing sector remains subdued, affected by low demand, destocking, and persistent bottlenecks to production (OECD, 2021:133).

The COVID-19 crisis has created an imperative for companies to reconfigure their operations and an opportunity to transform them. To the extent that they do so, greater productivity will follow (Sneader & Singhal, 2021). What is clear is that the next normal will be different. It will not mean going back to the conditions that prevailed in 2019. Indeed, just as the terms “pre-war” and “post-war” are commonly used to describe the 20th century, generations to come will likely discuss the pre-COVID-19 and post-COVID-19 eras (Sneader & Singhal, 2021).

1.2 PROBLEM STATEMENT

Until 2020 a lot of hype has built around Industry 4.0 and Digital Manufacturing, but some disillusionment has also crept in. McKinsey & Company published a study in September 2019 that showed that Industry 4.0 could have an estimated value-creation potential for manufacturers and suppliers of $3.7 trillion in 2025 (Garms *et al.*, 2019:6). However, the same study also showed that only about 30 percent of companies surveyed were capturing value at scale from digitisation pre-COVID-19. The main reasons for this were limited skilled resources, the high cost of scaling, a lack of clarity about business value, and an overwhelming number of potential use cases (Garms *et al.*, 2019:6).

When the world became confronted with the largest health and economic crisis in recent history by the COVID-19 pandemic, companies across the globe and in all industry sectors were forced to implement extraordinary measures to protect their workers and maintain operations. Some companies did better than others. While some manufacturers were content to keep operations running while trying to limit risk and exposure to their workers, and facing shortages in raw materials, others struggled to keep up with the spike in demand. However, data on how the COVID-19 pandemic affected manufacturing companies is starting to emerge. However, more data and information are yet to be collected and interpreted. Six months into the COVID-19 pandemic, McKinsey surveyed 400 global organisations and found that 94% stated Industry 4.0 helped them keep operations flowing, and 56% said these technologies were vital to their crisis responses (Agrawal *et al.*, 2021:2). No South African or African companies were surveyed.

Interviews with South African manufacturing technology leaders published in ITWeb highlighted and recognised the relevance and role that smart manufacturing can and should play (Carew, 2020:1). The article also explored the impact of the COVID-19 pandemic on those manufacturers and what mitigating procedures they deployed to limit the impact. The respondents in the article all referred to the impact of the National Lockdown and the measures they took to protect their workers and to secure a work-from-home environment, focussed on administrative and sales staff. None of the respondents clearly explained how they used smart manufacturing to mitigate the impact of the pandemic. A few examples of companies that successfully scaled Industry 4.0 use cases have emerged. A consumer-packaged goods (CPG) company in Asia had built a digital twin of its supply chain before COVID-19. The Company was able to use the digital twin of its supply chain to simulate multiple scenarios during the pandemic, thus preparing themselves for sudden shutdowns of manufacturing locations or disruptions in raw-material supply (Agrawal *et al.*, 2021:2). Another example in the CPG industry in South Africa exists. A well-known global CPG company with operations in South Africa, in the process of increasing its capacity by installing a new manufacturing line at its Cape Town manufacturing plant, it was able to commission the line using augmented reality-based remote assistance for project execution.

The COVID-19 pandemic was particularly unkind to the manufacturing industry in South Africa. According to Statistics South Africa (StatsSA), manufacturing production in South Africa decreased by 48.7% year-on-year in April 2020 and an overall decline for the year 2020 of 10.9% (StatsSA, 2021:9).

Table 1.1 – Year-on-year percentage change in the volume of manufacturing production

Month	2015	2016	2017	2018	2019	2020	*2020 year-to-date*
Jan	-2,1	-2,5	0,6	2,3	0,9	-1,9	*-1,9*
Feb	0,1	2,1	-3,7	0,6	0,4	-2,1	*-2,1*
Mar	4,2	-2,3	0,3	-1,7	1,0	-5,5	*-3,3*
Apr	-2,2	3,2	-4,5	1,2	4,7	-49,4	*-15,0*
May	-1,8	4,1	-0,8	2,2	0,4		
Jun	-1,0	5,1	-1,8	0,5	-3,6		
Jul	4,6	-0,5	-1,2	2,8	-0,6		
Aug	-0,2	2,3	1,6	1,6	-1,5		
Sep	1,4	0,3	-1,9	-0,1	-2,3		
Oct	-2,0	-2,8	2,1	3,2	-0,4		
Nov	-1,3	2,2	1,8	1,1	-3,5		
Dec	0,2	-2,2	1,8	0,0	-6,3		
Total	**0,0**	**0,7**	**-0,4**	**1,1**	**-0,9**		

Source: (StatsSA, 2021)

Some recovery in South African manufacturing production was seen during the first half of 2021, but recovery across the manufacturing sector remains subdued (OECD, 2021:133).

Considering the value creation potential that digital manufacturing may bring to manufacturers and the overall negative impact of the COVID-19 pandemic on South African manufacturing, this study aims to set a management framework for digital manufacturing in the "new normal" after COVID-19. In addition, should there be any other supply chain interruption, due to any factors whatsoever, this managerial framework should assist in managing those adverse effects.

1.3 RESEARCH OBJECTIVES

Based on the preceding research problem, the following research objectives will be formulated:

1.4 THE PRIMARY OBJECTIVE

The primary objective of this study was to develop a managerial framework to guide manufacturing companies in the CPG industry in South Africa wishing to start or continue to implement digital manufacturing as part of their process and strategy. The purpose of the managerial framework was to create a practical framework of best industry practices that could be applied to implement a successful digital manufacturing strategy in the South African context.

1.5 SECONDARY OBJECTIVES

The secondary objective to support the primary aim of this study is that the research, will assume the following related tasks:

- What the "new normal" may look like for manufacturing in the CPG industry in South Africa.
- The benefits that digital manufacturing can bring to the entire value chain of the CPG industry in South Africa.
- Efficient data handling in manufacturing in South Africa and how to maximise the effective use of data.
- The impact that digital manufacturing will have on the basic education of a typical manufacturing industry worker in South Africa.
- How workers in the manufacturing industry can be re-skilled to eliminate job losses and to offset automation use cases.
- How can digital manufacturing contribute to the health and Safety of manufacturing workers?

1.6 IMPORTANCE AND BENEFITS OF THE STUDY

Due to the COVID-19 pandemic, most manufacturing businesses in South Africa had to adopt new technology at a rapid pace. This was done out of necessity, with an outward rippling effect on all associated processes, from cybersecurity to e-commerce.

Consumer packaged goods (CPG) companies will need to focus on various business strategies to meet consumer expectations and satisfaction while also taking control of their demand and supply chain management. As a result, digitisation of industrial processes and production-level automation will require to meet the rising demand. Manual processes will be automated with AI, and data from sensors will be utilized to improve inventory insights. Equipment monitoring can also better understand machine health and provide preventive maintenance.

Strategic focus also needs to be applied in the areas closer to the HR domain and how technology can support new ways of working. E-Business and local monitoring of processes on the manufacturing floor, with a physical presence in the factory was, in some cases, replaced out of necessity by a remote form of monitoring. The CPG industry will need to determine a new regiment for their staff working from a manufacturing plant, offices, and facilities. Consideration to determine flexible work options, remote monitoring of processes and staff, and staff management, while at the same time taking care of their wellbeing, will have to be made. As organisations begin to prove use cases and operationalize automation, machine learning, and robotics, a reskilling strategy will be needed to prepare people for a "digital everything" future. The strategy should be in line with Industry 5.0 principles and aimed at putting people at the core of their operations, thus preventing job losses, and aiming to upskill and reskill their workforce.

CPG would have to take a more holistic approach to commerce, with technology playing an essential part. Compared to traditional batch-level visibility, IoT-based solutions provide unit-level visibility on the shop floor. The emergence of the era of smart manufacturing enables real-time, autonomous interactions among machines and systems. IoT also has the potential to change the way they target and engage with customers every day. The available amount of data can be better applied through digital technologies that can help to develop more innovative and improved products, improve operations, perform predictive maintenance, and harness the benefits of becoming more agile and competitive and drive customer satisfaction.

During the pandemic and now as we start to see some recovery and return to normality, the world has experienced something like a white-water rafting environment. One that is full of dangers and hidden obstacles as well as being dynamic, fluid and highly unpredictable.

This study aimed to determine what a management framework for digital manufacturing in the new normal era will comprise of in the CPG industry in South Africa, and to establish what characteristics and requirements a managerial framework should constitute.

1.7 LIMITATIONS AND SCOPE

The study was limited to South African-based CPG companies who manufacture their product in South Africa. The study focussed on South African-based CPG companies listed on the Johannesburg Stock Exchange (JSE). There are twenty companies in the CPG sector listed on the JSE as published by Listcorp (2021:1) (Anon, 2022). If CPG companies were inaccessible or lacked a manufacturing base, the sample size were smaller than planned. The study was limited to the available literature on the internet, journals, and other electronic databases.

1.8 DEFINITION OF KEY TERMS

Table 1.2 – Key terms and phrases presented in this study:

Abbreviation	Meaning
AGI	Artificial General Intelligence
AI	Artificial Intelligence
AR	Augmented Reality
COVID-19	Coronavirus disease 2019
CPG	Consumer Packaged Goods
HR	Human Resources Department
IC	Integrated circuit
ICT	Information and communication technology

IIoE	Industrial Internet of Everything
IIoT	Industrial Internet of Things
IoE	Internet of Everything
IoT	Internet of Things
IT	Information technology
JSE	Johannesburg Stock Exchange
OT	Operational Technology
UNESCO	The United Nations Educational, Scientific and Cultural Organization

1.9 LITERATURE REVIEW

1.10 INTRODUCTION

The revolution businesses experience today, will continue to reshape how they operate. The impact will be across all industries. Improved product tracking and streamlined operations are part of the functionality used today, including in the CPG industry. With the Internet of Things (IoT) in existence for a substantial amount of time, we still see limited use, yet we are only beginning to optimise what the technology can bring.

Michael Porter co-authored an article in 1985 that discussed how information gives a competitive advantage. What he said, is still mostly valid and applicable today: "Information technology is changing how companies operate. It is affecting the entire process by which companies create their products (Porter & Heppelmann, 2014). Furthermore, it is reshaping the product the entire package of physical goods, services, and information companies provide to create value for their buyers." (Porter & Millar, 1985:2). In 2020, industrial digitisation experienced the ultimate test to date. Faced with the worst health and economic crises in recent history, businesses were forced to take extreme measures to protect their employees and keep their operations running, while doing their best to protect their bottom line and future operations (Agrawal, Eloot*, et al.*, 2020:2).

A recent international operation practice research report, done by McKinsey & Company, Agrawal (Agrawal, Eloot*, et al.*, 2020:2) suggested three outcomes for companies due to the COVID-19 pandemic:

- a win for companies that had already scaled digital technologies;
- a reality check for those that were still scaling; and
- a wake-up call for those that had yet to start on their Industry 4.0 journeys.

Various remedies and efforts have been implemented to get back to what a new normal will look like after COVID. These efforts, together with further uncertainty of what may still lie ahead, brought us to the cusp of further rapid and transformative change. Companies in the CPG industry are typically not the fastest adopters of disruptive technologies, as shown by the 2018 Annual Study of Digital Business by MIT Sloan Management Review and Deloitte. The study indicated that on the digital maturity spectrum, respondents from the consumer products companies rated themselves at the mid-to-lower end compared to other consumer-facing industries (Renner *et al.*, 2018:1). But the ongoing COVID-19 pandemic is forcing faster adoption for CPG companies. Some of the change is driven by consumer behavioural changes where the consumers were faster to adopt change and thus forced the CPG companies to step up. From a workforce perspective, the faster adoption of technology may also be attributed to persons from Generation Z, who are generally regarded as "Digital Natives" starting to enter the workforce. Awareness amongst consumers of privacy and data are also coming together to accelerate adoption.

1.11 RESEARCH METHODOLOGY

Qualitative or quantitative methods can be used to collect data or a mixed approach of combining both. These can be self-developed tools, such as self-completion questionnaires, participatory observation plans for structured interviews, focus groups, surveys, observations, interpretation of sub-documents and information, internet research and technology (Bryman et al., 2016:383).

The primary data collection instrument in this study was a questionnaire that was sent to the participants in the form of an e-mail invitation to a survey instrument.

The study was focused on South African-based CPG companies listed on the Johannesburg Stock Exchange (JSE). There are twenty companies in the CPG sector listed on the JSE as published by Listcorp (2021:1) (Anon, 2022).

Each company could contribute two individuals to the survey so that at least forty participate. These individuals that participated in the survey were a sample from the population.

Representatives of the CPG companies who was requested to complete the questionnaire consisted of any of the following levels, titles, or roles:

- Chief executive Officer
- Chief Innovation Officer
- Chief Technology Officer
- Chief Marketing Officer or Head of Marketing
- Chief Information Officer
- Chief Strategy Officer
- Chief Digital Officer, or
- Any other designated senior managerial roles in the organisation.

This literature study aimed to establish what characteristics and requirements a managerial framework should constitute so that it may be of value to CPG companies and others that aim to start or continue to implement digital manufacturing as part of their manufacturing process and strategy. The purpose of the managerial framework is to create a practical framework of best industry practices that can be applied to implement a successful digital manufacturing strategy in the South African context.
No face-to-face contact or interviews was conducted from a COVID protocol perspective, and all questionnaires were collected electronically using SurveyMonkey.

1.12 DESCRIPTION OF OVERALL RESEARCH DESIGN

The term research design refers to a framework for the collection and analysis of data. The selected research design reflects decisions regarding the priority given to the research process (Bryman et al., 2016:382).

1.13 PRIMARY DATA COLLECTION

Primary research was collected via a literature study as well as a questionnaire. Firstly, a detailed theoretical search of the relevant and available literature was done, attempting to gain theoretical knowledge on the fundamentals of Digital Manufacturing. Secondly, a quantitative approach was used towards the research objective as a

means of testing objective theories by examining the relationship between variables (Creswell, 2014:4). These variables can be measured by using instruments that make use of analysing numbered data statistically (Creswell, 2014:4).
The questionnaire used for this study applied a five-point Likert scale to collect data from the sample. According to Bryman *et al.*, (2016:379), a Likert scale is a widely used format developed by Rensis Likert for asking attitude questions. Respondents are typically asked about their degree of agreement with a series of statements that form a multiple-indicator or -item measure. The scale is deemed then to measure the intensity with which the respondents feel about an issue.

The five-point scale is used because, according to Marton-Williams (cited by Chen & Dubinsky, 2003:336), previous research has found that a five-point scale is readily comprehensible to respondents and enables them to express their views Research also confirms that data from Likert items (and those with similar rating scales) becomes significantly less accurate when the number of scale points drops below five or above seven (Johns, 2010:6).

The overall research design will be to finalise the research instrument and methodology and determine the population size. Participants in the study will be asked to complete the questionnaire with specific questions, including some open-ended responses to the questions asked. These answers and comments will be analysed qualitatively and used to add value to the results obtained from the theoretical research. The last step will be to analyse the data and write up the report.

1.14 RESEARCH STRATEGY

Quantitative research usually emphasises quantification in the collection and analysis of data. As a research strategy, it's deductivist and objectivist and uses a positivist-influenced natural science model. (Bryman *et al.*, 2016:382).

A cross-sectional research design involves collecting data on more than one case at a single point in time. This is usually done to collect quantitative data concerning two or more variables (Bryman *et al.*, 2016:106, 376).

Survey research comprises of a cross-sectional design to collect data mainly by questionnaire or structured interview on more than one case and at a single point in time. This is done to collect a body of quantitative or quantifiable data in connection to two or more variables, which are then examined to detect patterns of association (Bryman *et al.*, 2016:107, 384).

The research strategy that was followed in this study was a non-probability quota sampling strategy using a questionnaire survey.

1.15 POPULATION

The study focussed on the major leading CPG companies with a manufacturing base in South Africa. The companies primarily are those listed on the Johannesburg Stock Exchange (JSE). There are twenty companies in the CPG sector listed on the JSE as published by Listcorp (2021:1) (Anon, 2022).

The unit of analysis is a clearly defined group of individuals or items that is recognised to share traits; these individuals or things frequently have a common quality that unites them (Trochim, 2020). The population can be described as a universe of units or things from which a sample containing the information required by the researcher is to be chosen (Bryman *et al.*, 2016:381).

Each company can contribute two individuals to the survey so that at least forty individuals participate. These individuals that will partake in the survey will be a sample from the population.

Representatives of the CPG companies to be interviewed and who will be requested to complete the questionnaire can consist of any of the following levels, titles, or roles:

- Chief Executive Officer
- Chief Innovation Officer
- Chief Technology Officer
- Chief Marketing Officer or Head of Marketing
- Chief Information Officer
- Chief Strategy Officer
- Chief Digital Officer, or

Any other designated senior managerial roles in the organisation.

1.16 RISKS

There are no risks to the participants participating in this study as no physical or medical samples will be conducted and no personal, psychological, or medical questions will be asked.

1.17 SECONDARY DATA COLLECTION

Secondary data analysis is the analysis of data by researchers who will not have been involved collecting data for purposes that may not have been envisaged by those responsible for the data collection. Secondary analysis may entail either quantitative data or qualitative data (Bryman *et al.* 2016:383).

Secondary data analysis comprised but was not limited to, a theoretical search of the relevant and available literature, which attempted to gain theoretical knowledge on the fundamentals of Digital Manufacturing and related technologies.

Please note that this study did not use secondary data *per se.*

1.18 SAMPLING

Please find the informed consent letter to conduct the research, attached as APPENDIX B.

Sampling refers to the segment of the population that is selected for research. In the case of this study, it is ***full saturation of the full population***. The selection process can be based on probabilistic or non-probabilistic sampling (Bryman *et al.* 2016:383).

Data saturation refers to the point in the research process when no new information is discovered in data analysis, and this redundancy signals to researchers that data collection may cease. Saturation means that a researcher can be reasonably assured that further data collection would yield similar results and serve to confirm emerging themes and conclusions. When researchers claim that they have collected enough data to achieve their research purpose, they should report how, when, and to what degree they achieved data saturation (Faulkner & Trotter, 2017:1).

Non-probability sampling is a sample that has not been selected using a random sampling method. This implies that some units in the population are more likely to be selected than others (Bryman *et al.*, 2016:380).

Quota sampling refers to a sample that non-randomly samples a population in terms of the relative proportions of people in different categories. It is a type of non-probability sampling (Bryman *et al.*, 2016:382).

Executives and middle managers with solid viewpoints and expertise of their organisations who are willing to engage in the research will assist to define what a management framework for digital manufacturing would look like in the South African CPG industry. The participants are not randomly selected, and a sample from the population will be targeted. This will be done due to the participants' manufacturing experience in the CPG industry. The aim is thus that the full population identified will take part in this survey.

The information received from the questionnaire will be treated with respect, and the researcher will adhere to ethical rules. The data collected during the interview will only be used for research purposes.

1.19 DATA COLLECTION

Quantitative research with a questionnaire.

The nature of data that will be collected is aimed at developing a managerial framework to guide manufacturing companies in the CPG industry in South Africa that wish to start or continue to implement digital manufacturing as part of their manufacturing process and strategy. The purpose of the managerial framework is to create a practical framework of best industry practices that can be applied to

Secondary objects support the primary aim of this study in that the research will assume the following related tasks:

- What the “new normal” may look like for manufacturing in the CPG industry in South Africa.

- The benefits that digital manufacturing can bring to the entire value chain of the CPG industry in South Africa.
- Efficient data handling in manufacturing in South Africa and how to maximise the effective use of data.
- The impact that digital manufacturing will have on the basic education of a typical manufacturing industry worker in South Africa.
- How workers in the manufacturing industry can be re-skilled to eliminate job losses and offset against automation use cases.
- How can digital manufacturing contribute to the health and Safety of manufacturing workers?

Appendix “A” contains the sample questions that will be asked:

It is expected that the questionnaire be completed in 30 minutes or less. The questionnaire will be in an electronic format. Data will be collected online via SurveyMonkey. The electronic platform automatically captures the data as soon as a respondent completes his/her survey. Therefore, the researcher will, only have access to the collective data and will be unable to identify any of the respondents or isolate any specific response. This will ensure anonymity.

The data collection consisted of several steps. These are:

Step 1: Digitise the questionnaire into SurveyMonkey and add as the first page the letter of consent. (See Appendices A and B). The Statistical Consultation Services of the Potchefstroom campus of NWU will be used to assist in this process.
Step 2: The researcher will be acting as a gatekeeper of the personal information of the participants, including their e-mail addresses.
Step 3: The researcher will distribute the questionnaires and collect the data.
Step 4: The Statistical Consultation Services of the Potchefstroom campus of NWU will be engaged to provide the statistical analysis of the survey.
Step 5: Draft a letter of invitation. The invitation letter contains a live link on which the participants can click to transfer them to the first page of the questionnaire.
Step 6: After clicking on the link, the participants will receive the first page of the questionnaire which will be the consent form. They will have to agree that their data

may be used for research purposes only by clicking on “Yes” after reading the informed consent form.

Step 7: If they agree and consent for their data to be used, the questionnaire opens, and the participants can complete the questionnaire.

Step 8: After completion, the data is automatically saved with the other responses. It is not possible to connect any respondent to any specific data entry. The data is anonymous.

Step 9: The researcher received the final data set and cannot, by any means, identify any of the individual responses. The data can then be analysed.

1.20 DATA ANALYSIS

The data was analysed using IBM’s Statistical Programme for Social Sciences.

1.21 ASSESSING AND DEMONSTRATING THE QUALITY AND RIGOUR OF THE PROPOSED RESEARCH DESIGN

The data that will be collected will only be used for research purposes. The participants will be participating voluntarily. A summarised copy of the final dissertation will be made available to all the participants if they request it. The research will not include any personal information of participants.

1.22 PROPOSED CHAPTER LAYOUT

The proposed chapter layout of this research study will consist of the following:

Chapter	Main aim of the chapter
Chapter 1	Nature and scope of the study:
Chapter 2	Literature study: Review the literature: Appropriate information will be gathered and discussed in this chapter:
Chapter 3	Research methodology and results: To describe the research method and interpret the data and findings:
Chapter 4	Conclusions and recommendations: To present conclusions and recommendations.

1.23 CONCLUSION

Topic and content are researchable. It has the potential to contribute to the management of organisations that operate in a manufacturing environment whether they are in the process to digitise or are starting on their digitisation journey.

1.24 SUMMARY

This research aims to determine how South Africa's CPG industry will manage digital production in the new normal era. It aims to establish its traits and requirements to benefit the CPG industry and all South African manufacturing businesses.

The proposal covered managerial challenges and opportunities presented by the COVID-19 pandemic and touched on what the future of work may look like in the new normal after COVID. It also described the strategic need for a new way of work in an office, manufacturing and other environments and touched on aspects that will need to be reshaped.

The proposal then covered technological forecasting and the main technological concepts that will contribute to the progress of digital manufacturing. It covered the resurgence and importance of the different forms of IoT and the importance having everything connected to harness the power of data. The proposal also covers the importance of Industry 4.0 and the shift to place humans in the centre and as the prime benefactor of technology by introducing Industry 5.0 and the Fifth Industrial revolution, briefly touching on the differences between the two concepts.

The technological forecast also covered how the smart factory represents a leap forward from more traditional automation to a fully connected and flexible system where constant data from connected operations and production systems is available to learn and adapt to new demands. It showed that a truly smart factory can integrate data from system-wide physical, operational, and human assets to drive manufacturing, maintenance, inventory tracking, digitization of operations through the digital twin, and activities across the entire manufacturing network.

The result can be a more efficient and agile system, less production downtime, and a greater ability to predict and adjust to changes in the facility or broader network, leading to better positioning in the competitive marketplace.

The proposal goes through the research methodology and explains the overall research design. The study will take a quantitative approach, and the instrument used will be a questionnaire with structured answers on a five-point Likert scale. The proposal also describes the organisations that will be part of the study. Furthermore, it shows the questions that will be asked and how these questions will be analysed and interpreted. Lastly, the proposal ensures the anonymity of the participants taking part in the study.

CHAPTER 2 – LITERATURE STUDY

2.1 INTRODUCTION

During the COVID-19 crisis, digitization, is one sector that has witnessed rapid expansion (Sneader & Singhal, 2021). Digitization includes everything from online customer service, remote working, supply-chain innovation, and the use of artificial intelligence (AI) and machine learning to improve operations; this implies that the COVID pandemic has been the primary accelerant of technical advancement in recent years and that the future of work, the future of industry, and a more resilient supply chain may have arrived sooner than predicted. Microsoft CEO Satya Nadella noted in April 2020 that "we've seen two years' worth of digital transformation in two months" (Spataro, 2020).

Volatility and uncertainties remain the theme of the day as the world is doing its best to understand what the new normal looks like. The disruptions caused by extreme weather, the high cost of climate action, and a volatile geopolitical environment make for complete uncertainty in the world economy and people's daily lives.

In South Africa, digitalization is taking place within an economy that has prematurely deindustrialized, where there is a large digital capability gap in terms of digital infrastructure and skills, and where businesses need to make significant investments in retrofitting their existing information technology infrastructure (Andreoni *et al.*, 2021).

This chapter presents a literature study about potential solutions for problems identified and is theoretically positioned. The consulted literature discussed throughout this chapter consists of academic journals, technology surveys, information management magazines, and technology management model guides. The literature study attempts to assess what qualities and criteria a managerial framework should have to create a successful digital framework. The study may benefit CPG companies and others that want to implement digital manufacturing in their production process and strategy. The purpose of the managerial framework is to create a practical framework of the best industry manufacturing strategy in the South African context.

2.2 CONCEPTUAL FRAMEWORK

2.2.1 DIGITAL MANUFACTURING

Digital manufacturing enhances a company's production and optimises manufacturing processes, thus eliminating bottlenecks, reducing inventory, enhancing quality, minimising time to market, pivoting quickly to match consumer needs, and increasing production. Digital manufacturing enables businesses to build a connected, networked, and integrated factory, which uses real-time data analytics to automate the production process and boost operational efficiency and productivity (Queen, 2020:1; TWI-global, 2020:1). From 2015 to 2018, investments in digital factories have resulted in increases of ten percent in production output, eleven percent growth in factory capacity utilisation, and twelve percent growth in labour productivity on average (Wellener, 2019:7).

A genuine, smart factory would use data from system-wide physical, operational, and human assets to drive manufacturing, maintenance, inventory monitoring, digital twin operations, and other activities across the industrial network. It can learn and adapt by collecting and analysing data from networked operations and production systems.

The result may be a more effective and agile system, less production downtime, and an improved capacity to predict and respond to changes in the facility or broader ecosystem, which could lead to enhanced positioning in the market. Sensor embedding, networked data analytics, and AI enable data collection throughout the production and consumption cycle. They allow for a variety of data uses (Andreoni, 2021).

Digital manufacturing's true power lies in its ability to evolve and grow in tandem with the organization's changing needs, whether those needs are shifting customer demand, expanding into new markets, or developing new products or services. Predictive and responsive operations and maintenance and near-real-time production changes become part of normal operations. This is due to improved processing and analytical capabilities, and larger ecosystems of smart, connected assets. Digital manufacturing would enable businesses to respond to changes in ways that were previously difficult, if not impossible, to achieve (Andreoni *et al.*, 2021; Burke *et al.*, 2017:5; Wellener, 2019).

The smart factory is shown in Figure 2.1, along with its key attributes, including connectivity, optimization, transparency, proactivity, and agility. Each of these attributes has the potential to facilitate better decisions and enable organisations in optimizing their manufacturing. No two smart factories will ever match one another, and organisations can prioritise the areas and features essential to their particular needs.

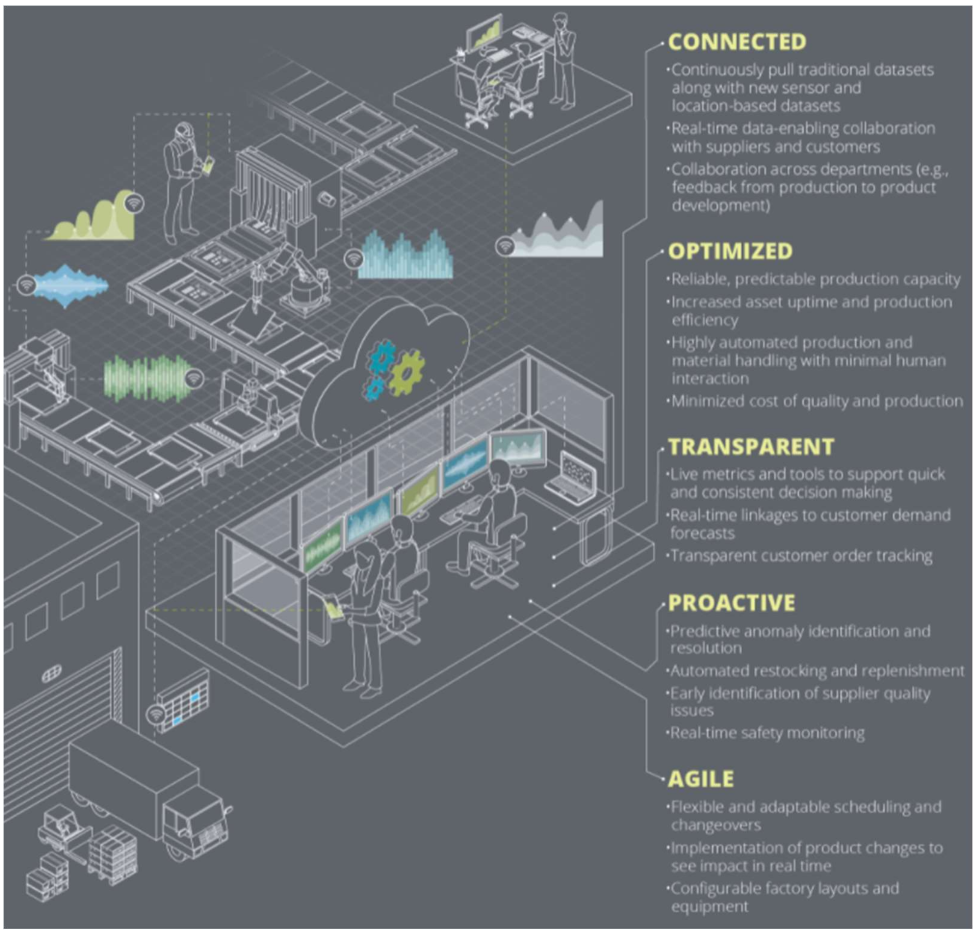

Figure 2.1: Five key characteristics of a smart factory
Source: (Burke *et al.*, 2017:6)

2.2.2 TECHNOLOGICAL FORECASTING

With the amount of innovation that we see today and that we will continue to see over the next decades to come, we need to keep in mind the three technology laws:

- Moore's Law
- Gilder's Law
- Metcalfe's Law

The observation by Gordon Moore in 1965 that the number of transistors in a dense integrated circuit (IC) doubles every two years, is known as Moore's law. From observable evidence, it was hypothesized that the number of transistors on a microchip doubles every year. The specifics of Moore's law have been modified throughout time to represent the development more accurately in transistor density. First, the doubling interval was raised to two years, and subsequently, it was lowered to roughly 18 months (Gianfagna, 2021:1; Kocovic, 2008:137).

Gilder's Law states, that the total bandwidth of communication systems triples every twelve months (Kocovic, 2008:141; Pinto, 2013:1).

Metcalfe's Law, states that the value of a network is proportional to the square of the number of nodes. As a result, the value of being a part of a network increases exponentially while the cost per user stays the same or even decreases (Kocovic, 2008:139; Pinto, 2013:1).

2.2.3 THE INTERNET

The Internet is the underlying technology supporting the concept of the IIoT and Industry 4.0, and originates from ARPANET project, which started in 1969. The overarching goal of the ARPANET project was to create methods for, and acquire the necessary experience to connect computers used by the United States Department of Defence (Featherly, 2016). The project aimed to increase computer networking research and discoveries (Clark, 1988). The original ARPANET eventually evolved into what is now known as the internet. This term was widely adopted in 1983 (Featherly, 2016). The internet concept was founded on several independent networks of random design, beginning with the ARPANET as the pioneering packet switching network, but soon included packet satellite networks, ground-based packet radio networks, and other networks (Leiner *et al.*, 2009:5).

On October 24, 1995, The Federal Networking Council (FNC) unanimously passed a resolution defining the term, Internet (Leiner *et al.*, 2009:17).

Internet Protocol made the world wide web of networks and networked computers possible.

Most people regard the Internet as a continuous pillar of today's world, thinking it was invented as is, and has only existed since then. However, the Web we know today was not originally envisioned. To understand this better, a breakdown of the Web into a couple of iterations will be introduced (Dabit, 2021).

2.2.4 WEB 1.0

Web 1.0 consisted primarily of static websites, controlled by businesses. Additionally, there was no interaction between users, and individuals contributed very little material during this time. Most participants were content consumers, while most creators were web developers who created text- or image-based websites (Dabit, 2021). Web 1.0 is known as the "read-only web".

2.2.5 WEB 2.0:

Web 2.0 refers to the web in its most recent iteration. With the arrival of social media, the Web became a read-write. Instead of supplying content, companies started giving platforms for user-generated content and user-to-user interactions. As more individuals went online, a few corporations dominated the Web's traffic and value. Web 2.0 created the ad-based revenue model. Users could now generate material, but not own it and neither profit from it (Anon., 2022). The biggest problems and challenges for Web 2.0 companies are situated around how they secure data and how they use data to grow their companies and make money from it, often to the detriment of the consumer or user of the Web.

2.2.6 WEB 3.0:

Web 2.0 has highlighted the need for too much trust, and Web 3.0 may solve this problem. Most of the Web people know and use today is based on trusting a few private companies to behave in the public’s best interest.

Web 3.0 is the next level in the Internet's evolution, allowing it to interpret data in a human-like manner. It will use AI technology, Machine Learning, and Blockchain to offer smart applications to users. This will allow for the intelligent generation, and dissemination of highly personalised content to every internet user (Anon, 2022d).

Even though Web 3.0 is still in its initial stages and even with the probability of exaggerated outcomes, the technology could change the world if even a small part of its full potential is reached.

Web 3.0 is important because all businesses need to know what could happen in their core markets, and where they could find opportunities in future. The emergence of Web 3.0 offers a chance to simplify the internet experience, allow individuals to retake ownership of the data that belongs to them and open up the possibility of mass customization. Web 3.0's use of wallets and other identification platforms can disrupt the traditional approach to online identity and resource storage (David Crawford *et al.*, 2022:15 - 22).

2.2.7 INTERNET OF THINGS (IOT)

A very simplified definition of the Internet of Things (IoT) is the concept of linking any device that can be turned on or off over the Internet to one another, and the Internet in general, without human or computer interface (Morgan, 2014:1; Winter, 2020).

The term “Internet of Things” or IoT was first used in 1999 by Kevin Ashton during a presentation made at Proctor & Gamble (P&G) (McFarlane, 2015:1). Although he was the first to use the terminology, the concept of connected devices, particularly connected machines, has been around for a long time.

The first electric telegraphs, built in the late 1830s, were early examples of machines interacting with one another. Radio voice communications, wireless (Wi-Fi) technology, and supervisory control and data acquisition (SCADA) software, were other technologies that represent what we know today as IoT. The first connected smart appliance was a customised Coke machine at Carnegie Mellon University in 1982. Students could find out which drinks were stocked and whether they were cold using the university's local network (ARPANET) (Anon., 2022c).

If you examine the phrase "Internet of Things," the two keywords that stick out are "Internet" and "Things," which provide context for what the phrase represents—supporting the idea of the internet functioning as the underlying technology. The Internet of Things is thus a vast and global network of interconnected "things," which may also include people (Morgan., 2014:1).

Although the concept has been around for a substantial amount of time, most people are still trying to figure out how to make the Internet of Things work for themselves and their businesses. With Industry 4.0 and 5.0, as well as 5G, as primary supporting technology, IoT is again at the forefront and should experience significant growth and maturity.

Having a basic understanding of how the internet of things (IoT) touches the lives of people across the world, as well as every aspect of business, including manufacturing, is essential for this study. As part of their digital transformation initiatives, many businesses currently use IoT to understand consumer needs in real-time, become more responsive, increase machine and system quality, streamline operations, and develop novel ways to operate. McKinsey forecasts that the entire economic impact of IoT within factories will range between 1.2 and 3.7 trillion dollars per year by 2025 (Patel *et al.*, 2017).

2.2.8 INTERNET OF EVERYTHING (IOE)

The concept of the Internet of Everything (IoE) originated at Cisco. The IoE connects people, processes, data, and things to enable information flow and generate new opportunities for innovation. Sensors and devices collect data from previously disconnected processes and their components, enhancing data's role in decision-making across the organisation (Howe, 2014:2).

With IoE enablement, companies across all sectors can increase efficiencies, continue to innovate, and focus on scaling their product to the extent where the customer, and not the product, is at the core of what they do. Companies of all sizes and industries will be searching for competitive advantages broadening brands and markets and increasing their revenue and sales. To accomplish this, they would prioritise meeting the needs of their customers. By linking things and thus connecting products, manufacturing lines, the supply chain, and finally, people, the IoE is the ultimate platform for obtaining analytics and information in the form of previously inaccessible huge amounts of data. It can interact with platforms and convey and analyse data in real-time (Bradley *et al.*, 2013).

2.2.9 5G CONNECTIVITY

5G is the fifth generation of cellular technology. It is designed to increase speed, reduce latency, and improve the flexibility of wireless services (Cisco). While 4G and LTE, the first two generations of cellular technology, primarily focused on ensuring connectivity, 5G takes connectivity to the next level by offering customers cloud-based linked experiences. Cloud technologies are used by 5G networks, which are virtualized and software driven.

Mobility will be made more accessible by the 5G network's seamless open roaming capabilities between cellular and Wi-Fi connections. Mobile users can stay connected when they switch between outside wireless connections and wireless networks inside buildings, without user intervention or requiring users to re-authenticate (Cisco:1).

2.2.10 INDUSTRIAL INTERNET OF THINGS (IIOT)

The Industrial Internet of things (IIoT) refers to the extension and use of the internet of things (IoT) in industrial sectors and applications. IIOT integrates machine sensors, middleware, software, and backend cloud computation and storage systems to improve company operations and asset visibility. It transforms corporate operational processes by using advanced analytics to query massive data sets (Gilchrist., 2016:3). The IIoT helps industries and businesses to improve their operational efficiency and reliability by incorporating industrial applications and software-defined manufacturing processes resulting in reduced unplanned downtime, optimised efficiency, and profits.

The IIoT extends beyond the typical consumer gadgets and physical internetworking associated with the IoT. What distinguishes it is the convergence of Information Technology (IT) and Operational Technology (OT) (TrendMicro:1).

The backbone of digitization is secure communication, which leads to the safe exchange of data between operational technology and information technology (IT). Internet-connected IoT devices can be remotely hacked. These objects were created without security, making them simple targets. Once in control, hackers can take over the object's functionality and steal the user's digital data. A crucial component of any future IIoT architecture is to ensure security is built into the design and planned from the outset. Security by design builds security into software and hardware from the start rather than as an afterthought (Atoui, 2018).

2.2.11 OPERATIONAL TECHNOLOGY (OT)

Operational technology (OT) is the hardware and software used to update, monitor, or control physical devices, processes, and events in an organisation. This technology is used in industrial settings, and its equipment has more autonomy than IT devices or applications.

Industrial control systems (ICSs) such as programmable logic controllers (PLCs), distributed control systems (DCSs), and supervisory control and data acquisition (SCADA) systems, are examples of operational technology (Anon., 2022a).
Operational technology relies on devices to accept data from input devices or sensors, process it, and perform specific tasks or output specific information based on pre-programmed parameters. As an example, PLCs monitor machine productivity, track temperatures, and automatically stop or start processes. They also trigger alarms when machines malfunction. Due to their specialisation, these devices rarely run on mainstream operating systems (like iOS or Windows) and require custom software (Silagy, 2019:1).

Some challenges exist in the convergence of IT systems and operational technology and need to be considered when a company moves forward to have these systems connected to harvest data. The first consideration is to take the technology life cycle into account. The life cycle of an operational technology system can span decades, whereas IT systems, such as laptops and servers, typically last four to six years. In practice, this means that operational technology security solutions should account for outdated infrastructure that may not even be patchable.

Traditionally IT and operational technology networks are frequently two separate systems that cannot communicate with one another, or track operations in a holistic manner across an organization's infrastructure. Ownership of IT and operational technology often land under the care of separate teams, with operational technology systems typically under the control of the Electrical engineers or the Manufacturing operational teams. These teams often report to different leadership teams. Each team manages half the ecosystem, dividing and duplicating security and threat management efforts and making it more challenging to safeguard the organisation from cyber threats (Anon, 2022b). As part of this convergence, IT software is now used, to support operational technology processes and may be accessible via operational technology networks.

Operational technology hardware and software, typically classed under the Industrial Internet of Things (IIoT) handle equipment, assets, and processes that can include dangerous machinery. Ensuring their security is critical to human safety, as the associated cyber risk increases. Cyber-attacks in the operational technology environment have moved from immediate process disruption, such as plant closure, to compromising industrial environments to cause physical damage (Moore, 2021).

From a benefits perspective, more organisations are considering core technology platforms capable of unifying disparate data systems used by both the business and operations sides. This is a fundamental shift for industrial processes that previously disconnected from other systems.

2.2.12 INDUSTRY 4.0 AND MOVING INTO INDUSTRY 5.0

The term ‘industry 4.0’ refers to the next developmental stage in the manufacturing industry’s organisation of the entire value chain process. It is also known as the “fourth industrial revolution.” The German government originally developed the notion of industry 4.0 as a high-tech strategy to stimulate the digitisation of its manufacturing industry (Pillay *et al.*, 2017:6; Winter, 2020).

Industrial digitalization and the advancement in the way organisations manufacture goods, as a result, is such an undeniable evolution that it has been termed Industry 4.0, the fourth manufacturing revolution (Marr, 2018). With the help of cyber-physical systems like operational technology, and the IoT, manufacturers and producers can now analyse and optimize their processes with the help of the vast amounts of data being collected.

Overall, it can be concluded that an integrated and secure network mesh is required as the primary layer or "highway" on which Industry 4.0 functions. Once this layer is in place, IIoT, IT, and operational technology (OT) enables you to collect and aggregate data, analyse it, and make automated decisions based on the data insights.

The terminology and understanding of the notion of Industry 4.0 vary significantly, but all of these phrases and concepts have in common, is the recognition that old manufacturing and production methods are undergoing a digital revolution. Industry 4.0 is more than just connecting equipment and products via the Internet. It represents a paradigm shift in how we organise, manage, and conduct business (Dhaese, 2021; Winter, 2020).

Figure 2.2 shows the application of the four fundamental technologies of Industry 4.0, which should be applied along the value chain. These technologies comprise connectivity, advanced analytics, automation, and advanced-manufacturing technologies. Before COVID-19, acceleration was the key concept and Industry 4.0 was booming, enabling organisations to transform their operations in all areas, from manufacturing effectiveness to product customisation, with gains in time to market, the value of services, and the development of new business models (Agrawal, Eloot*, et al.*, 2020:2).

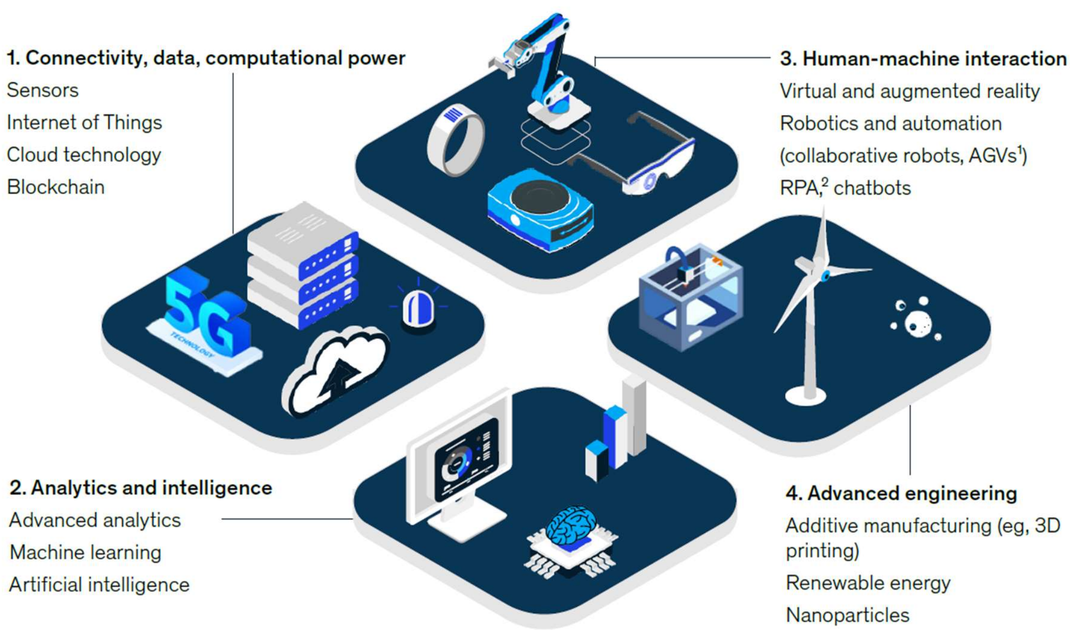

Figure 2.2: Industry 4.0 is characterized by 4 foundational technologies applied along the value chain.

Source: (Agrawal, Eloot*, et al.*, 2020:2)

The human dimension to Industry 4.0 gave rise to Industry 5.0, and while Industry 4.0 can be a concept that we have moved on from, its pillars are the building blocks for Industry 5.0.

In modest terms, the main difference between Industry 4.0 and Industry 5.0 is that Industry 5.0 emphasizes the well-being of humans as a primary concern and places people at the core of the idea.

The term Industry 5.0 refers to people collaborating with robots and smart machines. It is about robots assisting humans in working better and faster by leveraging innovative technologies like the Industrial Internet of Things (IIoT) and big data. It adds a personal human touch to the Industry 4.0 baseline of automation and efficiency (Jardine, 2020:1).

The order of the five industrial revolutions is displayed in Table 2.1. An interesting point to keep an eye on is the duration of each revolution to observe how it sets the stage for the subsequent one.

The textile business was mechanised during the first revolution. The assembly line, large-scale production, and mass consumption were all outcomes of the second industrial revolution. The third enabled the digital capture of data and its efficient, cost-effective transformation, manipulation, and transmission. Robotics, artificial intelligence, augmented reality, and virtual reality have all been made possible by the fourth industrial revolution. Between the first and second industrial revolutions, almost two hundred years passed. In our lifetimes, the majority of us will have participated in the last three industrial revolutions, and there will be many more to follow (RegInsights, 2020).

Table 2.1 – The sequence of the five industrial revolutions

1st Industrial Revolution	2nd Industrial Revolution	3rd Industrial Revolution	4th Industrial Revolution	5th Industrial Revolution
Mechanisation	Electrification	Automation and Globalisation	Digitalisation	Personalisation
Occurred during the 18th and 18th centuries, mainly in Europe and North America	From the late 1800s to the start of the First World War	The digital revolution occurred around the 1980s	Start of the 21st century	2nd decade of the 21st century
Steam engines replacing horse and human power	Production of steel, electricity and combustion engines.	Computers, digitisation and the internet,	AI, robotics, IoT, blockchain and crypto.	Innovation purpose and inclusivity.
Introduction of mechanical production facilities driven by water and steam power	Division of labour and mass production, enabled by electricity.	Automation of production through electronic and IT systems	Robotics, artificial intelligence, augmented reality, virtual reality	Deep, multi-level cooperation between people and machines. Consciousness.

Source: (RegInsights, 2020:1)

Industry 5.0 has arrived, while most companies are still figuring out Industry 4.0. The next industrial revolution must define how humans and machines interact, specifically when it comes to contentious areas such as when artificial intelligence makes judgment decisions (Vollmer, 2018:1). AI can improve forecasts; however, it cannot always choose the best conclusion or action. AI may not account for all hidden costs, rewards, and risks. Decision-making requires human judgement. Technology may allow machines to make decisions even when humans might make better ones. This means that machine prediction is only as good as the information it relies on, but as technology improves, machines can potentially be relied on to make conclusions even when human input is better (Bhuyan, 2018). Various biases and ethical dilemmas may arise in the future, and UNESCO has made a strong start by adopting a global accord known as the Recommendation on the Ethics of Artificial Intelligence (UNESCO, 2022). This work will hopefully become an ethical compass and global normative framework for digital rule of law.

In another sense, Industry 5.0 can also refer to the 5th industrial revolution in that it attempts to boost productivity through technology, and improve human quality of life (Mekkunnel, 2019:6).

2.2.13 ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML)

The massive transformation seen in the manufacturing industry can be credited to digital technologies that are streamlining the way sophisticated operations are controlled. Manufacturers can optimise their operations by reducing machine downtime, anticipating maintenance needs, and effectively utilising factory floor resources. Artificial intelligence (AI) and machine learning are helping to disrupt the manufacturing business in several areas by making it simple to collect data on machine performance and quickly identify and propose solutions (Anon., 2022d).

Artificial intelligence (AI) is a catch-all phrase describing the skills demonstrated by learning systems that humans interpret as intelligence. Speech, picture, and video recognition, autonomous objects, natural language processing, conversational agents, prescriptive modelling, enhanced creativity, smart automation, advanced simulation, complicated analytics and forecasts, are all standard AI capabilities today (Brosset et al., 2019:3).

In the wake of the global COVID-19 pandemic, manufacturers are working to strengthen their companies' resilience. The adoption of AI in manufacturing is accelerating due to significant benefits that make AI particularly effective for manufacturers, to launch on their advanced analytics journey. Intelligent maintenance, demand planning and forecasting, and product quality control provide the greatest benefits.

The COVID-19 pandemic has highlighted the necessity of manufacturing processes that are digital from end to end. AI and Machine Learning (ML) technologies have climbed to the top of the manufacturing priority list, because they enable companies to change their business models, create operational strategies to support those models, and monetise information to reach higher levels of efficiency (Bodor, 2020; Kroupenev, 2022; Paquin, 2020; Pressley, 2021).

Machine Learning (ML), algorithms and statistical models are used to learn how to efficiently carry out a given task without being programmed. As a result, human intervention is unnecessary, and decisions are made automatically based on observed patterns and inferences. In addition, it equips computers with the ability to learn and develop autonomously without being explicitly programmed (Paquin, 2020:2).

A considerable value that AI potentially offer, is freeing up time for people to focus on tasks that still require the human aspect to complete. while AI handles repetitive or time-consuming tasks, frontline workers, technicians, and supervisors can concentrate on higher-value tasks. To reap the most benefits from AI, employees must learn how to use it.

AI contributes towards manufacturing because it enables smart production, predictive and preventative maintenance, supply chain optimisation, improved safety, product development and optimisation, AR/VR (Augmented and Virtual Reality), cost reduction, quality assurance, green operations (energy management) and more.

The impact of artificial intelligence and machine learning expanding digital capabilities is being felt all over the manufacturing industry. However, it is more than another technology. AI in manufacturing is altering how we work and think, both in how we execute in the market and on the factory floor. In fact, a catchphrase, "hyper-automation," is emerging, which is taking task automation to the next level by including processes across various departments and automating solutions, all made feasible by the usage of AI and ML (Hennessey, 2021; Pressley, 2021; Sheridan, 2022).

2.2.14 VIRTUAL REALITY (VR AND AUGMENTED REALITY (AR)

According to the Oxford English Dictionary, Virtual Reality (VR) is a computer-generated simulation of a lifelike environment that can be interacted with, in a seemingly real or physical way by a person, especially employing responsive hardware such as a visor with a screen or gloves with sensors (OED, 2019). Augmented Reality (AR), in turn, is defined as Augmented Reality (AR) is the addition of computer-generated output, such as images or sound, to a person's view or experience of his or her physical surroundings employing any of various electronic devices (OED, 2019).

In the context of manufacturing and product design, virtual reality (VR) implies the digital duplication of a product or environment, with the user typically having the ability to interact with the environment and fully submerging oneself within it.

Augmented reality (AR) uses a mobile device or headset to display digital content in real life. These elements might be flat graphics or seem like "3D" objects. Instead of a digitally created background like in virtual reality, the digital product or information is projected onto a background of the actual world (Lynch, 2022; PwC, 2019:3).

Although virtual reality technology has been around for a while, manufacturing facilities have only begun to use it. When employed in the manufacturing sector, virtual reality can help with various difficulties, including raising production, lowering training costs, and boosting the accessibility of new items to the market.

Early adopters in the manufacturing sector are using AR and VR creatively. They are thinking about how to use these potentially disruptive technologies to, among other things, enhance productivity, decrease training expenses, improve worker safety, hasten the release of new products to market. PWC predicts that by 2030, the potential impact of VR and AR on the global economy will reach $1.5 trillion (PwC, 2019:4).

Organizations can use VR and AR to teach staff and test operations, especially by simulating real-world and high-risk situations. VR and AR applications in manufacturing can include almost any operation area. Still, these technologies are well-advanced and frequently used in the areas of assembly, design, training, and web-based reality. VR and AR technology may expedite the creation of new products by bringing together teams from many locations in a single virtual area. Design teams do not need to spend a lot of money on physical prototypes to explore, test, and evaluate various concepts rapidly. This might make it possible for businesses to launch higher-quality products swiftly.

Additionally, the advantages go far beyond process improvement. Organisations are coming to understand the chance to diversify current revenue streams and develop new ones. While gaming and entertainment firms are utilising technology to create new experiences and products, retail, hotel, and automotive industries are already exploring the potential to sell and showcase items via VR and AR.

Whole new business segments and sources of income are created through new companies that invent, design, and support VR and AR services and technologies (Brooks, 2022; PwC, 2019:5,6; Shiratuddin & Zulkifli, 2001:3 - 11). One well-known example is when Facebook changed its name to Meta to position itself for the future and a new world built, in virtual and augmented reality.

2.2.15 CONSUMER PACKAGED GOODS (CPG) COMPANIES.

Consumer packaged goods (CPG) are items with a generally short lifespan, intended to be used quickly and often daily. In other words, these goods are used and replaced frequently. Items such as food, beverages, clothes, makeup, personal care, and household products.

The packaging of CPGs is typically distinctive and recognised by consumers, as the name implies, and can be displayed on the shelves of retail establishments (Anon, 2019).

The cheap switching costs and significant market saturation make the CPG sector an extremely competitive one. Consumers intending to buy CPG products have an inexpensive and simple way to change their brand allegiance. Despite these obstacles, this industry's consumer product demand has largely remained stable (Anon, 2019). CPG is sometimes also called fast-moving consumer goods (FMCG).

2.3 THEORETICAL FRAMEWORK

2.3.1 SECURITY IN DIGITAL MANUFACTURING

Increased equipment is connected via IoT as digitalization becomes a global trend and a gauge of growth. Robotics, AI, and autonomous machines are gradually replacing human labour by taking over administrative chores, frequently unsupervised. Due to the volume of data generated by all of this, maintaining the security of all personal and professional data has proven to be difficult and a source of significant concern for organisations going down the route to digitise their manufacturing facilities.

As data may be exchanged readily in a fully realised digital world, privacy concerns are a significant challenge in the digital transition, including operational security, people security, and physical security. Every time data is gathered that could be used to identify a person, there may be a privacy issue. This might be contact information for employees or clients, or any data gathered by specific IoT sensors, cameras, or biometric authentication tools. It is crucial to understand that, even if data from a single device might not raise privacy issues, data aggregated with data from other devices might.

Unquestionably, the security of personal data within the platform concerns both management and staff. Any breach could potentially result in significant losses, or, worse, the complete failure of the business (Anon, 2021b; Kannan, 2021).

As data may be exchanged readily in a fully realised digital world, privacy concerns are a significant challenge in the digital transition, including operational security, people security, and physical security. Every time data is gathered that could be used to identify a person, there may be a privacy issue. This might be contact information for employees or clients, or any data gathered by specific IoT sensors, cameras, or biometric authentication tools. It is crucial to understand that, even if data from a single device might not raise privacy issues, data aggregated with data from other devices might (Anon, 2021b).

Confidentiality, integrity, and availability are the three fundamental security needs that the IT manufacturing sector depends on. Confidentiality is the maintenance of the secrecy of information flow throughout the production chain. A breach of confidentiality could result in serious financial losses for the business, the compromise of customer information, intellectual property, trade secrets, and more. The consistency, accuracy, and dependability of information passing through the production chain and the consistency and reliability of physical components during a product's life cycle are represented by production systems' integrity. A variety of physical and cyber-attacks by attackers on that system could jeopardise the availability of the production system. These attacks can inflict service outages that simultaneously disable several product lifecycle components, which can stop the entire production system.

The most common types of cyberattacks, amongst other types of attacks, threatening Industrial systems and manufacturing facilities are Distributed Denial of Service (DDoS) attacks and Ransomware. Both can cause severe damage in the short- and long-term and have lasting impacts on the organisation affected.

A Distributed Denial of Service (DDoS) attack is a malicious attempt to compromise a network by overwhelming its capacity to manage legitimate traffic and requests. As a result, the victim is denied service, and there is downtime and financial loss as a direct consequence. A DDoS attack is a network-based attack that targets network devices that connect your company to the internet by taking advantage of network-based internet services and equipment (Horak *et al.*, 2021:3; Stanger, 2021; Worp).

Due to the COVID-19 pandemic, attacks increased in 2020. Hackers used this to disrupt and make money and state-sponsored actors wanted to destabilise the global economy. The alarming part of this is that DDoS attacks can be quite simple to carry out despite the potential for enormous damage to the target. Booters or Stressors, often known as “botnets for hire”, have made it possible for someone without any programming experience to launch a successful DDoS attack (Stanger, 2021).

Ransomware is malware that encrypts networked data and renders them inaccessible until hackers’ demands are met. If a ransom (typically in the millions) is not paid, these threat actors may threaten to sell or leak important data (Miller, 2021).

The manufacturing sector took the brunt of all cyberattacks in 2021. A report called “X-Force Threat Intelligence Index” released by IBM revealed how supply chains were impacted by ransomware and other vulnerabilities, with manufacturing being the most frequently hit sector overtaking the financial services and insurance sectors (Singleton, 2021:6).

Attackers used the domino effect that occurs when a manufacturing organization's production flow is interrupted. Threat actors were aware that due to the attacks, their downstream supply chains would demand them to pay the ransom. The survey also noted that 47% of attacks inside the manufacturing sector were caused by vulnerabilities that businesses failed to patch, stressing the necessity for all manufacturers to incorporate vulnerability management into their security strategy (Singleton, 2021:43). As discussed earlier in this paper, multiple endpoint vulnerabilities are created by the extensive network of Operating Technology (OT) devices present throughout a lengthy supply chain, and fragmented systems create security holes.

The manufacturing industry is an attractive target because they have little tolerance for downtime. This is known to ransomware actors, who take advantage of operational pressures made worse by the pandemic.

2.3.2 FOUNDATIONS OF THE ADOPTION OF TECHNOLOGY

One of the earliest social science theories is the Diffusion of Innovation (DOI) Theory, which E.M. Rogers created in 1962. The diffusion of innovations theory describes how new scientific, technological, and other developments diffuse throughout civilizations and cultures before becoming widely used (Rogers, 2003). The diffusion of innovations hypothesis aims to explain how and why new concepts and methods spread over potentially lengthy durations. Adoption depends on a person's ability to see an idea, behaviour, or product as novel or inventive. This allows for the possibility of the idea or product to spread. Early adopters differ from late adopters. Understanding the target population's characteristics that will aid or hinder innovation adoption is crucial when promoting an idea. Different tactics are employed while advertising innovation to appeal to the various adopter segments. There are five recognised categories of adopters:

- **Innovators** - those who are willing to take risks and are the first to try new things. Not much has to be done to appeal to this market.
- **Early Adopters** - those who are eager to experiment with new technologies and determine their societal value. How-to guides and implementation information sheets are two tactics to appeal to this demographic.
- **Early Majority** - People who are both a part of the broader public and open the door for the adoption of an innovation. Success stories and proof of the innovation's usefulness are some strategies to appeal to this demographic.
- **Late Majority** - The group of people who accept innovation as a part of their daily lives after following the early majority. Information on how many other individuals have tried the innovation and successfully adopted it is one tactic to appeal to this audience.
- **Laggards** - Late adopters of modern products and ideas. They are risk-averse and cautious. When innovation is widely adopted, it becomes essential to daily life and work, and they must use it.

(Halton, 2021; LaMorte, 2019; Rogers, 1961, 2003)

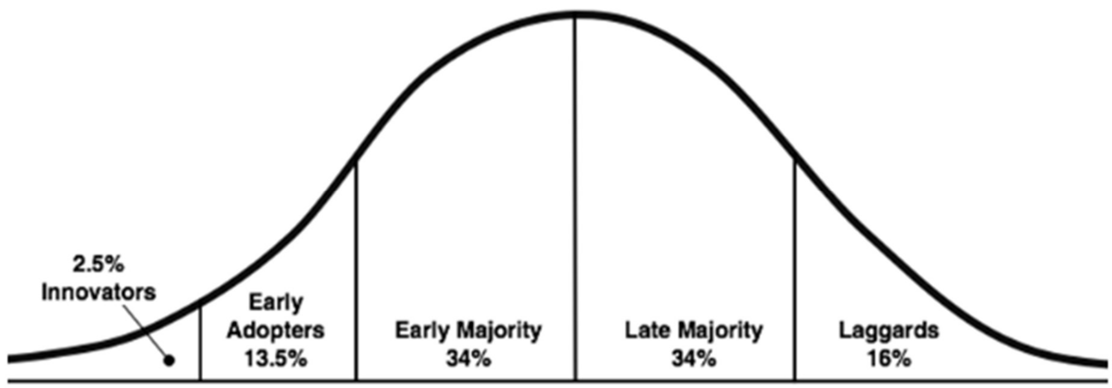

Figure 2.3: Adopter categorisation based on innovativeness.

Source: (Rogers, 2003:247)

Figure 2.3 shows the average frequency distribution divided into the five adopter categories, along with an estimation of the proportion of people in each category. The innovators are the first 2.5 per cent to adopt an innovation. Early adopters are the next 13.5% to adopt the new idea. The early majority, 34% of adopters, are between the mean date of adoption minus one standard deviation. The late majority, which comprises 34%, adopted the new notion between the mean and one standard deviation to the right. Laggards are the last 16% (Rogers, 2003:246).

2.3.3 TECHNOLOGY ACCEPTANCE MODEL (TAM)

According to the Technology Acceptance Model (Davis, 1989), two criteria affect whether potential users of a computer system will accept and use it:

1. **Perceived usefulness** - It refers to a person's perception of the technology's usefulness for their intended use.
2. **Perceived ease of use** - If the technology is simple and easy to use, then the obstacles have been removed. No one is interested in using something if it is difficult to use and has a confusing interface or poor performance.

This model's emphasis on the perceptions of the potential user is its key trait. Even while a technological invention’s inventor may think it is practical and user-friendly, the item will not be accepted by potential customers until they also have the same views.

TAM has been criticised on many fronts, yet it still offers a helpful overarching framework. But it still takes a very broad view and implies that people will be willing to adopt the technology if the requirements are met. However, because each individual is different, the perception may vary depending on age, gender, and several other factors (Charness & Boot, 2016:389 - 407; Davis *et al.*, 2020; Thompson).

2.3.4 BUSINESS 2.0 AND RESPONSIBLE BUSINESS 2.0

Business 2.0 represents a new way of thinking and doing. It is about running entire business operations off Internet-based services. You'll immediately realise the potential that Business 2.0 offers since we already recognize it if you consider industry disruptors like Uber, Salesforce.com, and Amazon (Kerr, 2016).

As a result of globalisation, society is becoming increasingly interconnected, resulting in an ever-growing network of business stakeholders. Environmental deterioration has also put the planet in danger by upsetting ecosystems by depleting resources like air, water, and soil. Corporate behaviour must strike a balance between the goals of economic profit and the social and environmental well-being of a globalised society due to the ongoing degradation of the environment.

The 3C’s model is an approach to sustainable business that has been expanded into Responsible Business 2.0, which aims to identify best practices in ethical and sustainable commerce. The three concepts of corporate governance, corporate social responsibility, and corporate sustainability are the 3Cs' main highlights and focus.

The Responsible Business 2.0 concept was created to close the gaps between the theory and practise of corporate social responsibility as outlined in the 3C's. Responsible Business 2.0 assists businesses in putting these concepts into practice (ESCAP & Council, 2016:14,15).

2.3.5 WORKAROUND THEORY

Steven Alter, in 2014 theorized about workarounds and described a workaround as a goal-driven adaptation or other changes to one or more elements of an existing work system to get around, avoid, or lessen the effects of perceived barriers, exceptions, anomalies, accidents, established practices, management expectations, or structural restraints that keep that work system or its participants from achieving the desired level of efficiency, effectiveness, or other organisational or personal goals (Alter, 2014:18,19).

When processes are unavailable, sluggish, or inadequate, when technologies are malfunctioning, or when situational constraints limit performance, it may be required to implement workarounds.

The inability to use new manufacturing technology due to poor or incomplete change management and upskilling of workers, is one of the main problems with the digitisation of a manufacturing environment. Workers must make an effort to understand how to employ advanced data analytics, AI and machine learning, and automation as they increase their technological growth in manufacturing. People are, unfortunately, quite resistant to change. Therefore, it is best to avoid forcing change wherever feasible. Instead, it is essential to stress the benefits of the move toward digitalisation because doing so will enable staff to make the space they require for improvement and adaptability. The effectiveness of digital transformation might be hampered, and workarounds may start to become part of the standard way of working if leaders are not aware of the hazards of rigid organisational structures, ineffective procedures, and poor leadership styles. This was never more obvious than in 2020 when companies struggled to quickly adapt to remote or work-from-home business models (Anon, 2021b).

In Figure 2.4, known as the “Five voices of workarounds”, Alter (Alter, 2014:9) seeks to bring together all of the many features of workarounds that can be found in the existing literature and align them in such a way that they are more practical. The five voices represented in the literature on workarounds are phenomena connected to workarounds, types of workarounds, direct impacts of workarounds, perspectives on workarounds, and organisational difficulties and dilemmas related to workarounds.

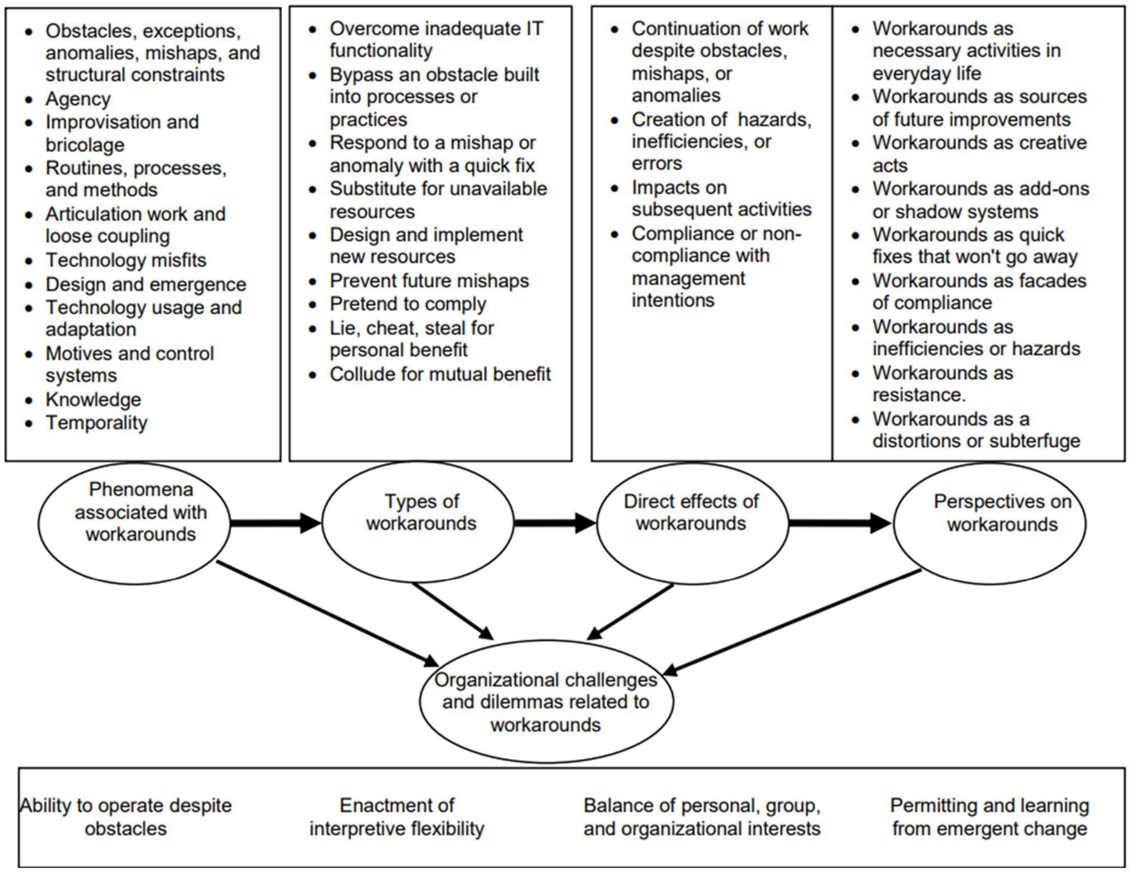

Figure 2.4: Five "Voices" of workarounds found in the literature.

Source: (Alter, 2014:10)

2.3.6 MANAGERIAL ASPECTS OF FLEXIBLE WORK / HYBRID WORK

Most businesses prioritised a crisis response when the COVID-19 pandemic hit, primarily focusing on the health and safety of their employees and the continuation of critical services. Companies are currently in varying stages of recovery from the pandemic, but most of them need to consider the future and what the new normal would look like as part of their strategic plans for thriving post-COVID.

Given the uncertainty surrounding the long-term efficiency of vaccines, this recovery will not be typical because COVID-19 is unlikely to stop soon. As they go from crisis response to recovery, organisations must prepare for various scenarios and time horizons. Additionally, they must prepare for the potential occurrence of several waves of additional pandemics and other disruptions with a global and uneven footprint.

Organizations must set critical priorities over the next 12 to 24 months for a workforce strategy to prepare for new realities (Schwartz *et al.*, 2021:4).

The way we work has changed everywhere, and while opinions may differ as to whether these changes are for the better or worse, the fact remains that they have occurred, and businesses now need to decide how they will restructure their future. Both companies and employees have adopted new behaviours and skills that, for the most part, have improved how they run things (Philippov, 2021:1).

A hybrid workforce consists of both employees who work from an office or other central location and those who work remotely. Employees can then work from wherever they choose, whether in a central area like, a warehouse, factory, retail space, or a remote location like their home. Employees can work in the environment that is most comfortable for them, thanks to hybrid workforces. Employees can also work in their preferred environment or a hybrid of the two if they feel more productive there (Rosencrance, 2021:1).

According to Andrey Philippov (2021:1), some of the most significant shifts in the way we work are:

- **Shift from office culture to a supportive culture**. For decades, we thought a nine-to-five office job was ideal for business. As firms adjust to remote working, productivity and employee freedom have changed.
- **Virtual-First Companies**. Many companies now provide remote and in-office employment. More companies are "virtual first" due to this shift in labour. Offices and homes are becoming workplaces, and people can choose how and where they work. Organisations must be equipped to operate virtually. Virtual teams must be managed, trained, and evaluated by leaders in this new way, and the necessary technological infrastructure must be in place to support this. Technology for remote communications must be in place, and several platforms, such as Zoom, MS TEAMS, and Skype (to name a few), are available to facilitate this. This also implies that data is stored in the cloud, and cybersecurity measures are in place for the various working modes for the technology you use and the teams that use it.
- **A Crash Course on Modern Technology.** The pandemic required the workforce to obtain new skills and experiences. Everyone has been forced to

take a crash course in modern technology, and as a result, more people than ever can work efficiently from flexible locations. Businesses have been forced to embrace technology in new ways. COVID-19 allowed many employees and businesses to acquire knowledge about new technology.

- **Overlapping Personal and Professional Lives**. Before the pandemic, we separated work and life. With Zoom meetings and remote work, we know our co-workers better. Every video chat and virtual meeting exposes our colleagues, executives, and clients' personal lives, and seeing their children and pets is now normal. These unique insights may seem like a distraction from work, but they can improve relationships. Overlapping personal and professional lives can improve teamwork and understanding.
- **Increased Focus on Mental Wellbeing**. Companies are doing more to promote mental wellness in employees than ever before. After the epidemic, workplace mental health should remain a priority. Many companies are obligated to identify and understand mental health at work.

Another shift in how we work needs to be **Increased focus on supplier relationship management.** Digital supply networks are replacing the old concept of a linear supply chain and focusing on optimising for your own business only. These new networks allow for end-to-end visibility, cooperation, responsiveness, agility, and optimization by bridging functional silos inside your organisation (Kilpatrick & Barber, 2020:16). These digital supply networks are increasingly being built and configured to anticipate outages and reorganise themselves appropriately to mitigate their impact.

Managers face numerous challenges in post-COVID-19 hybrid workplaces. To ensure fair and flexible workflow and sync between office- and remote workers, you must design new guidelines to cater to these new scenarios. It is necessary to make decisions about how and when to communicate, who should be involved in what decisions, and how individuals will plan their days. All team meetings will continue to be held online because hybrid meetings are unfair to those who cannot attend in person. It is possible that establishing priorities and goals for the week would be more productive. This will ensure that everyone is aware of the activities that need to be completed first. Because of this, teams will be able to maintain their adaptability in the face of expected disruptions (Knight, 2020:1).

2.4 CONCLUSION

The Internet of Everything has the potential to have an impact on and significantly disrupt the Consumer-Packaged Goods (CPG) industry. There is potential to develop, use, and perfect technology to drive value across the CPG value chain, particularly in the areas of product development, sales, distribution, manufacturing, procurement, and supply chain, as well as customer management, particularly in the context of the South African market.

The technological trends that are “coming of age” and moving are mentioned above and, in general, are out in the public domain. The technologies coming of age and at the forefront to be used in digital disruption in CPG companies and indeed across industries are data as well as Machine Learning (MI) and Artificial Intelligence (AI). These technologies have transcended the hype cycle and raised questions such as "Is it viable?" “Is a business case in place?” is no longer necessary. IoT, as mentioned, has been around for a long time in more minor use cases and is again at the forefront, and perhaps now maturing, with Industry 4.0 and Industry 5.0 and with 5G as the main complementary technology attributing to its renewed rise in addition to IIoT and IoE. The apparent need for a resilient supply chain during this period of volatility told us that this is “not it” yet and good connectivity and communication between “things” have a significant role to play.

Immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) are also technologies that have been around for a long while and are being effectively used in some industries, but as a disruptive technology in the CPG industry, perhaps have not yet reached the maturity needed and lacks clear use cases. The COVID-19 Pandemic, together with developing hybrid work habits, may have a significant impact on this technology's rapid and exciting progress.

With the enormous progress in retailing and e-commerce in the CPG industry, there should be some exciting advancements in the usage of autonomous vehicles in regulated areas like factory and warehouse facilities.

2.5 CHAPTER SUMMARY

This chapter provided background information on Digital Manufacturing and the mainstream technologies supporting technological advances in this area. It also illustrated the progression of some of these technologies and associated uses, such as the move from Web 1.0 to Web 3.0. This part also covered the advances made in connectivity and its practical uses.

The second part of the chapter focussed on Industry 4.0 and the progression into Industry 5.0. This part investigated and explained the importance of striking a balance in both technological advancements as well as business advancements, including manufacturing and the supply chain, towards responsible corporate behaviour. The social and environmental well-being of humans and the planet must become a practical goal as much as, if not more, than what economic profit is.

The last part of the chapter first covered aspects of cybersecurity risks and challenges associated with manufacturing industries, but also all businesses in general. This part also stressed that confidentiality, integrity, and availability are the three fundamental security needs that the IT manufacturing sector depends on. In this part, well-known theories on information management and technology were also covered. Lastly, managerial and workplace practices that were accelerated and forced upon organisations by the COVID-19 pandemic were covered, including workaround theories.

CHAPTER 3: RESEARCH METHODOLOGY AND ANALYSIS

3.1 INTRODUCTION

The literature study in Chapter 2 gave an overview of Digital Manufacturing and the technologies that are the mainstream elements supporting technological advances in this area. To address the objectives of this study as outlined on pages 11 and 12, this chapter gives a brief description of the research methodology, techniques used, and guideline values applied to get the required data from the sample of South African-based CPG companies, listed on the Johannesburg Stock Exchange (JSE). This part also details the procedures the researcher used to select the sample, gather the data, and assure the validity and reliability of the study. This chapter's concluding section covers the study's conclusions and suggestions.

This study's primary data collection instrument was a questionnaire sent to the participants in the form of an electronic live link invitation to a survey instrument.

The study questionnaire was evaluated to ensure face validity and levels of understanding. The eventual questionnaire consisted of two sections.

All the statistical analysis for this study was performed by the Statistical Consultation Services at the North West University campus in Potchefstroom.

3.2 RESEARCH APPROACH

Quantitative methods were used to analyse specific factors to answer the research topic.

This quantitative study aims to assess what qualities and criteria a managerial framework should have to create a successful digital framework. The study may benefit CPG companies and others that want to implement digital manufacturing in their production process and strategy. The purpose of the managerial framework is to create a practical framework of the best industry manufacturing strategy in the South African context.

In the quantitative paradigm, a quantitative study tests a hypothesis based on variables, measured with numbers, and statistically analysed to see if its predictions hold (Babbie & Mouton, 2010:646). According to Creswell, a quantitative technique can be used to test objective hypotheses by looking at how variables are related. These variables can be measured with equipment that uses statistical analysis of numerical data (Creswell, 2014:4). A quantitative method also makes it simple to quantify and possibly very accurate to collect numerical data (Du Plessis *et al.*, 2007:21). In the collecting and interpretation of data, quantitative research often places a strong emphasis on quantification. It employs a natural science research process model that is deductive, objectivist, and particularly one influenced by positivism (Bryman *et al.*, 2016:382).

The researcher chose a quantitative method due to its advantages and cost- and time-savings. Quantitative methods are reliable, objective, and show variable interactions. A complex problem should have fewer moving pieces. Finally, quantitative analysis is more objective.

3.3 RESEARCH DESIGN

This study used a cross-sectional method to examine data from a particular moment in time. Think of a cross-sectional study as a snapshot taken at a certain point in time of a certain set of individuals. The advantages of using this method include that it does not involve manipulating variables, and it enables a researcher to examine several qualities simultaneously. This study adds the advantage that can be used to explore the prevalent attributes in a specific population (Cherry, 2022:1).

This is a practical and cost-effective way to ensure that sufficient primary data are acquired to satisfy the study objectives. Cross-sectional study data can be used to direct future, more sophisticated research to provide more detailed responses on related questions.

3.4 RESEARCH METHOD

3.4.1 RESEARCH PARTICIPANTS

The unit of analysis is a clearly defined group of individuals or items that is recognised to share traits; these individuals or things frequently have a standard quality that unites them (Trochim, 2020). The population can be described as a universe of units or things from which a sample containing the information required by the researcher is to be chosen (Bryman *et al.*, 2016:381).

For this study, the population can be regarded as the leading CPG companies with a manufacturing base in South Africa. These 20 companies are listed on the Johannesburg Stock Exchange (JSE) in the CPG sector, as published by Listcorp (Anon, 2022).

3.4.2 MEASURING INSTRUMENT

A research instrument is any device a scientist uses to collect, measure, and analyse data. The subject-specific data comes from participants in the study investigation (Collins, 2021).

A good research instrument should, in the first place, collect data appropriately for the study question. It must address the study's aims, objectives, and questions and confirm or reject its premise. It should also be apparent how to use it without bias (Anon, 2020).

The study used a questionnaire with two sections and a cover page asking for consent. The questionnaire was delivered electronically via SurveyMonkey, and respondents answered the questions on the electronic platform. The consent letter is also the first page of the questionnaire. Respondents are asked to provide their permission for their feedback to be used. They do it by checking the appropriate box to indicate that they agree. If they agree, the questionnaire will open, allowing them to provide feedback on their company's digital manufacturing practices.

The questionnaire did not include any demographic information because demographics are not central to the study's purpose, and there are no hypotheses about their impact.

The first portion of the survey asked respondents about the managerial impact of the COVID-19 pandemic on their manufacturing capabilities. The second section of the questionnaire gathered information regarding the qualities and needs that should be included in a managerial framework for implementing digital manufacturing as part of their manufacturing process and strategy.

3.4.3 DATA COLLECTION

The questionnaire was created electronically. SurveyMonkey was used to collect data online. When a responder completes the survey, the electronic platform instantly collects the data. As a result, the researcher only has access to aggregate data and cannot identify any of the respondents or isolate any single response. This ensures anonymity.

The data collection consists of several steps. These are:

Step 1: Create a digital, cloud-based version of the survey in SurveyMonkey and include the letter of consent on the first page. (See Appendices A and B). The Statistical Consultation Services of the Potchefstroom campus of NWU was used to test the questionnaire for face validity.

Step 2: Draft an invitation. The invitation includes a live link that clients can click to get to the first page of the questionnaire, where they will find the letter of agreement; they must accept that their data will only be used for research purposes.

Step 3: Participants will receive the first page of the questionnaire - the consent form - after clicking on the link. After reading the informed consent form, they must accept by clicking "Yes." If they decline, they will be thanked for their time but will not be given the questionnaire to complete.

Step 4: If they agree and consent to their data usage, the questionnaire opens, and the participant can now complete it.

Step 5: Following completion, the data is automatically saved among the other responses. It is impossible to link any respondent or the company for which they work to any single data input. The information is anonymous.

Step 6: The researcher downloaded the final data set from the survey tool but could not identify any of the individual responses in any way. After that, the data was analysed using IBM's Statistical Program for Social Sciences (Version 25). (IBM SPSS, 2018). Based on the findings, the report was created.

3.4.4 SAMPLING DESIGN

In situations in which it would be impracticable to target the entire population, sampling is necessary. Essentially choosing which members of a particular population should be the focus of a certain study is what the sample is all about (Blair *et al.*, 2013:222, 346; Chandra & Sharma, 2013:31).

During the sample design process, the following steps were taken:

Step1: Determine the Target Population

The target population is the group of people who were the subject of the investigation and from whom the data were collected. They are also a prospective group of individuals from which a researcher might select a sample. Thus, a target population is a group of people with the knowledge the researcher needs to reach certain conclusions about a particular topic (Ngulube & Ngulube, 2022:364, 450). The target population identified for this study includes individuals from the 20 South African-based CPG companies, listed on the Johannesburg Stock Exchange (JSE). These individuals should preferably have knowledge spanning both digital and Information Technology as well as knowledge about their manufacturing operations.

Step 2: Decide on a sampling technique

A sample is a portion of the population chosen for research purposes. The selection method can be either probability or non-probability (Bryman *et al.*, 2016:383).

Access to people or organisations influences sample methodology. The sampling technique must be practical, reliable, and able to help the researcher answer their study issue while being representative of the population. Non-probability, or non-random, sampling gives the researcher distinct ways of selecting samples and is often more subjective. In some cases, a non-probability sample may be the best option, but the researcher risks missing the problem's full scope (Bryman *et al.*, 2016:171, 381; Saunders *et al.*, 2009:314, 432, 580, 678). Quota sampling is a non-probability sampling technique. This means that members of the population are chosen on a non-random base and that not every member of the population has an equal probability of being chosen to be a part of the sample group (Bryman *et al.*, 2016:382). Quota sampling seeks to simulate the population of interest. The researchers' goal will be to create a sample that accurately represents the characteristics of the population chosen. Quota sampling is used when time or money is limited because it is a quick sampling procedure. It's also utilised when researchers have certain criteria or limits for doing their research, such as tracking the amount of participants allowed to complete a survey based on specific traits or not having access to an entire community (Bryman *et al.*, 2016:180; Saunders *et al.*, 2009:284 - 285; Sekaran & Bougie, 2016:278).

For this study, a non-probability quota sampling strategy was used.

Step 3: Determine the sample size

The questionnaire used in this study was distributed to individuals representing the 20 CPG companies with a manufacturing base in South Africa and listed on the Johannesburg Stock Exchange (JSE) in the CPG sector, as published by Listcorp (Anon, 2022). Nineteen usable questionnaires were returned, which aligns with the generalised scientific standards for sample sizes illustrated in Table 3.1 below (Sekaran, 2003:293).

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Table 3.1: Sample size for a given population size

Source: (Sekaran & Bougie, 2016:294)

In research, the theoretical framework contains multiple variables of interest, and the question of how to calculate a sample size when all variables are considered arises. Table 3.1 provides a considerably simplified size decision that considers universal scientific guidelines for sample size decisions and ensures a good decision model (Sekaran & Bougie, 2016:293).

3.5 DATA PREPARATION

It must first undergo a preparation process to use statistical tools or procedures to analyse raw data (Kumar *et al.*, 2002:356). Data preparation is the process through which data collected is converted to be analysed. Data preparation entails editing, coding, and tabulating respondents' responses into tables for analysis (Hair *et al.*, 2008:392).

3.5.1 EDITING

Editing is purifying data to ensure that it is complete, correct, and appropriate for processing. Data editing aims to improve the quality of information (Seebacher, 2021:30). All questionnaires were reviewed for unanswered and improperly answered questions as part of the editing process, and their appropriateness for further processing was then determined. The study excluded any surveys that were not valid.

3.5.2 CODING

Coding is assigning numbers or other symbols to replies or responses that may be counted and categorised into a restricted number of classes or categories. Coding can take various forms, such as colour coding, specific abbreviations, or numerals (Blumberg *et al.*, 2014:480). Numbers and codes were assigned to each question in the questionnaire during this process.

3.5.3 STATISTICAL ANALYSIS

The researcher used the Statistical Consultation Services at the NWU Potchefstroom campus, which used the IBM SPSS Statistics Version 27 software tool to analyse the data. Frequency tables and descriptive statistics were used.

3.5.4 ETHICAL ASPECTS

The researcher acquired an ethical clearance certificate from North-West University, although no sensitive information from the respondents was requested. The researcher also included a short paragraph introducing himself and describing the purpose of the study on the first page of the questionnaire.

3.5.5 LIMITATIONS

The following limitations for this investigation were discovered and were consistent with the methodologies used:

- Respondents may not have given honest and objective answers.

- Respondents' perspectives may be skewed toward their personal understanding and involvement with the subject rather than the company objectives that they represent.
- The respondents may not fully represent the companies targeted to be the population in this state.

3.6 RESULTS AND DISCUSSION

3.6.1 FLEXIBLE WORKPLACE ARRANGEMENTS AND COVID-19 IMPACT

The first eight questions in the survey asked about how organisations perceived flexible workplace arrangements for their employees and how those perceptions changed from before the COVID-19 pandemic to the "new normal" after the pandemic. On the surface, these questions addressed the managerial challenges and opportunities posed by the COVID-19 pandemic. This was investigated to see if organisations recognised the need for investment in the underlying IT stack, which would, among other things, serve as a solid foundation for future digital manufacturing initiatives.

The COVID-19 pandemic involuntarily forced organisations to reconsider how they should manage their overall operations. Most companies were forced to pivot and adapt their working methods when forced to work from home or alternative locations. This way of thinking also implies how companies will allow their employees to work in the future and how they will not manage their supply chain and manufacturing operations.

When the COVID-19 pandemic struck, most businesses prioritised a crisis response, focusing on employee health and safety and the continuity of critical services. What remains to be seen is how these flexible work arrangements will be maintained, improved, or changed in the future.

Did you allow your employees to work from a flexible location/work from home BEFORE the COVID-19 pandemic?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 No	4	21,1	21,1	21,1
	2 Yes up to 25% of the time	12	63,2	63,2	84,2
	3 Yes, up to 50% of the time	3	15,8	15,8	100,0
	Total	19	100,0	100,0	

Table 3.2: Question 2 - Did you allow your employees to work from a flexible location/work from home BEFORE the COVID-19 pandemic?

According to table 3.2, 21% of respondents said their companies did not allow their employees to work from a flexible location or at home before the covid pandemic. 79% of respondents reported that their employers allowed them to work from home for up to half of the time. It's worth noting that none of the companies represented permitted their employees to work from home for more than half a day before the pandemic.

During the COVID-19 pandemic, employers had little choice but to comply with government regulations allowing employees to travel to and from work and to follow social distancing guidelines when working from the office or manufacturing facilities.

In this post-COVID working climate, do you allow your workers to work from a flexible location or from home?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 No	2	10,5	10,5	10,5
	2 Yes up to 25% of the time	6	31,6	31,6	42,1
	3 Yes up to 50% of the time	6	31,6	31,6	73,7
	4 Yes up to 75% of the time	3	15,8	15,8	89,5
	5 Yes up to 100% of the time	2	10,5	10,5	100,0
	Total	19	100,0	100,0	

Table 3.3: Question 5 - In this post-COVID working climate, do you allow your workers to work from a flexible location or home?

Employers' attitudes toward flexible workplace arrangements have shifted, as evidenced by the responses in Table 3.3. According to the respondents, their employers now give their employees more freedom to choose where they work, and 26% of the companies represented in the survey allow their employees to work from flexible locations for more than half of the time.

Not all employees can work from home, especially in the manufacturing industry. Many jobs require employees to be physically present on the factory floor. Although many manufacturing workers may not be able to work remotely, there are some things we can do to provide more flexibility. Encourage plant engineers, for instance, to work with their managers to identify tasks like project management and data analysis that may be completed elsewhere (Edwards, 2021:1). According to Figure 3.1, 55% of the companies represented in the survey stated that their employees are unable to work from a flexible location.

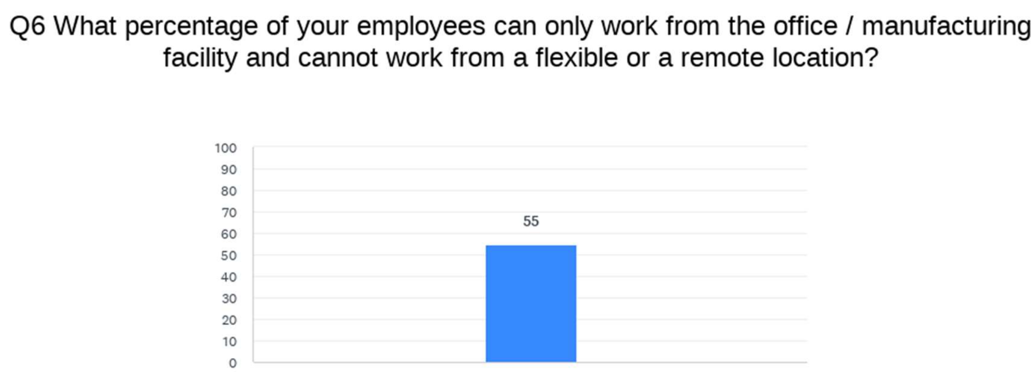

Figure 3.1: Percentage of employees that can only work from the office/manufacturing facility.

As shown in Figure 3.2, the majority of companies surveyed experienced some impact on workforce availability and structure due to the COVID-19 pandemic. 15.8% of respondents indicated a significant impact.

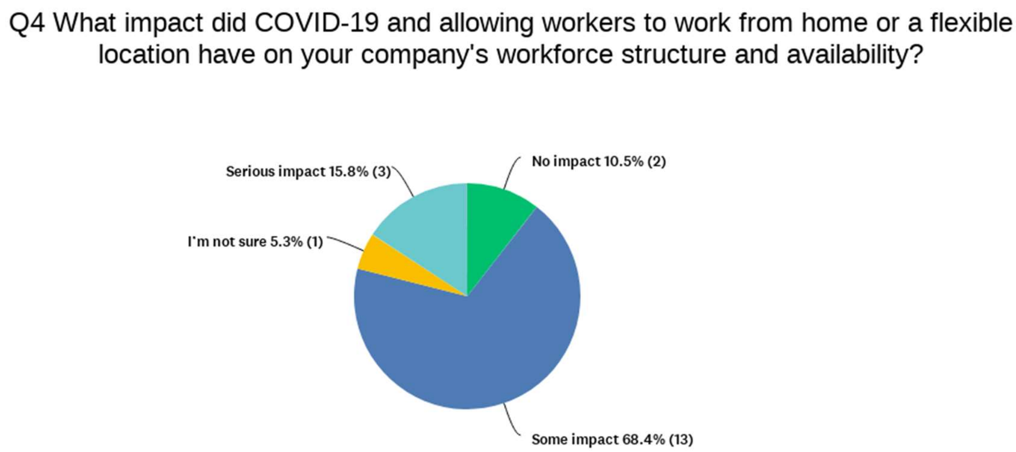

Figure 3.2: Impact on workforce structure and availability.

3.6.2 REMOTE MANAGEMENT OF STAFF AND OPERATIONS

The responses varied regarding the organisations' ability to manage their staff, manufacturing facilities, and supply chain remotely. Most organisations (89.5%) indicated that they can manage their employees remotely, but in 73.7% of cases, doing so has a minor impact. 10.5% of respondents said that while they can manage their employees remotely, it has a significant impact.

Figure 3.3: Managing staff remotely

More than two-thirds of respondents said they can manage their supply chain operations remotely, with 57.9% saying it comes with minor challenges. 15.8% of respondents were unsure whether or not they could manage their supply chain operations remotely.

The picture changes when it comes to organisations' ability to manage their manufacturing operations remotely. 31.58% of respondents said they couldn't. A further 15.79% stated that managing their manufacturing facilities remotely presents significant challenges. Figure 3.4 shows that companies that can manage their manufacturing facilities remotely, including those with minor constraints, account for just over half of the respondents (52.6%).

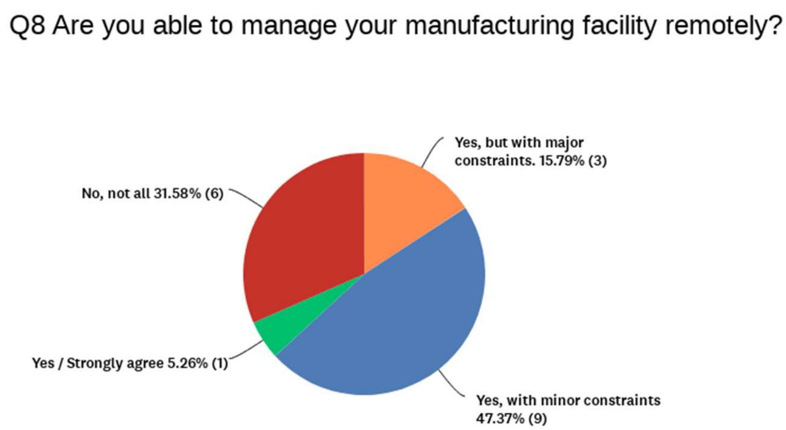

Figure 3.4: Managing manufacturing remotely.

3.6.3 COVID-19 IMPACT AND DIGITAL MANUFACTURING

Digitization was discussed in paragraph 2.1, and it was stated that digitization includes everything from online customer service, remote working, supply-chain innovation, and the use of artificial intelligence (AI) and machine learning to improve operations. It was also implied that the COVID pandemic has been the primary accelerant of technical advancement in recent years and that the future of work, the future of industry, and a more resilient supply chain may have arrived sooner than predicted. It was also implied that the COVID pandemic was the primary driver of technological advancement in recent years and that the future of work, the future of industry, and a more resilient supply chain might have arrived sooner than expected.

95% of the respondents representing the companies surveyed indicated that they do have a Strategy for Digital Manufacturing in place.

Respondents to the survey indicated that their organisations implemented approximately 24% of their digital manufacturing strategy before the COVID-19 pandemic and have now implemented half of their digital manufacturing strategy at 49.39% as shown in table 3.4.

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
What percentage of your digital manufacturing strategy did you place in operation before the COVID pandemic?	19	0	51	24,05	18,149
What percentage of your digital manufacturing strategy did you place in operation since the start of the COVID pandemic?	18	0	80	49,39	22,131
Valid N (listwise)	18				

Table 3.4: Implementation of Digital Manufacturing before and since the COVID-19 pandemic.

Since 2018, most companies surveyed have been actively implementing their digital manufacturing strategy. In the year leading up to the COVID-19 pandemic, 47.36% of companies surveyed began implementing their Digital Manufacturing strategy. According to one respondent, their implementation began around the year 2000, and their strategy and implementation "has been slowly evolving over the last couple of decades."

The impact on manufacturing and supply chain operations was felt across the board, with 90% of respondents reporting an impact from the COVID-19 pandemic, with 36.84% reporting that the impact had a serious or major impact on their operations (figure 3.5).

The top constraints amplified by the pandemic were:

- Absence of experience (27.8%)
- Lagging or outdated underlying IT/ OT technology stack (22.2%)

- Absence of the right digital technologies to support operations (22.2%)
- Cash/funding constraints (11.1%)

The remaining 16.7% of respondents had technologies in place mitigating the impact of the COVID-19 pandemic.

When asked how long it will take to recover manufacturing and supply chain operations, respondents split evenly, with half saying they are already fully recovered and the other half saying it will take up to 5 years.

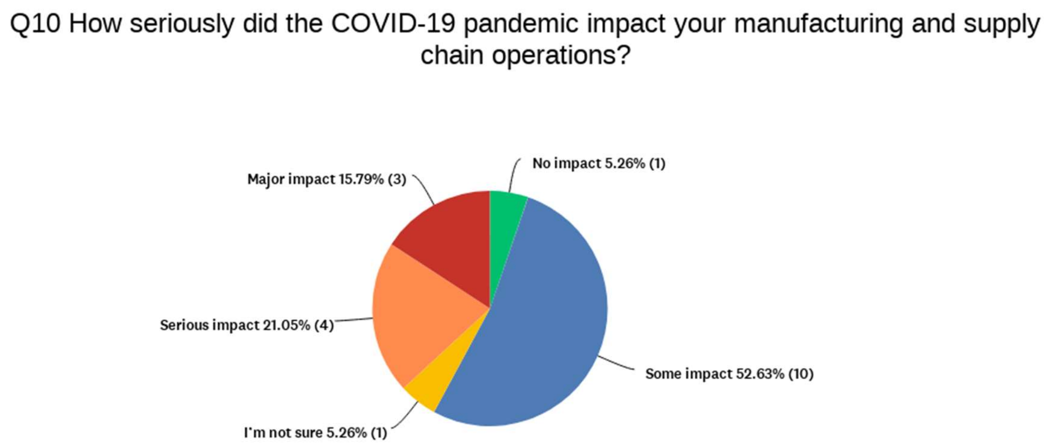

Figure 3.5: COVID-19 impact on operations.

In 90% of cases, companies that implemented some digital manufacturing components before the pandemic reported a definite value-add. More than half of those polled said the value add was a significant or major benefit. Approximately 10% were unsure about the value added.

Figure 3.6 shows that 94.45% of respondents reported a positive shift in their perception of the value that digital manufacturing can bring to operations. Two-thirds of participants believe digital manufacturing adds significant value to operations, and 27.78% believe it is a "total game changer".

Q19 How has your perception of the value of Digital Manufacturing changed since the pandemic?

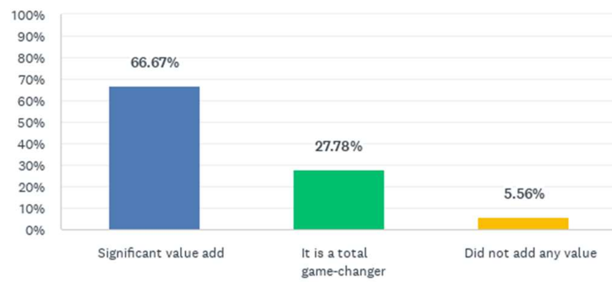

Figure 3.6: Perception change of digital manufacturing.

Despite the challenges posed by the COVID-19 pandemic and subsequent economic pressures, almost all the company representatives polled stated that they will continue to implement their digital manufacturing strategy and transformation plans. A small percentage of respondents (11.11%) indicated that they will restart their implementations within the next year, while 16.67% are unsure.

Examples of digital manufacturing initiatives that the companies that participated in the survey implemented before the COVID-19 pandemic are:

- Automated material handling
- Manufacturing quality control systems
- Automated scanning, printing, and adhesive of barcode labels
- Automated production declaration
- Dedicated digital manufacturing network infrastructure
- Manufacturing Execution Systems (MES), incorporating robotic process automation (RPA)
- OSIsoft PI System (collecting, historicizing, finding, analysing, delivering, and visualizing data)
- MS Teams to enable flexible work
- Digitalized client and service provider allowing for video and chat interaction (part of plumbing repair operations)
- Automation of repetitive work

- Mobile electronic data capturing (tablet-based) uploaded to private cloud to make work visible to management teams.
- Statistical process control (SPC) to control processes and production methods.

More than 60% of respondents said they could scale some of the technologies they implemented to other branches or parts of their operations.

3.6.4 CURRENT CHALLENGES FOR DIGITAL MANUFACTURING

In research, you routinely must analyse textual data, including statements, speeches, public announcements, and their impacts. Researchers used a variety of approaches to extract text and use it in their empirical design since text can be quantified and used for modelling and predictions. A word cloud is a straightforward but popular visualization for showing and comprehending the organisation of textual data (Korab, 2021:1).

Word clouds are images made of words used in a certain text, where the size of each word represents its frequency or importance and are used to summarise textual data. This straightforward graph is often used in both academic and business settings (Hudson & Ishizu, 2016:83).

Respondents were asked in the survey what their three biggest challenges are in implementing digital manufacturing solutions in the current environment. A Word Cloud was used to analyse the responses that were received. Figure 3.7 depicts the findings of this analysis.

The most frequently mentioned challenge was a shortage of skilled resources, followed by financial or budgetary constraints. User adoption and technological challenges tied for third place. An outdated OT stack, outdated IT infrastructure, and unreliable IT infrastructure are all examples of technology challenges.

Other prominent themes included job loss fears, resistance to change from the current workforce, and challenges to training or re-skilling their current workforce.

Figure 3.7: Biggest challenges for current digital manufacturing initiatives.

A few of the companies polled stated that they are not currently pursuing digital manufacturing initiatives. The following are the primary reasons given for not continuing:

- Extended implementation window
- Budget or financial constraints
- A knowledge gap in overcoming technological challenges
- A lack of skilled resources.

3.6.5 DIGITAL MANUFACTURING OBJECTIVES

Figure 3.8 is a summary of what respondents said are their company's top three most important objectives for digital manufacturing implementation.

Figure 3.8: Top 3 objectives for digital manufacturing.

Increased efficiencies and productivity are among the top goals that businesses hope to achieve with their digital manufacturing investments. The second highest priority is reliable and near-real-time data that can be relied on to make sound decisions. Among the top objectives are cost savings, which typically go hand in hand with efficiencies and increased productivity. Predicting failures on manufacturing assets and having a reliable preventative maintenance schedule in place round out the top goals.

Other top priorities mentioned include increased value, staying relevant and ahead of the competition, and increased speed to market for products from ideation to getting the products into the hands of consumers.

Employee well-being and rapid advances in safety are also among the priorities.

95% of the respondents foresee that re-skilling or specific training of their existing workforce will be part of their overall digital manufacturing strategy. They say that many of their factory workers did not gain new skills and the skills gap must be closed.

Automation and software enable people on the manufacturing floor to run the business.

According to respondents, the top skills that existing workers should be trained on are:

- Basic computer literacy
- Digital capabilities

Most companies foresee that part of the reskilling plan of their employees need to be to include career roadmaps to provide workers with a future roadmap to help them make well-informed decisions about their career and future career movements.

3.6.6 DIGITAL MANUFACTURING TECHNOLOGIES TO FOCUS ON

In chapter two, figure 2.2 shows the four fundamental technologies of Industry 4.0 and by implication, digital manufacturing which should be applied along the value chain.

These technologies comprise of:

- Connectivity, data and computational power;
- Advanced analytics and intelligence;
- Human-machine interaction (automation); and
- Advanced engineering.

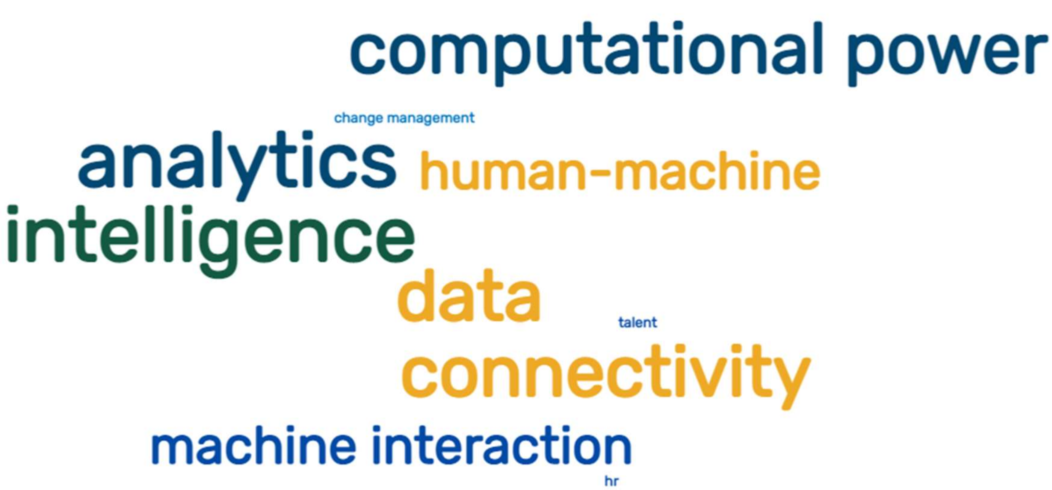

Figure 3.9: Technologies focussed on.

As illustrated in figure 3.9 the digital manufacturing technologies that are most focussed on by the companies surveyed are topped by advanced analytics and intelligence, which ties in with the top objectives mentioned in the aforementioned paragraph which are increased efficiencies and productivity. Computational power, data and connectivity are the second most mentioned followed by my human-machine interaction. Loose themes that were mentioned, but that also resonate with some of the challenges and opportunities mentioned are talent development and HR objectives together with the need for proper and well-communicated change management.

3.6.7 DIGITAL MANUFACTURING AND INDUSTRY 5.0

As discussed in chapter two, People and robots work together in Industry 5.0. Robots help people perform better and faster by using IIoT and big data. It humanises Industry 4.0's automation and efficiency (Jardine, 2020:1).

When asked about the concept of Industry 5.0 and how much of it they understand, all of the participants indicated that they have some understanding of the topic. 57.9% of respondents said they understood it well or completely.

Industry 5.0 is part of their future digital manufacturing strategy, according to 77.78% of respondents.

3.7 CONCLUSION

It was determined that there was a good fit between the literature and the results derived from the questionnaire analysis.

This chapter described the procedures used to collect and analyse empirical data for use in the design and compilation of a practical management framework for digital manufacturing in the new normal era.

The COVID-19 pandemic's impact on digital manufacturing was investigated, as well as how the pandemic affected flexible work arrangements. The survey respondents also indicated how employers' attitudes toward flexible workplace arrangements have changed. According to the respondents, their employers are now giving their employees more flexibility in terms of where they work.

It was also implied that the COVID pandemic was the primary driver of technological advancement in recent years and that the future of work, the future of industry, and a more resilient supply chain might have arrived sooner than expected.

Respondents reported that their perception of the value that digital manufacturing can bring to operations had improved. Finally, insights were gained into the challenges that South African CPG companies face in continuing to implement digital manufacturing initiatives. We learned what their most important goals are that they hope to achieve through their digital manufacturing strategies.

3.8 SUMMARY

The empirical study was completed in chapter three. A quantitative research study was chosen to allow the researcher to accomplish the objectives outlined in chapter one.

The sample was limited to persons representing the 20 CPG firms with a manufacturing presence in South Africa and are publicly traded on the Johannesburg Stock Exchange (JSE). The questionnaire analysis offered several insights about digital manufacturing strategies, aims, and focus.

Conclusions will be formed in chapter four based on the analysis done in chapter three. Recommendations will be made, and a practical management framework for digital manufacturing in the new normal era will be proposed, as indicated in chapter one.

Chapter 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

The primary objective of this study (paragraph 1.4) was to develop a managerial framework to guide manufacturing companies in the CPG industry in South Africa that want to start or continue to implement digital manufacturing as part of their process and strategy. The managerial framework's objective is to create a practical framework of best industry practices that can be used to implement a successful digital manufacturing strategy in the South African context.

Chapter 2 literature review focused on background information on Digital Manufacturing and the mainstream technologies that support technological advances in this area. Managerial and workplace practices that were accelerated and forced upon organisations because of the COVID-19 pandemic were also covered.

Chapter 3 discussed the empirical study, research methodology, and data analysis used in this study.

The study concludes with Chapter 4. This chapter's goal is to wrap up the research and make recommendations, as well as to suggest areas for future research. The final section of this chapter provides an overview of the study as well as possible future research in this field.

4.2 DISCUSSION OF CHALLENGES

The most difficult challenge encountered by the researcher during this study was determining the population and sample design. It became clear that the sample size could be expanded to include a broader category of South African manufacturers in order to increase the overall sample size. Respondents' perspectives may be skewed toward their understanding and involvement with the subject in smaller sample sizes, such as the one used in this study, rather than the company objectives that they represent. A larger sample size for each company, or a larger population overall, could provide more accurate results.

4.3 CONCLUSIONS

The primary and secondary objectives outlined in Chapter 1 of the study were the focus of this study. To accomplish this, a literature study on the relevant issues was conducted in chapter 2, and an empirical study was conducted in chapter 3 to identify the outcomes and findings.

Volatility and uncertainty are still major themes of the day in politics, the local, national, and international economies, as well as in the manufacturing sector. The world is making every effort to comprehend what the new normal represents. The international economy and people's everyday lives are completely unpredictable due to the disruptions brought on by extreme weather, the enormous expense of addressing climate change, and a fragile geopolitical situation. In South Africa, digitalization is happening in a country where the economy has already seen premature deindustrialization, where there is a substantial lack of digital infrastructure and talent, and where companies must invest a lot of money to upgrade their current IT systems. Digital manufacturing enhances a company's production and optimises manufacturing processes, thus eliminating bottlenecks, reducing inventory, enhancing quality, minimising time to market, pivoting quickly to match consumer needs, and increasing production.

There is potential to develop, use, and perfect technology to drive value across the CPG value chain, particularly in the areas of product development, sales, distribution, manufacturing, procurement, and supply chain, as well as customer management, particularly in the context of the South African market, according to the literature review.

The empirical study revealed that there was a good fit between the literature and the questionnaire analysis results.

The impact of the COVID-19 pandemic on digital manufacturing was studied, as well as how the pandemic affected flexible work arrangements. Employers' attitudes toward flexible workplace arrangements have changed, according to survey respondents, and employers are now giving their employees more flexibility in terms of where they work.

Manufacturing technological advancement and a more resilient supply chain may have arrived sooner than expected, owing to volatility and the need to deliver more value and benefits with limited resources.

The value of digital manufacturing to operations had increased. Finally, insights into the challenges that South African CPG companies face as they continue to implement digital manufacturing initiatives were gained. We learned about their top priorities, which they hope to achieve through their digital manufacturing strategies.

The study concludes that the main challenges for digital manufacturing advancement in the CPG industry in South Africa today are a shortage of skilled resources, followed by financial or budgetary constraints. The main challenges for training or re-skilling are user adoption, fears of job losses caused by automation and robotics, and resistance to change from the current workforce.

Technological challenges include an outdated IT- and OT stack, as well as the high cost of having a solid IT foundation to support manufacturers' digitization strategies.

The primary goals of digital manufacturing are to increase efficiencies and productivity. Priorities must also include reliable and near-real-time data on which to base sound decisions. The top goals are cost savings, which typically go hand in hand with efficiencies and increased productivity, asset uptime supported by the ability to predict failures, and having a reliable preventative maintenance schedule in place. Employee well-being and rapid progress in safety are also priorities.

4.4 MANAGEMENT FRAMEWORK

The summary of results in section 4.2 provided some insight into the gaps in how to maximise the benefits of a digital manufacturing strategy. These findings, along with the information from the literature review, provided input into the development of a management framework for digital manufacturing in the new normal era. This framework has not been tested in any organisation and so should only be used as a reference to aid in the development of new digital manufacturing efforts using a benefits management approach.

This management framework is based on the business benefits realisation approach as outlined by Peppard, *et al (Peppard et al., 2007)*.

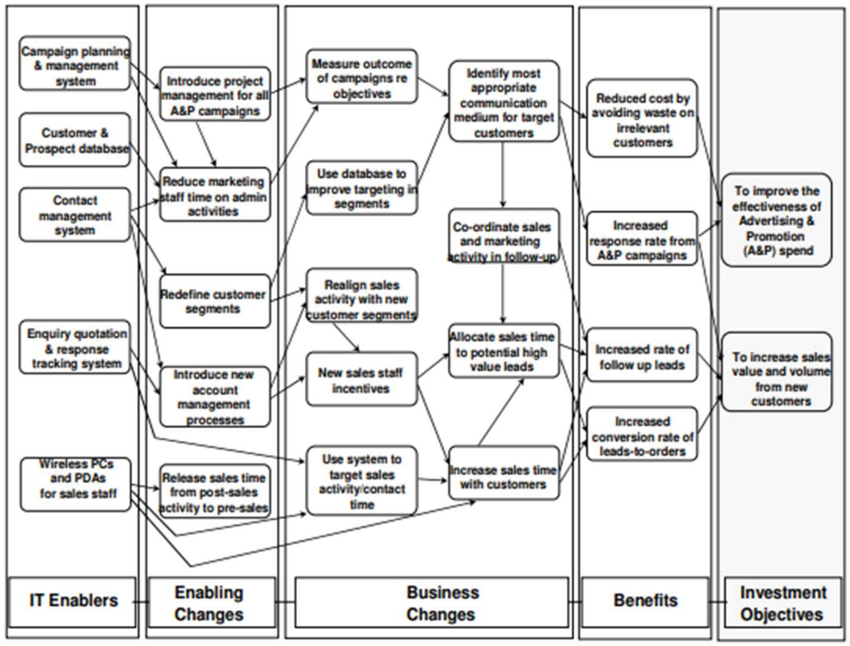

Figure 4.1: An example of a Partial Benefits Dependency Network (BDN) for the new CRM System at a European Manufacturer

Source: (Peppard *et al.*, 2007:11)

The majority of businesses prioritise technology implementation over achieving the anticipated business benefits when making IT investments. Consequently, despite a project's technical accomplishment, benefits are not flowing.

Five principles of realising benefits through technology, whether it is digital manufacturing or any other type of technology exist according to Peppard *et al*.

- **Principle no.1: Technology has no inherent value.**

  Having technology doesn't add value. Technology's value isn't in its possession, unlike gold or property investment. IT spending costs money. IT asset usage yields benefits (Peppard *et al.*, 2007:2).

- **Principle no.2: Benefits arise when technology enables people to do things differently.**

  Benefits only arise when an organization's employees, customers, or suppliers are more efficient or effective. New ways of working generally involve better information use. Technology can facilitate new methods of working by redesigning intra- and inter-organizational processes (Peppard *et al.*, 2007:2, 3).

- **Principle no.3: Only business managers and users can release business benefits.**
  Only business management, users, and maybe customers and suppliers can make changes to processes. IT and project workers can't be held responsible for technology investments' commercial advantages. Recognizing this principle is crucial to involving business people in "Technology projects" (Peppard *et al.*, 2007:3).
- **Principle no.4: All technology projects have outcomes, but not all outcomes are benefits.**
  Many technology projects yield negative results, potentially threatening the organization's future. Management must avoid unfavourable outcomes and ensure positive ones offer business benefits (Peppard *et al.*, 2007:3).
- **Principle no.5: Benefits must be actively managed to be obtained.**
  Benefits aren't guaranteed. Benefits often lag behind implementation, creating a latency gap between initial investment and payback. Managing for benefits doesn't end with technical implementation. Benefits management must continue until all anticipated benefits are realised or it's apparent they won't.

Technology benefits management can be defined as the process of organizing and managing so that the potential benefits of using technology are actually realized (Peppard *et al.*, 2007:3). To fully realize the benefits or *ends*, an organisation need to consider the *ways* and *means* of the overall technology implementation including the business aspects. For this management framework, we define means as the enabling IT capabilities, ways as the necessary changes to the business, and ends as the intended improvements.

The developed management framework for digital manufacturing in the new normal era has two approaches, but both have the goal to innovate, develop and discover efficiencies and process improvements as well as countless other benefits by utilizing digital manufacturing technology.

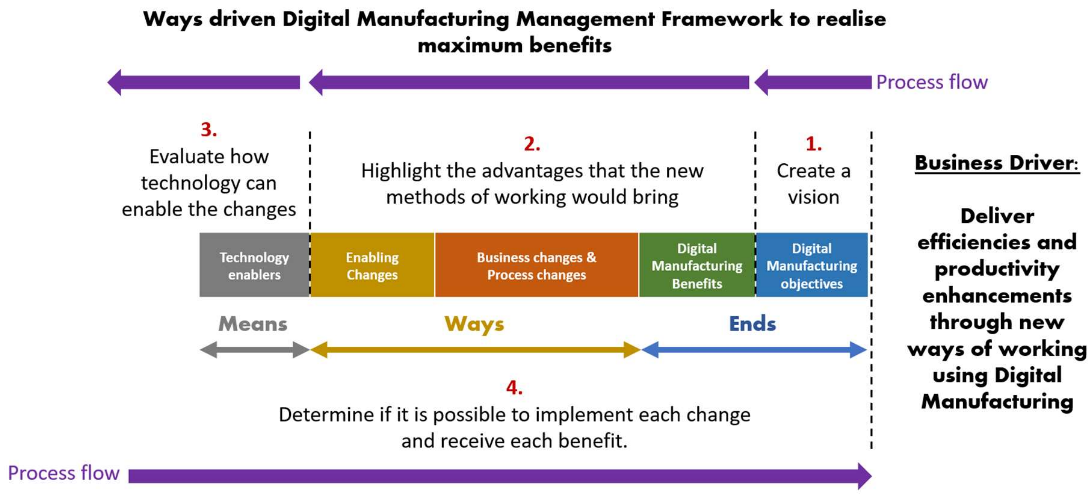

Figure 4.2: Ways-driven Digital Manufacturing Framework

Adapted from source: (Peppard *et al.*, 2007:8)

When an identifiable opportunity is identified, a ways-driven Digital Manufacturing Management framework is applied, as shown in Figure 4.2. The framework is designed to determine whether or not the organisation can make the necessary changes to capitalise on the opportunity. You must develop a "vision" that outlines the nature of the benefit (Step 1). This vision includes a set of preliminary goals that “paint a picture” of the future situation as if the advantage has already been obtained.

Step 2 entails identifying prospective business benefits as well as the types of business adjustments required to realise those benefits. Many of the changes will be new processes, competencies, and responsibilities that will be required to work in the new normal. The optimal technical means for each business change are then evaluated. This management framework's process is to work from right to left (Peppard *et al.*, 2007:8, 9).

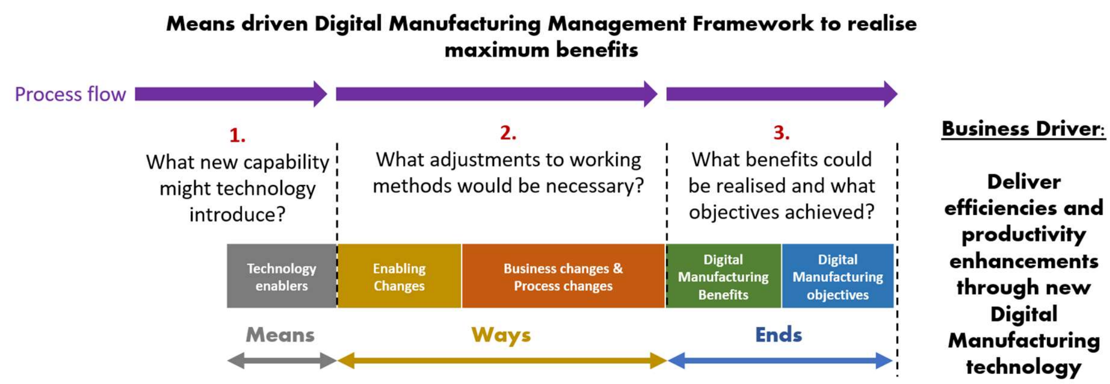

Figure 4.3: Means-driven Digital Manufacturing Framework

Adapted from source: (Peppard *et al.*, 2007:9)

The use of a means-based Digital Manufacturing Management framework (figure 4.3) begins when a new technology emerges to offer the potential to build an advantage. This implementation must concentrate on the types of prospective business prospects while also balancing this commercial perspective with a grasp of the new technology's capabilities and the business modifications required to capitalise on those capabilities.

The analysis of a means-based Digital Manufacturing Management framework is done from left to right. As the first step, an evaluation of the technology is performed. New technology-based innovations are inherently dangerous. Wherever practical, such an implementation should include a pilot study. It should move forward to confirm the scale of the anticipated advantages as well as the organisational changes required to deliver those benefits (Step 2). In Step 3, the organisation can agree on the overall objectives of the project (Peppard *et al.*, 2007:9).

A hypothetical Benefits Needs Canvas (BNC) has been built to explain how to apply this Benefits-based Digital Manufacturing Management Framework, as illustrated in Figure 4.4.

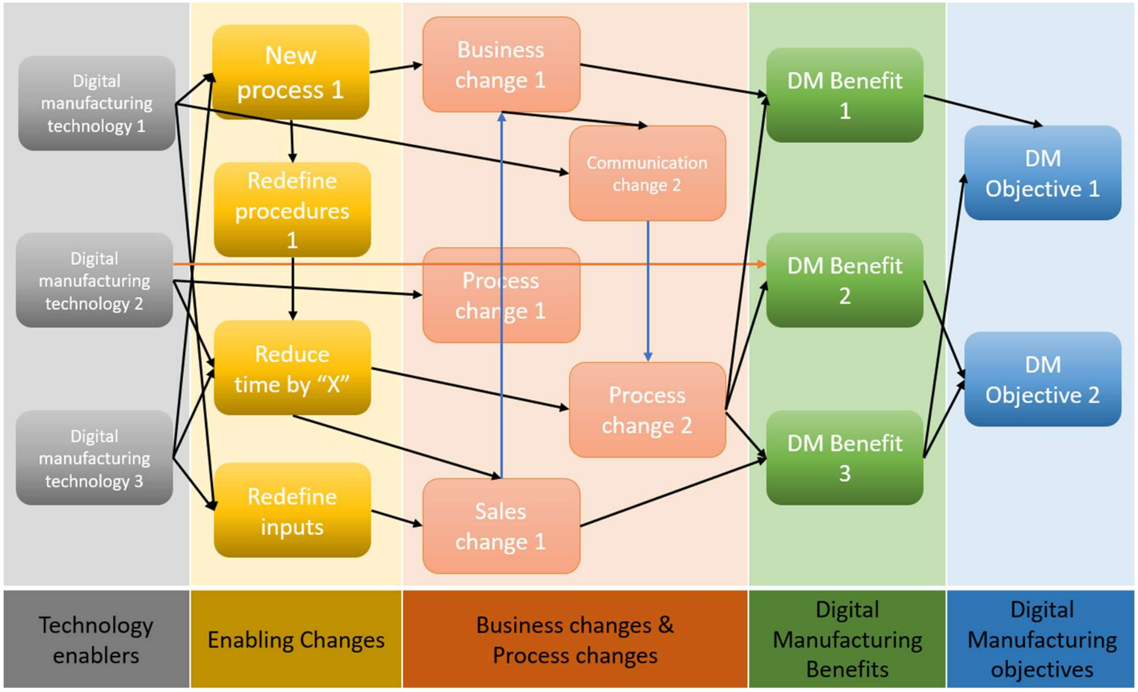

Figure 4.4: Benefits Needs Canvas for managing Digital Manufacturing (BNC)

Adopted from: (Peppard *et al.*, 2007:5)

Answering seven questions helps to create the BNC. The answers are used to establish a solid business case and a change management plan to deliver the advantages. These issues are about business and organisational changes, not technology. No single person knows to answer all of these questions. It should be distributed among several persons, who must supply replies (Peppard *et al.*, 2007:3). The seven questions according to Peppard *et al* (Peppard *et al.*, 2007:3, 4) to produce a benefits realisation plan are:

1. Why must we improve?
2. What improvements are necessary or possible? (Key stakeholders must agree to these improvements, which become the investment objectives.)
3. What benefits will be realized by each stakeholder if the investment objectives are achieved? How will each benefit be measured?
4. Who owns each benefit and will be accountable for its delivery? (The benefit owner will be responsible for the value assigned to the benefit in the business case.)
5. What changes are needed to achieve each benefit? (The key to realizing benefits is identifying explicit links between each benefit and required changes.)

6. Who will be responsible for ensuring that each change is successfully made?
7. How and when can the identified changes be made? (To answer this question, the organization must assess each stakeholder group's ability and capacity to make the identified changes.) .

When you introduce a new piece of technology into business such as the recently introduced Artificial General Intelligence (AGI) applications examples of ChatGPT and DALL.E2 by the AI research and deployment company OpenAI, it does not mean instant success and benefits to the company (Anon, 2023). In both Means-driven as well as Ways-driven technology deployments a holistic view must be taken to identify and plan for changes to be made in the general business environmnet to align to the new technology deployment. These changes that needs to be considered includes, business process changes underpinned by a solid change management and communications strategy. Technologies such as Artificial General Intelligence (AGI) applications may just be the start of Industry 6.0!

4.5 RECOMMENDATIONS

Digital manufacturing is a promising set of technologies for reducing production time and cost, as well as for customisation, improved product quality, and a faster time to market.

Due to the inherent high cost of technology implementations and the potentially long lead time to begin seeing a return on investments, adopting an implementation strategy where the benefits are identified should form the foundation of a company's digital manufacturing strategy. Ownership of these decisions and implementations needs to span across the business and IT. This approach should lead to clear planning, improved relationships between the business and IT, wiser investments, and a more accurate return on investments.

A fundamental principle of this method is that no implementations should be undertaken if the benefits cannot first be demonstrated in a way that is objectively verifiable and unanimously accepted. During the process of implementation, there needs to be a continuous assessment of the benefits case to determine whether or not the benefits objective has been fulfilled. This approach should be maintained over the duration of the investment as well.

Other recommendations arrived at during this study:

When we put all of the concepts and technologies incorporated in digital manufacturing, the term Industrial Internet of Everything (IIOE) is starting to come to the fore. This concept may be thought of as covering Industry 4.0, Industry 5.0, connectivity, and security, as well as the underlying technology stack. The term encompasses all aspects of technology used in a manufacturing environment that is linked and works in unison towards social responsibility and the advancement of people and the planet.

Can we refer to the Industrial Internet of Everything (IIoE) as the convergence/collage of the Industrial Internet of Things (IIoT), Information Technology (IT), and Operational Technology (OT)?

Research done by Splunk points to the three layers:

The devices and related connectivity form the basis. The data ingestion and activation layer are at the following level. The data coming from the device is collected, organised, and instructions are sent back down to the devices from this tier. Process orchestration, which places the data and action in a process context, is at the highest level (Paquin, 2020).

We also need to take notice of the potential that can be uncovered using Operating Technology (OT) in predictive maintenance.

4.6 RECOMMENDED FURTHER STUDIES

- Did the covid pandemic change the way we work for good? In what way?
- The benefits that digital manufacturing can bring to the entire value chain of the CPG industry in South Africa.
- Efficient data handling in manufacturing in South Africa and how to maximise the effective use of data.
- The impact that digital manufacturing will have on the basic education of a typical manufacturing industry worker in South Africa.
- How workers in the manufacturing industry can be re-skilled to eliminate job losses and to offset against automation use cases.

- How can digital manufacturing contribute to the health and Safety of manufacturing workers?

4.7 CONCLUSION

The primary aim of the study was to develop a managerial framework to guide manufacturing companies in the CPG industry in South Africa. The aim was to base this on a quantitative study. A literature study was done from which a questionnaire was developed to form the basis of the empirical study.

The questionnaire was distributed to the leading CPG companies that have a manufacturing base in South Africa. These twenty companies are listed on the Johannesburg Stock Exchange (JSE)

The analysis of the questionnaires revealed the areas to be focussed on to develop the managerial framework. A practical framework to managerial framework to guide manufacturing companies in the CPG industry in South Africa was constructed, based on the findings of the analysis of the data

from the questionnaires.

It can finally be concluded that the adoption and implementation of this framework lead to:

- Clear planning
- Improved relationships between the business and IT
- Wiser investments
- More accurate return on investments.

Through the study, other research opportunities were also identified and mentioned in paragraph 4.6 of this chapter.

4.8 CHAPTER SUMMARY

In Chapter 4, a number of conclusions and recommendations were made in an attempt to develop a managerial framework to guide manufacturing companies in the South African CPG industry. The conclusions from Chapter 3 were summarised at the start of this chapter. According to the study, the main challenges for digital manufacturing advancement in the CPG industry in South Africa today are a shortage of skilled resources, followed by financial or budgetary constraints. The main challenges for training or re-skilling are user adoption, fears of job losses due to automation and robotics, and resistance to change from the current workforce.

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APPENDIX A

- Data collection instrument – Questionnaire -

Data collection instrument - questionnaire:

Section 1:

Question 1: Did you allow your employees to work from a flexible location/work from home before the COVID-19 pandemic?

1	2	3	4	5
No, not all	Yes, up to 25% of the time	Yes, up to 50% of the time	Yes, up to 75% of the time	Yes, up to 100% of the time

Question 2: Did you / do you allow your employees to work from a flexible location/work from home during the COVID-19 pandemic?

1	2	3	4	5
No, not all	Yes, up to 25% of the time	Yes, up to 50% of the time	Yes, up to 75% of the time	Yes, up to 100% of the time

Question 3: What was the impact on your staff structure and availability?

1	2	3	4	5
Major impact	Serious impact	I'm not sure	Some impact	No impact

Question 4: Will you allow your employees to work from a flexible location/work from home once we return to a "new normal" post-COVID working environment?

1	2	3	4	5
No, not all	Yes, up to 25% of the time	Yes, up to 50% of the time	Yes, up to 75% of the time	Yes, up to 100% of the time

Question 5: What percentage of your staff will return to the office permanently?

1	2	3	4	5
No, not all	Yes, up to 25% of the time	Yes, up to 50% of the time	Yes, up to 75% of the time	Yes, up to 100% of the time

Question 6: Are you able to manage your staff remotely?

1	2	3	4	5
No, not all	Yes, but with major constraints.	I'm not sure	Yes, with minor constraints	Yes / Strongly agree

Question 7: Are you able to manage your manufacturing facility remotely?

1	2	3	4	5
No, not all	Yes, but with major constraints.	I'm not sure	Yes, with minor constraints	Yes / Strongly agree

Question 8: Are you able to manage your supply chain remotely?

1	2	3	4	5
No, not all	Yes, but with major constraints.	I'm not sure	Yes, with minor constraints	Yes / Strongly agree

Question 9: How seriously did the COVID-19 pandemic affect your manufacturing and supply chain operations?

1	2	3	4	5
Major impact	Serious impact	I'm not sure	Some impact	No impact

Question 10: How long do you expect it will take to fully recover your manufacturing and supply chain operations after the pandemic?

1	2	3	4	5
never	More than 5 years	I'm not sure	Up to 5 years	We are fully recovered already

Question 11: Do you know and understand the term "Digital Manufacturing"?

1	2	3	4	5
I do not know what it is	I understand very little of it	I'm not sure	I understand it rather well	I understand it completely

Question 12: Do you know and understand the term “Industry 4.0”?

1	2	3	4	5
I do not know what it is	I understand very little of it	I’m not sure	I understand it rather well	I understand it completely

Question 13: Do you know and understand the term “Industry 5.0”?

1	2	3	4	5
I do not know what it is	I understand very little of it	I’m not sure	I understand it rather well	I understand it completely

13.1:

Please give a very brief description of what you understand the term “Industry 5.0” means in your own words:

____

____

____

Question 14: Do your company have a strategy for digital manufacturing?

1	2	3	4	5
No	Yes, but we only recently started to formulate the strategy.	I’m not sure	Yes, we are almost done formulating the strategy.	Yes

Question 15: What percentage of your digital manufacturing strategy did you place in operation before the COVID pandemic?

1	2	3	4	5
0%	25%	50%	75%	100%

Question 16: What percentage of your digital manufacturing strategy did you place in operation since the start of the COVID pandemic?

1	2	3	4	5
0%	25%	50%	75%	100%

Question 17: How has your perception of the value of Digital Manufacturing changed since the pandemic?

1	2	3	4	5
Did not add any value	Added some value	Unsure	Significant value add	It is a total game-changer

Question 18: If you did not implement Digital Manufacturing technologies before the COVID-19 pandemic, to what extend did you find yourself constrained in your ability to respond to manufacturing and Supply Chain constraints?

1	2	3	4	5
Major impact	Serious impact	I'm not sure	Some impact	No impact

Question 19: Are you continuing or on track with your Digital Manufacturing transformation plans despite the pandemic's challenges?

1	2	3	4	5
No	Yes, but we are unsure when.	I'm not sure	Yes, we will restart in the next year.	Yes

Section 2:

Question 20: If you implemented Digital Manufacturing initiatives before the COVID pandemic:

20.1: Please give examples of initiatives that you implemented:

____

____

20.2: When did you implement these initiatives?

____

Question 21: Have you successfully scaled some Digital Manufacturing use cases?

21.1: How many cases?

____

21.2: Can you give examples of these use cases?

Question 22: If you did not implement any Digital Manufacturing technologies before COVID-19, did you find yourself:

22.1: Constrained in your ability to respond to COVID-19?

22.2: In what way were your operations constraint?

a) absence of digital technologies to support your operations?

1	2
Yes	No

b) Cash constraints (COVID related) making it difficult to catch up?

1	2
Yes	No

c) Absence of experience?

1	2
Yes	No

d) Lagging underlying IT/ OT technology stacks?

1	2
Yes	No

e) Any other reasons?

Question 23: What is your biggest challenge facing your Digital Manufacturing initiatives?

Question 24: If you halted your Digital Manufacturing investments due to the crisis, what are your top two reasons your company is no longer implementing Digital Manufacturing?

Question 25: What are the 3 biggest challenges facing your company in implementing Digital Manufacturing solutions in the current environment?

Question 26: What are your company's top 3 most important objectives for Digital Manufacturing implementation?

Question 27: Which 3 technologies are you focusing on the most when implementing Digital Manufacturing?

Question 28: Do you foresee Re-skilling/new training of your existing workforce in support of Digital Manufacturing?

28.1: Can you elaborate in brief on these plans?

Question 29: Does Industry 5.0 factor into your future Digital Manufacturing plans?

1	2
Yes	No

APPENDIX B

- Informed consent form -

Ethics informed consent form

MBA-STUDY: **A management framework ofr digital manufacturing in the new normal era**

FIELD OF STUDY: Master's in Business Administration

NORTH-WEST UNIVERSITY

RESEARCHER: H Barnard

SOUTH-AFRICA

CELL: +27 83 656 2942

Email: hhbarnard@gmail.com

Dear interviewee

This **Informed Consent Statement** serves to confirm the following information as it relates to the MBA mini-dissertation on **A management framework for digital manufacturing in the new normal era.**

1. The sole purpose of this study is to obtain information from experts (such as yourself) employed and/or operating in the Consumer-Packaged Goods (CPG) industry, in an attempt to determine the nature of your everyday experience related to the research topic. This study aims to determine what a management framework for digital manufacturing in the new normal era will comprise in the CPG industry in South Africa and to establish what characteristics and requirements a managerial framework should constitute, so that it may be of value to the CPG industry and perhaps all manufacturing industries in South Africa.
2. The procedure to be followed is a structured questionnaire including open-ended questions where you will have the opportunity to communicate your views on the relevant topic. Basic background information related will be asked e.g. your academic qualifications and related experience to the topic. The participants of the study aim to include, C-Level executives, and other senior management roles in the CPG industry.
3. The questionnaire should take no longer than a maximum of 30 minutes to complete.
4. This questionnaire is voluntary and at any point during the research process, you will have the option to end your participation in this research.
5. The confidentiality of the questionnaire is guaranteed.
6. Any confidential information that prohibits the researcher to publish it in the final dissertation should be communicated during the questionnaire.
7. A summarised copy of the final dissertation will be made available to the respondent upon request.
8. The data gathered from the questionnaire will only be used for research purposes and may be published.

☐ I, hereby declare that I have read and understood the contents of the Informed Consent Statement, and give my full consent to Mr H Barnard to progress with the questionnaire and use the information communicated by myself to him in his MBA dissertation.

APPENDIX C

- Certificates of language editing –

Psychmetrica

DESIGNING FUTURES

CERTIFICATE: LANGUAGE EDITING

Herein, confirmation that *Chapter 1* of the following document was edited:

MBA DISSERTATION
A management framework for digital manufacturing in the new normal era

H Barnard
Student #: 26989565

ORCiD.ORG/0000-0001-5068-7187

The following were edited according to the NWU Business School requirements, subject to Harvard Guidelines:

Spelling; clarity of document; conciseness; formalities; inclusiveness; punctuation; geopolitical referencing; vocabulary; similarity

W Smith
Registered Psychometrist
HPCSA: PMT0097012

---

www.psychmetrica.co.za; 083 390 4091 ; psychmetrica@gmail.com

Psychmetrica
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A management framework for digital manufacturing in the new normal era

H Barnard
Student #: 26989565

ORCiD.ORG/0000-0001-5068-7187

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Spelling; clarity of document; conciseness; formalities; inclusiveness; punctuation; geopolitical referencing; vocabulary; similarity

W Smith
Registered Psychometrist
HPCSA: PMT0097012

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www.psychmetrica.co.za; 083 390 4091 ; psychmetrica@gmail.com

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A management framework for digital manufacturing in the new normal era

H Barnard

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WENDY SMITH
W Smith
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