



**Impact of the COVID-19 Pandemic on Manufacturing Operations and Supply Chain Resilience: Effects and Response Strategies**

Journal:	<i>Journal of Manufacturing Technology Management</i>
Manuscript ID	JMTM-09-2021-0357.R3
Manuscript Type:	Article
Keywords:	Manufacturing operations, Production management, Sustainable production, Industrial performance, Supply chain management

SCHOLARONE™  
Manuscripts

---

# Impact of the COVID-19 Pandemic on Manufacturing Operations and Supply Chain Resilience: Effects and Response Strategies

**Purpose:** Manufacturing organisations are striving towards adapting and responding to the unprecedented challenges posed by the COVID-19 pandemic, along with the operations research streams endeavouring to support their recovery. With a view to bridging our knowledge gap on the impact of the COVID-19 pandemic on manufacturing operations, this paper investigates the key challenges and strategies formulated by manufacturing organisations operating in the Northern region of Cyprus.

**Design/methodology/approach:** The research was conducted through 10 in-depth interviews that analyzed the effects of the pandemic, the associated causes, and the response strategies implemented.

**Findings:** The effects of the pandemic on the manufacturing organisations investigated are identified, along with the associated causes, and the response strategies deployed. Learnings and countermeasures implemented to date are established in light of the insights captured from the practitioners. Learnings and countermeasures implemented to date are established in light of the insights captured from the practitioners.

**Originality/value:** Contributions are made to the body of knowledge on manufacturing management and manufacturing supply chain resilience (SCR) through fostering our understanding of the impacts that the pandemic had on manufacturing organisations, and practical contributions are presented through evidencing and transferring of the operations management knowledge and solutions devised in various sectors to date.

---

**Keywords:** COVID-19 pandemic; Manufacturing Operations; Production Management; Supply Chain Resilience, Industrial Sustainability.

## 1. Introduction

With its significant fatality rate (Spychalski, Błażyńska-Spychalska, and Kobiela 2020), and its high transmissibility (Yu and Yang 2020), the COVID-19 pandemic has brought together ‘a once-in-a-century pandemic’, majorly impacting our society, and dramatically changing our lives (Gates 2020). All business sectors, including the manufacturing industry, are still undergoing an unprecedented crisis as the COVID-19 pandemic has negatively influenced all stakeholders including suppliers, customers, workforce, governments, and the financial markets (Anderson et al. 2020).

Manufacturing, concerning a wide range of stakeholders, is a highly important phenomenon for the sustainable development and prosperity of nations (Herrmann et al. 2014). The manufacturing industry has a solid and noteworthy contribution to not only the global GDP but also to global employment rates, in particular after the 1970s, serving at the core of the growth of the developing countries (Haraguchi, Cheng, and Smeets 2017). Despite most manufacturing sectors are suffering adversely from the COVID-19 pandemic, they will play a key role in enabling organisations, supply chains and regions to recover from the economic impacts of the pandemic (Mogaji 2020), and to achieve the 2030 Sustainable Development Goals (United Nations 2020; Bastas and Liyanage 2019).

~~The influence of the COVID-19 pandemic on various sectors has been investigated to date by various research streams (Haleem et al. 2020), including its effects on the hospitality sector (Gursoy and Chi 2020), agricultural sector (Pan et al. 2020); tourism sector (Sigala 2020), restaurant industry (Song, Yeon, and Lee 2021), and waste management practices (Fan et al. 2021).~~ The barriers and enablers for manufacturing during the pandemic have been evaluated (Okorie et al. 2020), and the learnings captured from the automotive and airline industries on supply chain resilience concerning operating during the pandemic period have been outlined (Belhadi et al. 2021). Industry 4.0 applications and the associated opportunities have also been reviewed (Zimmerling and Chen 2021), and the impact on the human resource management practices have been explored (Gigauri 2020). Furthermore, a conceptual framework for manufacturing in the post COVID-19 era has been formulated from an Indian perspective (Deshmukh and Haleem 2020), and the disruptive crises experienced in the Italian manufacturing firms have been investigated along with the service-based recovery strategies formulated in this region

(Rapaccini et al. 2020). ~~The role of operational improvement programs in managing operational crises such as the COVID-19 pandemic has also further been evidenced by Dora and Kumar (2020).~~ On the other hand, despite these contributions, the existing literature, and therefore our current knowledge on the effects and ramifications of this hot global topic on both our society in general (Haleem et al. 2020), and manufacturing organisations and their operations in specific is still very limited.

This research contributes to our body of knowledge on manufacturing management and manufacturing supply chain resilience (SCR) through an exploratory study that aims at understanding the influence of the COVID-19 pandemic on manufacturing organisations by addressing the following two research questions (RQs) below:

**RQ1:** *What are the effects of the COVID-19 pandemic on manufacturing organisations and their operations?*

**RQ2:** *Which response strategies and/or countermeasures have been formulated by manufacturing organisations against the effects of the pandemic?*

It is clear that the pandemic is driving new ways of operating due to the many unprecedented impacts it caused (Deshmukh and Haleem 2020), and the answers to these fundamental questions are reflected to be fruitful to our understanding of this new era and the challenges that manufacturing industries are currently facing. Insights from various manufacturing sectors are captured, learnings and how manufacturing organisations are adapting to the effects of the pandemic are established, recovery solutions formulated to date are presented, along with the timeframes associated, e.g. short, medium and long terms, and findings analysed versus the extant manufacturing supply chain resilience disruption strategies in the literature.

Stemming from the explorative nature of the research questions the research has been undertaken with an inductive approach, engaging with executives that navigated their manufacturing operations in the Northern Cyprus region during the pandemic, via in-depth interviews. Taking into account that the impact of the global pandemic on manufacturing operations may vary regionally, each observed effect and the associated causes were analysed to differentiate between the region-specific and the general factors. These findings will prove useful not only to academics, through the supplementation of the

emerging research streams and the extant literature, but also these will benefit practitioners and industrialist readers by evidencing and facilitating the transfer of industrial responses and solution actions to the key effect themes experienced to date.

The rest of this article is structured as follows; the extant and similar works in the literature are reviewed in Section 2, outlining the position of this research within the relevant literature; the materials and methods adopted in this study are described in Section 3; the findings of the study are presented in Section 4, capturing the key themes identified and framing the influences of the COVID-19 pandemic on manufacturing organisations; the findings and implications of the research are evaluated and discussed against similar studies in Section 5; and finally, conclusions and contributions are drawn along with an appreciation of the limitations of the research and recommendations for future research directions in Section 6.

## 2. Literature Review and Theoretical Background

The COVID-19 pandemic has indisputably influenced academia and practice, with research streams springing to support all aspects of our society in responding to this unprecedented challenge (Haleem et al. 2020); ~~not only including~~ the manufacturing (Rapaccini et al. 2020; Juergensen, Guimón, and Narula 2020); and supply chain operations areas (Ivanov and Dolgui 2020); ~~but also in other key areas such as healthcare (Blumenthal et al. 2020); hospitality (Gursoy and Chi 2020); agriculture (Pan et al. 2020); and education (Cleland et al. 2020).~~

Innovative endeavours adapting and/or refining digital technologies (~~Zimmerling and Chen 2021~~); such as Industry 4.0 and its subsidiary technologies including artificial intelligence, internet of things and big data analytics (Zimmerling and Chen 2021); to provide solutions to the various operational issues that arose are prominent in the literature. Various effects on the management of organisations have been investigated, including evidencing of the negative impact on the business performance (Shen et al. 2020); ~~the role of collaboration and operational improvement programs for recovery from the impacts experienced (Dora and Kumar 2020); and~~ human resource management challenges (Gigauri

2020); and significant implications observed for marketing and corporate social responsibility strategies (He and Harris 2020).

In line with the research objectives, the existing works in the manufacturing operations research domain have been identified, and critically reviewed in Table 1, along with the identification of the research streams currently present in the literature. A major portion of the contributions published to date has been noted as short viewpoints, reviews or conceptual modelling studies in the absence of empirical data. Several scholars such as Deshmukh and Haleem (2020), Juergensen, Guimón, and Narula (2020), and Kumar et al. (2020) presented interesting perspectives on the potential or observed influences of the pandemic on the manufacturing organisations, synthesising the existing literature with their opinions to guide practitioners and to stimulate future thinking on the hot issues.

Okorie et al. (2020) further documented the enablers and barriers to manufacturing in the pandemic era in a survey that included opinions of practitioners from various continents. Belhadi et al. (2021) investigated the effects experienced at the specific automotive and airline sectors through the survey methodology, establishing the lessons learnt from the pandemic and formulating useful insights for the practitioners in these sectors. Rapaccini et al. (2020) undertook surveys, followed by in-depth interviews among the Italian manufacturing firms and put forward a stage-based crisis management model, underlining the importance of conversion to a service-based strategy for resilience in their exploratory study.

Even though these meaningful contributions, an evident consensus was established in the literature that further research is much required to investigate further empirically in different regions, the relationships between the pandemic and the operations of manufacturing organisations, to identify recovery strategies being adopted, and to support the exchange of best-practices across the manufacturing sectors for fruitful theoretical and practical research outcomes. This paper addresses the evident limitation in the extant 'effects and countermeasures' research streams through the adoption of an exploratory, expert-interviews based approach including various manufacturing sectors in a new region, establishing the effects experienced in manufacturing operations, outlining the understanding of these through identifying the causes driving these effects, documenting the countermeasures formulated

---

by industrial practitioners, and finally, providing a review of these strategies against the extant supply chain resilience strategies.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



**Table 1.** Similar works in the manufacturing operations literature and research gap analysis

Author (Year)	Title	Stream of Research	Method	Region	Remarks
Belhadi et al. (2021)	Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries	Supply Chain Resilience	Survey	Europe, Asia and Africa	Investigated the impact experienced by the automotive and airline organisations in various regions, identifying key response strategies
Deshmukh and Haleem (2020)	Framework for Manufacturing in Post-COVID-19 World Order: An Indian Perspective	Effects and Countermeasures	Conceptual	India	Undertook a PEST analysis on the manufacturing sector in the Indian region, authors presenting their perspective on how the pandemic has and will influence manufacturing practices in the region.
Juergensen, Guimón, and Narula (2020)	European SMEs amidst the COVID-19 crisis: assessing impact and policy responses	Effects and Countermeasures	Viewpoint	Europe	Effects of the pandemic on the European SMEs were discussed based on the intuitive impressions and viewpoints of the authors. No empirical data collected.
Kumar et al. (2020)	COVID-19 impact on sustainable production and operations management	Effects and Countermeasures	Viewpoint	N/a	Effects of the pandemic on sustainable production and operations management were reviewed through a literature based analysis and, discussed based on the impressions of the authors. No empirical data collected. The research is

highly subjective and general.

Li et al. (2020)	Intelligent Manufacturing Systems in COVID-19 Pandemic and Beyond: Framework and Impact Assessment	Intelligent Manufacturing Systems	Conceptual	N/a	Developed an intelligent manufacturing framework to structure production recovery decision-making during the pandemic
Okorie et al. (2020)	Manufacturing in the Time of COVID-19: An Assessment of Barriers and Enablers	Operations Continuity: Enablers and Barriers	Survey	Europe, Africa, North America, South America, Asia	Identified the barriers and enablers for manufacturing during the pandemic, capturing empirical data from practitioners and making future recommendations for the effectiveness and continuity of pandemic and post-pandemic manufacturing operations.
Paul and Chowdhury (2020)	A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19	Supply Chain Resilience	Conceptual	N/a	Proposed a production recovery model for supply continuity and profitability during the pandemic
Rapaccini et al. (2020)	Navigating disruptive crises through service-led growth: The impact of COVID-19 on Italian manufacturing firms	Effects and Countermeasures	Survey, Interviews	Italy	Investigated the business effects experienced by the Italian manufacturing firms, proposing a four-stage crisis management model and a servitisation based strategy as countermeasures to the pandemic
Zimmerling and	Innovation and possible long-term impact	Effects and	Review	N/a	Reviewed the various innovations and technologies driven

---

Chen (2021) driven by COVID-19: Manufacturing, personal Countermeasures by the Covid-19 pandemic in various sectors  
protective equipment and digital technologies

---

The COVID-19 pandemic has created unprecedented disruptions to global supply chains and manufacturing operations, posing significant challenges for manufacturing business continuity and supply chain resilience (SCRes) (Ivanov and Dolgui 2020; Belhadi et al. 2021). The extant operations and supply chain management literature categorize manufacturing SCR strategies as proactive (implemented pre-disruption) and reactive (implemented post-disruption), and an overview of these are provided in Figure 1 (Tukamuhabwa et al. 2015; Belhadi et al. 2021). The response strategies observed to be implemented against the COVID-19 pandemic at the manufacturing plant and supply chain levels are reviewed against these extant SCR strategies.

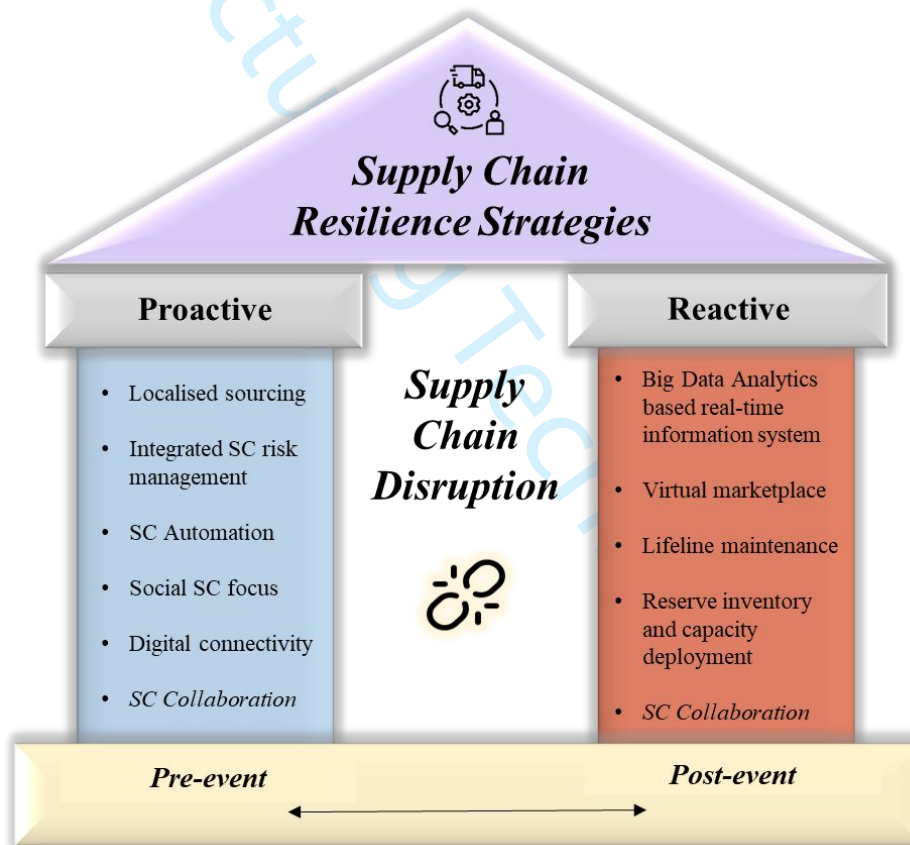


Figure 1. Extant Manufacturing Supply Chain Resilience Response Strategies

### 3. Materials and Methods

In line with the emerging nature of the research objectives, an exploratory study was conducted, to inductively explore and reveal the issues central to the phenomenon under investigation, i.e. the influence of the COVID-19 pandemic on the operations of manufacturing organisations—(Saunders,

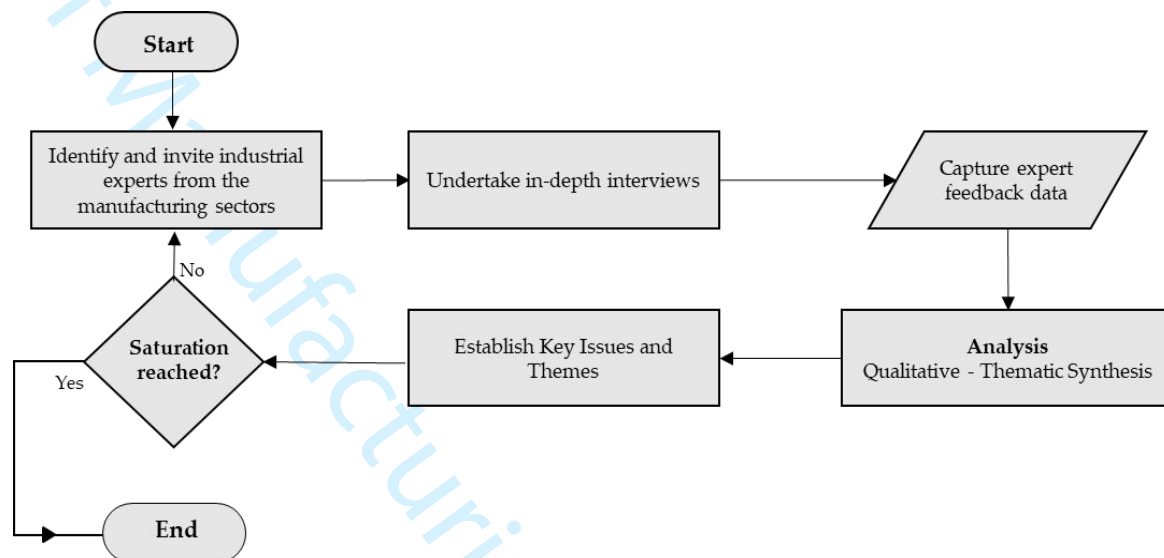
~~Lewis, and Thornhill 2015~~). This provided the openness, flexibility and adaptability required in operations and management research that seek to explore new concepts and themes (Saunders, Lewis, and Thornhill 2015). Exploratory studies are typically undertaken via in-depth individual interviews or focus group interviews (Saunders, Lewis, and Thornhill 2015). Relevant, immersive research methods such as case study, multi-case approach, and action research were not feasible during the data collection period, as the study was undertaken in the early days of the pandemic where access to manufacturing organisations was highly limited due to lock-down and social isolation measures, in the region studied. In-depth interviews are particularly effective in the investigation of new issues and enable the capturing of more comprehensive data when compared with other data collection methods such as surveys (Boyce and Neale 2006). In-depth interviews have been adopted in similar studies such as those of Rapaccini et al. (2020), Gigauri (2020) and ~~Körner et al. (2019)~~ in the wider manufacturing operations research community.

An overview of the research methodology adopted is presented in Figure 2. Industrial experts were established and invited to participate in the interviews from a diverse range of manufacturing sectors, as per the following defined expert criteria (Bastas and Liyanage 2018a; Bogner, Littig, and Menz 2009):

- Should possess at least 5 years of experience in tactical or strategic management of a manufacturing organisation; AND
- Should have been in this manufacturing operations management and/or directorship role during the COVID-19 pandemic.

The interviews were held via telephone or online meetings, posing the participants with open-ended questions with a view to explore the issues that they have experienced during the pandemic in their organisations, and any response actions or countermeasures that they have formulated and deployed. This enabled the capturing of a rich base of qualitative data, which was then systematically processed and analysed through the adoption of a thematic synthesis approach and its fundamental steps, i.e. compiling, disassembling, reassembling, interpreting and concluding (Castleberry and Nolen 2018). Accordingly, the interview data was listed, separated into codes, key issues and themes identified and synthesised, allowing for the interpretation of the results (Castleberry and Nolen 2018; Bastas and

Liyanage 2018b). The interviews were held until a saturation point was established in the themes generated (Galvin 2015; Boyce and Neale 2006).



**Figure 2.** Research Methodology Overview of the Study

10 interviewees were included in the study from a wide range of manufacturing sectors from the Northern Cyprus region (i.e. a developing region), the details of whom are presented in Table 2. Interviewees' details included the position that they hold in their organisations, their background in terms of the manufacturing sector(s) that they operate in, and the indicative products manufactured by their organisations. Some participant experts were noted to be the managing or operations directors of manufacturing organisations that operated in multiple subsectors (e.g. holding a leadership position in organisations that both produced beverage and plastics products).

**Table 2.** Position and sectoral background of the participants of the study

No	Position	Sector(s)	Typical Products
1	Managing Director	Beverage Manufacturing	Bottled Drinking Water
		Plastics Manufacturing	Recycled Plastic Products
2	Operations Director	Furniture Manufacturing	Furniture
		Fabricated Metal Products Manuf.	Windows

---

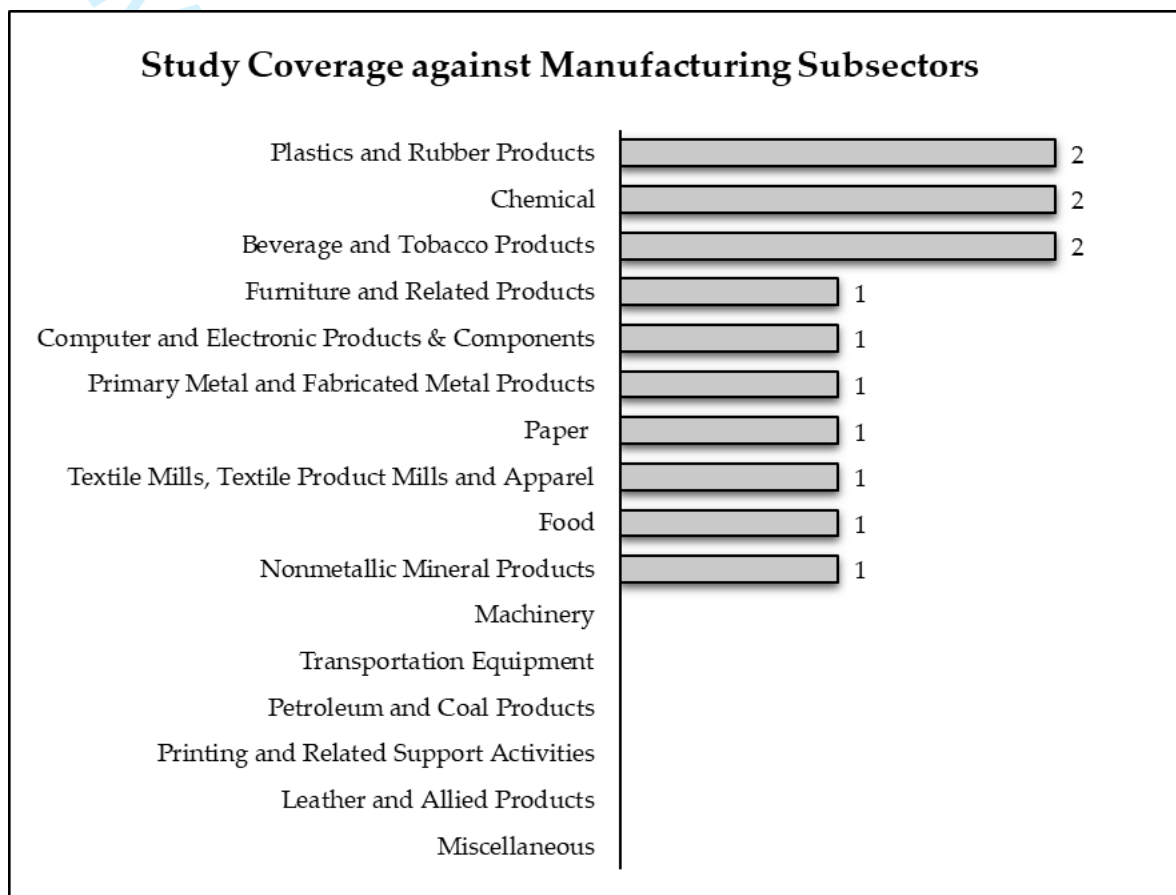
3	Managing Director	Plastics Manufacturing	Household Cleaning Tools
4	Operations Director	Electrical Component Manuf.	Electrical wires
5	Operations Director	Paper Manufacturing	Paper Cups
		Textile Manufacturing	Slippers
6	Managing Director	Beverage Manufacturing	Bottled Drinks
7	Operations Director	Chemical Manufacturing	Disinfectants & Detergents
8	Operations Director	Chemical Manufacturing	Paint & Construction Materials
9	Operations Director	Nonmetallic Mineral Products	Glass
10	Operations Director	Food	Packaged Bread, Frozen Food & Desserts

---

According to Galvin (2015), a sample of 10 interviewees, which were randomly selected as per expert criteria from a diverse range of manufacturing industries, are enough to capture themes that only occur in 25% of the population with a very high probability of 94.4%. This probability is much higher for themes that occur at higher percentages across the population, e.g. a sample of 10 interviewees will identify themes that occur at 50% of the population with a probability of 99.9%. This was further validated, ~~through the observation that~~ the interviews ~~reaching~~ a saturation point at the end of the 10 interviews undertaken, with themes reoccurring ~~(Cooper and Schindler 2014)~~. This is echoed by Glaser & Strauss (2009), who established 10 expert interviews to generally provide a reasonable level of confidence, in particular, if saturation is achieved. ~~A similar research methodology was adopted by Gigauri (2020), which investigated the impact of the COVID-19 pandemic on human resource management practices, conducting 10 expert interviews in the Georgian industry and thematically synthesizing the obtained data.~~

Stemming from the U.S. Bureau of Statistics (Statistics 2019), the manufacturing sector comprises several subsectors, which are grouped under 16 key categories. The sectors of the interviewees that took part in this study were mapped against these subsectors of manufacturing in Figure 3, demonstrating the

significant sectoral coverage of the present study. 10 out of 16 manufacturing subsectors were included in this study, providing a holistic view of the manufacturing industry and enriching the level of access with the manufacturing subsectors, enhancing the associated interview data capture.



**Figure 3.** Map of the interviewees of the study against manufacturing subsectors

## 4. Results

### 4.1. The influence of COVID-19 Pandemic on Manufacturing Organisations and their Operations

The influence of the COVID-19 pandemic on the operations of the interviewed manufacturing organisations and the related business functions is mapped in Figure 4, demonstrating and framing the key themes observed and the associated operations management categories (Slack, Brandon-Jones, and Johnston 2016). It was noted that the pandemic has had both direct and indirect effects on manufacturing operations through the related business functions, overall causing major implications to operations managers in all manufacturing sectors that were considered as part of the study.



The key themes were grouped under the key operations and related management categories, outlining the observed effects on the organisations, synthesizing the identified causes associated with the relevant effects, and analyzing the strength of the themes (i.e. the percentage of occurrence of each theme in the interviews). To establish the relevance of the observations to other regions, each factor was analysed, taking into consideration whether the cause(s) driving the effect was a local or region-specific factor (e.g. human resource or supply chain factors specific to the Northern Cyprus region), or general factor(s) with no clear, regional specificity, that apply to most regions and manufacturing sectors due to the global pandemic (e.g. COVID-19 virus transmission risks and its implications). The findings are presented in Table 3.

As a highly consistent theme ~~and echoing with Chiu et al. (2020) and Chernozhukov et al. (2021)~~, the importance of face masks, hand hygiene and social distancing measures were fully recognised by the manufacturing sectors, driving the associated implementation of health & safety procedures across the industry. Accordingly, all manufacturing organisations were observed to implement new health & safety measures, including issuance and implementation of face masks, social distancing and hand hygiene, driven by the government's legislation and to mitigate the risk of virus transmission. This was further noted to be supplemented by the implementation of regular disinfection processes across raw materials, recycled products and factory spaces, which was established as a highly common theme across the manufacturing sectors. ~~On the other hand,~~ Aalmost all of the manufacturing sectors were noted to be negatively or detrimentally affected by the pandemic in financial terms, suffering from the dramatic reductions in demand of up to 75% in some sectors. Such a sharp decrease in terms of turnovers was driven by the shrinkage in key markets including the export markets, and periods of lockdown that enforced factory shut-downs on most manufacturing sectors.

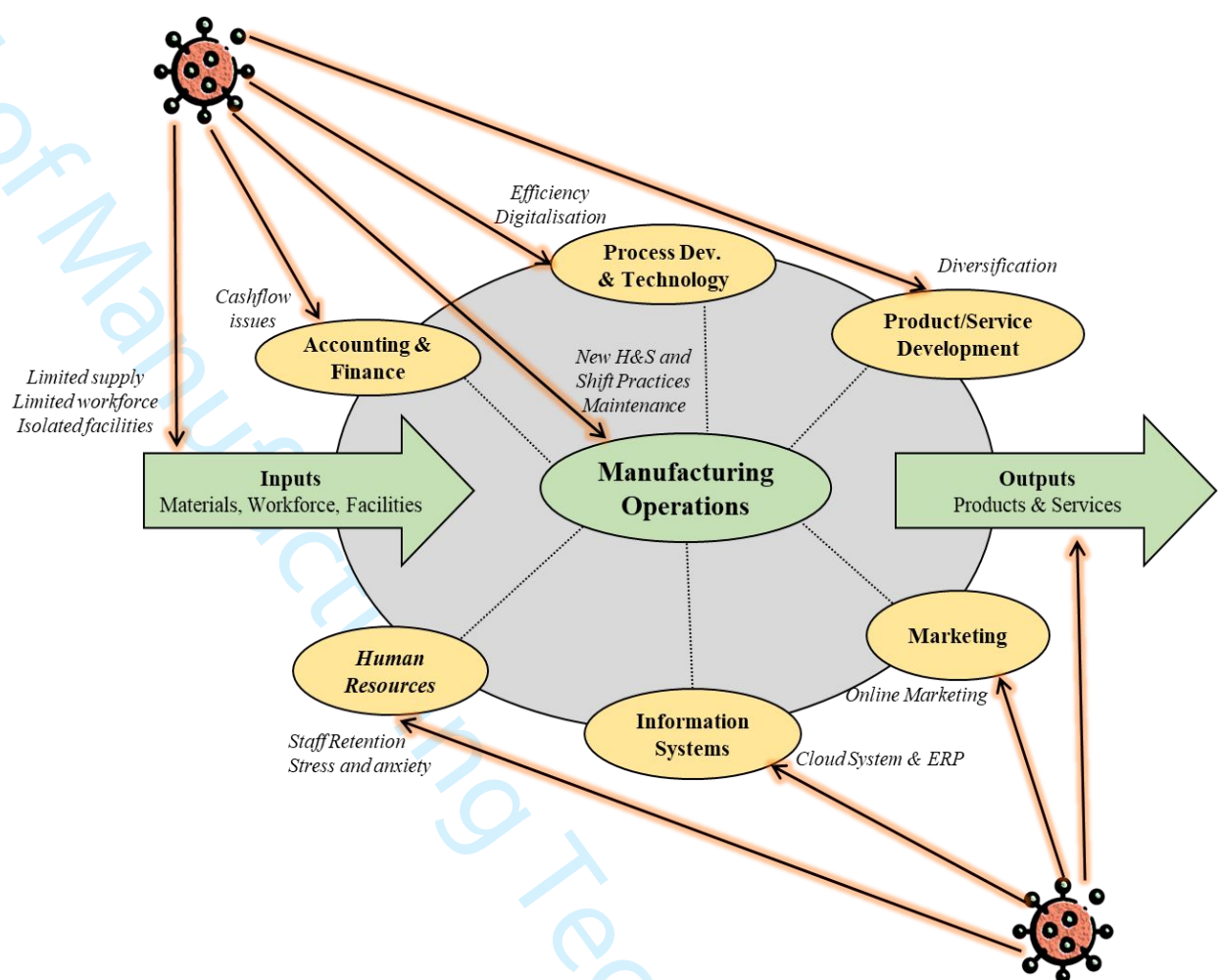


Figure 4. The influence of COVID-19 pandemic on manufacturing operations and the related business functions

**Table 3.** The effects of the COVID-19 pandemic on the manufacturing organisations and the associated causes

1

Category	Effect	Cause(s)	Region Specific / General	Theme Strength
Occupational Health & Safety	Implementation of new H&S measures including face masks, social distancing and personal hygiene	Risk of COVID-19 transmission among the workforce Legislation	General Region Specific	100%
Plant Maintenance	Regular disinfection of products and factory spaces	Risk of COVID-19 transmission among the workforce Legislation	General Region Specific	100%
Financials, Sales, Marketing & Product/Service Development	Cash flow/liquidity problems Reduced turnover/profitability Underutilised production capacity	Shrinkage of markets Factory closures due to lockdown periods Increased risk of bankruptcy and late payments Increased raw material costs	General General General General	90%
Human Resources	HR Shortages (unable to recruit competent and qualified manufacturing personnel) and highly limited access to new workforce pools	Travel restrictions and quarantine/lockdown regulations (unable to recruit from other countries and regions with richer skills pools) Disruption due to COVID-19 exposure of employees (quarantine, isolation etc.) Losing key employees to other businesses or government due to better/more consistent salary payments	Region Specific General Region Specific	80%

Financials & Business Planning	Unable to plan and make key business decisions concerning key business resources including future investments and recruitment	The investment funds being transferred to the retention of employees or cash flow management funds Uncertainties and lack of visibility regarding the future of the business	General General	80%
Occupational Health & Safety	Isolation of inter and intra organisational operations and reducing contact among stakeholders	Risk of COVID-19 transmission among the workforce Legislation	General Region Specific	70%
Supply Chain and Logistics	Longer lead times and increased costs on raw material supply	Revised/more complex customs procedures Limited supply and container shortages Excessive stocking (Bullwhip effect) Disruption in global supply chains	Region Specific General General General	70%
Occupational Health & Safety	Regular medical checks	Risk of COVID-19 transmission among the workforce Legislation	General Region Specific	60%
Relationship Management	Reduced effectiveness of interactions/engagement with suppliers and customers	Risk of COVID-19 transmission Key customer or supplier site visits cancelled Factory closures due to lockdown periods	General General General	50%
Human Resources	Reduced performance, efficiency and effectiveness of employees	Reduced cooperation/communication/concentration among the workforce Key employees working from home due to being in medical risk-groups	General General	50%

Plant Maintenance	Disruption to key maintenance and servicing activities	Travel restrictions and quarantine/lockdown regulations	Region Specific	50%
Plant Maintenance	Disruption to new equipment installations	Travel restrictions and quarantine/lockdown regulations	Region Specific	40%
Human Resources	Stress and Anxiety	Fear of being infected	General	30%
		Fear of job loss/redundancies	General	
Supply Chain and Logistics	Employment of new, local truck drivers and revised logistics practices	Drivers are no longer able to travel freely with their trucks across countries or regions	General	30%
Human Resources	Disruption to training & development activities	Travel restrictions and quarantine/lockdown regulations	Region Specific	30%
Bureaucracy	Reduced bureaucracy & faster approval processes	Online documentation and approval procedures implemented in relevant governmental institutions	Region Specific	30%
Production Planning & Control	Revised shift patterns	Risk of COVID-19 transmission among workforce	General	20%
Certification & Calibration	Disruption to lab calibration & certification activities such as TSE and ISO9001	Travel restrictions and quarantine/lockdown regulations	Region Specific	20%

The reduced demand rates further resulted in under-utilized resources and production capacities, and brought together financial cash flow problems, due to organisations struggling to receive their payments on time and the same having a domino effect in the sectors. These financial effects were deepened by increased raw material costs due to the pandemic and were established as a major cause of concern for the economic sustainability of the manufacturing organisations.

A high percentage of manufacturing sectors were seen to face human resource (HR) shortages due to travel restrictions highly limiting the access of manufacturing organisations to skill pools in other regions. It was indicated that the pandemic made it a lot more difficult for manufacturing organisations to identify and relocate competent and qualified employees, who are at the heart of manufacturing operations that rely on technical skills. Moreover, several organisations suffered from losing their key employees as they were unable to return from their visits abroad and stemming from the aforementioned cash flow issues, some businesses experienced staff losses to other less affected sectors such as governmental institutions. Although a major spread and closure were not observed to date across the manufacturing sector in the Northern Cyprus region, a few organisations further suffered from HR limitations due to some employees having to self-isolate or quarantine and thus, being unable to attend work and carry out their duties.

Another noteworthy influence of the pandemic was established on the strategic business planning activities of the manufacturing organisations, heavily impacted by the lack of future visibility and uncertainties introduced to the business climate. This was seen to influence growth strategies of the manufacturing organisations, most cancelling or delaying their key machine and labour investments due to lack of visibility, financial issues and channelling of financial resources towards the retention of key employees.

Significant effects were also evidenced on the supply chain and logistics practices including longer lead times and increased costs of raw materials. The drivers of these influences stemmed from more complex customs procedures, actual or perceived shortage of supply and the associated bullwhip effect (Metters 1997), and the overall disruption experienced in the global supply chains. A major implication was further indicated regarding the logistics organisations dispatching the trucks/containers to regions

with travel restrictions or quarantine regulations without their drivers, and local drivers being recruited to pick up and complete the deliveries in the relevant local regions.

In addition to the aforementioned occupational health & safety practices, a noteworthy effort was noted in manufacturing organisations to mitigate the risk of transmission of the disease. As a strong theme, most organisations isolated their operations, keeping contact to a minimum among internal and external stakeholders. These were supported by regular medical checks undertaken for all employees and revised shift patterns as required with the objective to reduce contact among employees as much as possible and to prevent full factory closures, in the case of an employee carrying the virus.

Furthermore, inter-organisational relationship management and communication were impacted by the pandemic. For example, key supplier or customer site visits had to be cancelled while product/service deliveries were also negatively influenced due to factory closures or supply shortages. Similarly, there was reduced organisational engagement due to limited or no personal interactions among key stakeholders. Similar effects were experienced among intra-organisational relationships, performance, morale and effectiveness of employees generally dropping, and some employees having to work from home due to being in medical risk groups. Stress and anxiety caused by the risks and uncertainties of the pandemic period and fear of redundancies were also reported in some organisations.

The travel restrictions and quarantine/lockdown regulations brought together by the pandemic further posed challenges to the maintenance/servicing activities of manufacturing organisations, and to the commissioning/decommissioning and installation of new manufacturing equipment as the specialists and/or consultants were unable to travel to the factories to oversee and undertake the necessary activities. Training, development, management system certification, e.g. ISO9001, and accreditation, e.g. TSE, CE, activities were similarly affected negatively, as the necessary visits and audits had to be cancelled or the scope of the same narrowed down.

On the positive side, the pandemic was reported to reduce the bureaucratic burden on manufacturing organisations, driving the legislative institutions to switch to online processes, which speeded up certain legislative processes for the companies.



### 3.2. Response Strategies & Countermeasures

The response strategies, countermeasures adopted and/or opportunities identified against the effects of the COVID-19 pandemic were captured and tabulated in Table 4, along with the evaluation of the links against the extant manufacturing supply chain resilience strategies.

In terms of occupational health & safety, several response strategies were observed in manufacturing organisations. All organisations issued masks to their employees along with some organisations preferring to put in place tailor-made, comfortable masks to increase the chances of employees following and adapting to the use of PPE requirements. Further, some factories implemented clear demarcations of social distancing measures in the work stations using tape and signage, facilitating the operationalisation of the social distancing measures. Disinfectants were made available and disinfection stations were set up in various areas of the factories. Training activities were held to raise awareness of the workforce regarding the COVID-19 disease and the importance of compliance with the new rules and regulations. Periodic disinfection of products and factory spaces as part of a formal and documented maintenance process was put in place, and disinfection was included in routine maintenance activities of the organisations.

Additionally, to further mitigate the risk of transmission of the disease, the contact of employees with other internal and external stakeholders was minimised or eliminated where possible to isolate working groups from each other as much as possible. As a response strategy, the contact between the factory staff and staff working outside the organisation (e.g. marketing or delivery staff) was eliminated in most organisations that took part in the interview. Some manufacturing organisations further isolated their workforce by splitting their employees into teams (e.g. purchasing team could only contact/interact with the relevant and essential personnel in the same team, but it could not physically interact with the packaging team). The organisations that were working multiple shifts made shift arrangements to reduce the labour involved in each shift to reduce contact and to isolate groups of the workforce, in case a positive COVID-19 transmission was seen in one shift, other shifts could still operate. The receiving and despatch of goods and the associated deliveries were now undertaken contactless in all organisations.



**Table 4.** The effects of the COVID-19 pandemic on the manufacturing organisations against the response strategies and/or countermeasures implemented

3

Category	Effect	Response Strategies, Countermeasures or Opportunities / Timeframe	Extant SC Resilience Strategies Link
Occupational	Implementation of new H&S	Demarcation of social distancing measures / Short-term	N/A
Health & Safety	measures including face masks, social distancing and personal hygiene	Issuance of comfortable face masks / Short-term Training activities to raise awareness / Short-term Implementation of disinfection stations / Short-term	
Plant	Regular disinfection of products and factory spaces	Implementation of a regular and effective disinfection process, and making disinfection as part of maintenance routine and part of the TPM system / Short-term	N/A
Financials, Sales,	Cash flow/liquidity	Online marketing activities (development of marketing websites and/or applications) / Short-term	Virtual Marketplace as a reactive response strategy was observed.
Marketing &	problems	Government incentive and support schemes / Short-term	
Product/Service	Reduced	Governmental tax relief schemes / Short-term	
Development	turnover/profitability Underutilised production capacity	Bank support schemes and relaxed debt payment terms / Short-term Diversification into new markets, products and services for risk mitigation / Medium and long-terms Reducing production costs through increasing production efficiency and/or reducing labour (increasing level of automation) and reducing material consumption (Reduced workload is providing an opportunity for improvement) / Medium-term	

Human Resources	HR Shortages (unable to recruit competent and qualified manufacturing personnel) and highly limited access to new workforce pools	Key employee retention / Short-term Hiring from other organisations that had to make redundancies / Short-term Channelling limited HR to critical/higher risk processes / Short-term Outsourcing of lower risk processes to suppliers / Short and Medium-terms	Supply chain collaboration as a reactive response strategy was observed through the outsourcing of lower risk processes. A tendency towards local/regional suppliers was also noted as a proactive strategy.
Financials & Business Planning	Unable to plan ahead and make key business decisions with reference to key business resources including future investments and recruitment	Diversification into new markets, products and services for risk mitigation / Medium and long-terms	N/A
Occupational Health & Safety	Isolation of inter and intra organisational operations and reducing contact among stakeholders	Isolation of the factory personnel from personnel that work externally (closed-circuit working patterns) / Short-term Division of factory employees into teams (personnel that must interact placed in the same teams) and prevention of physical contact among teams / Short-term Contactless deliveries (to/from the factories) / Short-term Monitoring delivery/marketing personnel via GPS to ensure essential company travel	Moving towards new/revised contactless delivery methods was an example of lifeline maintenance as a reactive strategy. Cloud system implementation could be noted

		activities are carried out only / Short-term	as both reactive (real-time
		Cloud system implementation / Medium and long-terms	information system) and
			proactive (digital connectivity)
			resilience strategies were
			observed.
Supply Chain and Logistics	Longer lead times and increased costs on raw material supply	Dual or alternative sourcing / Medium-term Safety/buffer stock implementation / Short-term Advanced ordering to guarantee supply / Short-term Process and product engineering changes to process alternative raw materials and supplies that are available, even at the expense of increased scrap rates / Short and Medium-terms	Reserve inventory and capacity implementation and deployment were observed as a reactive response strategy.
Occupational Health & Safety	Regular medical checks	Weekly PCR Testing of employees / Short-term Temperature checks of employees on entry to offices and factory spaces (identified infected personnel and prevented the spread of the virus in the factory) / Short-term	N/A
Relationship Management	Reduced effectiveness of interactions/engagement with suppliers and customers	Essential interactions being held via online meetings / Short-term Online purchase order and delivery tracking system implementation / Short-term	Virtual Marketplace as a reactive response strategy was observed.

Human Resources	Reduced performance, efficiency and effectiveness of employees	Online meetings with key personnel / Short-term Step up of younger members into leadership roles / Short-term	N/A
Plant Maintenance	Disruption to key maintenance and servicing activities	Obtaining online support via online meetings / Short-term Stocking of high-risk parts and critical spares / Short and medium-terms Development of in-house capabilities / Medium-term	Reserve inventory and capacity implementation and deployment were observed as a reactive response strategy.
Plant Maintenance	Disruption to new equipment installations	Obtaining online support via online meetings / Short-term	Supply chain collaboration as a reactive response strategy was observed.
Human Resources	Stress and Anxiety	Key employee retention / Short-term Regular communication from management to increase motivation and to clear anxiety / Short-term	N/A
Supply Chain and Logistics	Employment of new, local truck drivers and revised logistics practices	Truck driver HR development / Medium-term Each truck delivery now has two or more designated drivers in each country / Short-term	Lifeline maintenance to ensure continuity of transport and logistics was observed as a reactive strategy.
Human Resources	Disruption to training & development activities	Deployment of online training and development activities / Short-term	N/A

---

---

Bureaucracy	Reduced bureaucracy & faster approval processes	Online documentation and approval procedures / Short and medium-terms	N/A
Production	Revised shift patterns	Segregation of resident employees from others through separation of shifts / Short-term	N/A
Planning & Control		Dividing workforce into separate shifts to mitigate the risk of full closure in the case of an employee carrying the virus / Short-term	
Certification & Calibration	Disruption to lab calibration & certification activities such as TSE and ISO9001	Online certification audits / Short-term Obtaining online support via online meetings / Short-term	N/A

---

Moreover, to ensure that only essential visits were being carried out by the employees, one of the organisations further implemented a vehicle monitoring system via GPS technology, tracking the location of their employees. To further reduce the physical interaction among the employees, cloud systems and ERP system enhancements were noted to be implemented to facilitate digital communication and to support operations management via online means. Actions implemented to monitor the health status of the employees included the implementation of weekly PCR tests (van Kasteren et al. 2020) for all employees and temperature monitoring on entry to the offices and factory spaces. It was further noted that the temperature monitoring process successfully detected a COVID-19 positive employee in one of the interviewed organisations, preventing the virus from being carried into the organisation's facilities.

As response strategies to the financial issues being experienced across the manufacturing sectors, the organisations were actioning diversification strategies into new markets to recover their sales, developing new products and services. Implementation of online marketing activities such as enhancing the company websites and implementing new mobile applications to foster online customer interaction and sales was also established as a common theme in this area. Moreover, it was indicated by several interviewees that, as their capacity was now underutilized, they were endeavouring to make the most out of this low activity period through focusing on operational improvement activities, with a view to drive down costs and aid the financial impasses that they were facing. It was reported that talks were ongoing with crediting institutions to secure better repayment terms and to secure additional funding to support cash flow management. The industrial interviewees all resonated that governmental support was of paramount importance in the survival of the businesses, further relaxation of taxes and obligations was noted as a key theme.

Endeavouring to tackle the HR limitations, the manufacturing organisations were implementing staff retention policies to hold on to their key employees. As a countermeasure, several organisations were also outsourcing some of their operations to subcontractors, channelling their limited human resources to the higher risk processes. All essential communications, including communications with customers, suppliers and communications among the workforce of the employees were being held

1  
2  
3  
4  
5 online, via online teleconferencing applications and online systems. Essential technical support  
6  
7 regarding the installation of equipment, maintenance, and training was being held similarly. It was noted  
8  
9 in one of the interviews that an organisation had their ISO9001 audit through an online meeting, and  
10  
11 another organisation received real-time, production equipment servicing support through the same. In  
12  
13 the medium term, some organisations were investing in the stock of critical and high-risk parts for the  
14  
15 maintenance of their key manufacturing equipment and are looking at developing the required technical  
16  
17 maintenance and machine commissioning support skills in-house.  
18

19  
20 In addition to the online meetings, regular communication from the senior management was being  
21  
22 delivered to the workforce to settle down the stress and anxiety issues observed, articulating the staff  
23  
24 retention policies where applicable. Some key manufacturing personnel had to work from home due to  
25  
26 being under risk groups. Although this was reported to negatively influence the effectiveness of some  
27  
28 operations and the overall morale of the workforce, it was reflected that this provided an opportunity for  
29  
30 younger and developing members of teams to be promoted to develop new leaders among their  
31  
32 workforce.  
33

34  
35 On the other hand, the supply chain and logistical challenges were seen to be addressed through  
36  
37 several response strategies. Due to higher lead times and overall disruption observed in some raw  
38  
39 material commodities, some organisations implemented safety stocks to reduce the risk of production  
40  
41 line stoppages. Furthermore, alternative sources were being developed as contingency and backup  
42  
43 supply plans. Organisations were also adopting a more proactive approach to purchasing, planning and  
44  
45 ordering in advance to guarantee supply. In the cases of commodities where supply was highly limited  
46  
47 and there were significant supply risks, process and product changes were investigated to accommodate  
48  
49 alternative materials and suppliers, at the expense of increased costs or internal scrap rates.  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## 5. Discussion

The findings of this study have been evaluated collectively with the viewpoints of the extant literature on the impacts of the COVID-19 pandemic. All in all, it was evidenced that the pandemic influenced all key organisational management parameters across the supply chains (Kumar et al. 2020), including the firm performance and financial performance due to the adverse effects on the production, operations and sales, echoing with H. Shen et al. (2020), and Juergensen, Guimón, and Narula (2020) that investigated the European SMEs. A noteworthy shrinkage of markets and related detrimental socio-economic impacts were observed (Nicola et al. 2020), as also reported by ~~Sahoo and Ashwani (2020)~~ and Okorie et al. (2020), although some industries were seen to be more affected than the others as outlined by Rapaccini et al. (2020) in the Italian region. Although the demand significantly dropped for a lot of sectors e.g. textiles, it skyrocketed for certain products due to the shift in the consumption behaviour e.g. sanitisers, ventilators, critical food items (Kumar et al. 2020). Similar observations were noted in the northern region of Cyprus, where this study has been undertaken. For instance, furniture, glass and food manufacturers were observed to be much less affected than the other sectors with regards to weakening demand.

Furthermore, there is a consensus across the literature and with the findings of this study that, support and incentives from the governments and key stakeholders such as the creditors are of paramount importance to support and to enable business survival in the unstable and uncertain climate of the pandemic (Kumar et al. 2020; Deshmukh and Haleem 2020; Okorie et al. 2020), especially for the SMEs (Juergensen, Guimón, and Narula 2020). The cash flow issues being experienced by the manufacturing organisations that were observed in this study are not specific to the Northern region of Cyprus, but appears as a general theme across various regions such as the European region (Juergensen, Guimón, and Narula 2020), and both the governments and banks have a major role to play with their monetary and fiscal instruments (Deshmukh and Haleem 2020), to mitigate the risks of liquidity crises and rises in the unemployment rates, which has detrimental long term effects on the economies (Petrosky-Nadeau and Valletta 2020). Resonating with Juergensen, Guimón, and Narula (2020), the



1  
2  
3  
4  
5 manufacturing organisations are looking for industry-friendly policies, including tax, debt and social  
6 security payment reliefs, grants, and support to their utility payments.  
7

8  
9 The imposed travel restrictions (Chinazzi et al. 2020), the risk of rapid transmission of the disease  
10 and the associated risk of factory closures (Yu and Yang 2020), major disruptions to supply chains  
11 including increased costs and higher lead times (Aday and Aday 2020), were observed as some of the  
12 key causes of the experienced effects. Driven by the health concerns and associated regulations (Okorie  
13 et al. 2020), the manufacturing organisations have implemented workplace reorganization measures  
14 including social distancing, hygiene and PPE measures, regular temperature and health checks, which  
15 appears to be a common theme across various authors (Kumar et al. 2020), and regions such as Italy  
16 (Rapaccini et al. 2020), and others (Okorie et al. 2020; Juergensen, Guimón, and Narula 2020). These  
17 actions are mainly being driven by governmental legislation (Juergensen, Guimón, and Narula 2020).  
18 Even though social distancing and face mask usage are effective measures in reducing the spread of the  
19 disease in public, and in the workplaces (Eikenberry et al. 2020), vaccination of the workforce will  
20 provide a preventive, risk mitigation measure for manufacturing organisations (Farthing and Lanzas  
21 2021). Face mask detection technologies utilising ~~artificial intelligence or~~ machine learning methods are  
22 also under development, which may offer risk mitigation until the workforce is fully vaccinated and  
23 COVID-19 prevalence is at low levels (Loey et al. 2021).  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39

40  
41 As articulated ~~by He and Harris (2020) and~~ by Belhadi et al. (2021), the manufacturing firms are  
42 adapting their marketing, and relationship management practices with several countermeasures  
43 including diversification into new markets, switching to online marketing tools (such as customer  
44 interface websites, virtual marketplaces and applications), and continuing their essential interactions  
45 with their customers through online meetings. Okorie et al. (2020) highlighted the importance of  
46 organisational flexibility for achieving diversification, placing repurposing of products and  
47 reconfigurability of production plants as key parameters for manufacturing resilience. The reaction that  
48 was noted in the manufacturing organisations towards driving their costs down, and penetrating new  
49 markets is further being adopted by the European SMEs (Juergensen, Guimón, and Narula 2020).  
50 However, the diversification efforts should take into account the changing consumption patterns ~~(He~~  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

and Harris 2020), and social media may provide an avenue for determining the consumption trends and behaviour in the pandemic and post-pandemic period, as there is an observed increase in social media adoption (Kumar et al. 2020).

Resonating with several scholars (Belhadi et al. 2021; Gigauri 2020; Okorie et al. 2020; Kumar et al. 2020), major influences were noted on the human resources, mainly with regards to staff retention and loss of key skills due to closures and financial issues being observed as a key theme. Effectiveness and efficiency of staff were further impacted due to stress, uncertainty and anxiety caused by the pandemic along with adaptation issues to the new regulations, working practices and online tools, which were also noted by Belhadi et al. (2021), Kumar et al. (2020), Deshmukh and Haleem (2020) in the Indian region, Rapaccini et al. (2020) in the Italian region, and Gigauri (2020) in the Georgian region. Juergensen, Guimón, and Narula (2020) highlighted that the workforce requires formal training to readjust to their changing roles and the digitalised working systems such as the online marketing and ERP systems. Rapaccini et al. (2020) envisage permanent and significant changes in job roles, with increased remote collaborations and new employment terms.

~~With a view to~~ To clear employee anxiety, and to facilitate adaptation to the 'new normals' (Rapaccini et al. 2020), several manufacturing organisations are adopting regular management communication to employees at all levels, which is in line with Sanders et al. (2020)'s viewpoint, however, consistency is a key factor, as conflicting messages from the managers can do more harm than benefits. Sanders et al. (2020) further exemplified this as, managers should not direct employees towards prioritising their well-being and then later on in the week, stress the importance of achieving their objectives, which is likely to influence the workforce motivation negatively.

By evaluating the response strategies that we observed versus the extant manufacturing supply chain resilience strategies found in the literature, we have evidenced that manufacturing organisations have adopted a number of reactive response strategies. These included the (1) implementation of virtual marketplace practices for online engagement with customers; (2) reserve capacity and inventory deployment, including safety stocking of critical items; (3) supply chain collaboration to reduce supply chain impacts of the pandemic and outsourcing of lower risk processes; (4) lifeline maintenance through

1  
2  
3  
4  
5 the development of truck driver human resources and enabling of contactless deliveries, and (5)  
6  
7 implementation of real-time information systems such as a Cloud system for plant and supply chain  
8  
9 operations management decision-making. On the other hand, a tendency towards local suppliers, and  
10  
11 investments/development projects towards implementing and developing further digital connectivity of  
12  
13 the supply chain were identified as proactive resilience strategies. A prominent human resource focus  
14  
15 brought together by the COVID-19 pandemic to minimise its disruption through revised occupational  
16  
17 health and safety, human resource performance and retention practices can also be reflected as  
18  
19 countermeasures that may be associated with the social supply chain focus dimension as a proactive  
20  
21 supply chain resilience strategy.  
22

23  
24 According to Kumar et al. (2020), the increased lead times, parts shortages, logistics bottlenecks  
25  
26 experienced were anticipated impacts on the supply chains. There is an agreement in the literature that  
27  
28 supply chain coordination and collaboration will be key to resilience in the challenging times of the  
29  
30 COVID-19 pandemic, and any other unexpected contingencies or disasters (Juergensen, Guimón, and  
31  
32 Narula 2020; Belhadi et al. 2021; Kumar et al. 2020). Impacted from the travel restrictions and supply  
33  
34 shortages, necessary 'field interventions' by specialist contractors were not carried out and/or critical  
35  
36 spare supplies running at critical levels (Rapaccini et al. 2020), which are significant implications to  
37  
38 plant maintenance and servicing that are at the heart of manufacturing operations efficiency and  
39  
40 availability. Belhadi et al. (2021) proposed digital connectivity, localised sourcing, supply chain  
41  
42 simulation for decision making, and deployment of business continuity plans as key response strategies.  
43  
44

45  
46 Ultimately, as noted in this study, digital infrastructure and digital transformation are the current  
47  
48 hot topics as a resilience strategy for the manufacturing operations theory and practice, during the  
49  
50 pandemic and post-pandemic era. As articulated by Deshkmukh and Haleem (2020), a tighter coupling  
51  
52 between the cyber and the physical world is now a reality brought together by the COVID-19 pandemic.  
53  
54 Under the umbrella of Industry 4.0 (Khanna et al. 2020); key technologies such as big data analytics (Li  
55  
56 et al. 2020); internet of things (Belhadi et al. 2021); and intelligent manufacturing technologies such as  
57  
58 the digital twins (Ivanov and Dolgui 2020); are fruitful avenues for manufacturing supply chain  
59  
60 resilience. These innovative technologies, while reinforcing the deployment of COVID-19 transmission

prevention measures via. reducing or eliminating physical contact among stakeholders will support all aspects of manufacturing operations management including production planning and control, logistics, supply chain coordination and collaboration, marketing, stakeholder relationship management, human resource management, remote testing and maintenance, and other essential functions.

## 6. Conclusions

This research investigated the effects of the COVID-19 pandemic on the organisations and their operations, from the lens of the manufacturing sectors. Important and practical insights were developed from operations and managing directors of various manufacturing organisations, revealing the influence of the pandemic on their operations, the reasons behind these effects, and harnessing associated response strategies. The manufacturing organisations are striving to respond to the challenges posed, including revised health and safety practices and associated virus transmission risk-mitigating measures, isolation of employees from internal and external stakeholders where possible, digitalization and software application efforts, diversification strategies, alternative sourcing approaches, staff retention policies, and executing essential business interactions via online methods.

The theoretical contributions of this study include shedding light on our understanding of how the pandemic is impacting the operations of manufacturing organisations and why, along with its implications on the operations management practices. Furthermore, the practical implications of this research include fostering the industrial understanding of cause and effect relationships of various manufacturing operations management factors brought by the pandemic, capturing of the learnings, practical insights and the recovery strategies formulated in the various manufacturing sectors, and supporting the cross-industry benchmarking through sharing and dissemination of the best practices (Okorie et al. 2020; Kumar et al. 2020). It is hoped that the practitioners will benefit from these analyses and countermeasures, drawing upon the experiences of their peers and recognizing that this is a global issue that concerns and requires cooperation from all stakeholders, including employees, management, suppliers, customers, creditors, researchers and the governmental institutions (Dora and Kumar 2020).

The main limitation of this study can be reflected upon as all 10 contributing interviewees were from a specific, developing region (i.e. Northern Cyprus manufacturing industry). However, manufacturing and operations management are international disciplines, and all of the organisations that were observed during this study are part of the international manufacturing community with their employees, suppliers, customers, investors and other stakeholders. Further, similar and consistent observations were noted in similar studies (Juergensen, Guimón, and Narula 2020; Kumar et al. 2020; Rapaccini et al. 2020; Okorie et al. 2020), which demonstrates the applicability and validity of the findings of this study to a certain extent. On the other hand, studies in other regions with different demographics (e.g. developed regions) are suggested for enrichment and fortification of the findings of this study. Similarly, although a high number of manufacturing sectors were included in this study, the sectors that were not included may also prove fruitful for further investigation. Although such a methodological option was not feasible to us as we carried out our data collection during the early period of the pandemic, future studies could also be based on case studies or large surveys to conduct more extensive research.

~~Additionally,~~ This study was undertaken during the initial period of the pandemic, where the focus of the operation was more on the short-term and medium-term issues, and associated countermeasures, which has reflected in the results obtained. Future studies aiming to evidence the effectiveness of these countermeasures, and to formulate longer-term response strategies against the effects of the COVID-19 pandemic will be valuable as a future research direction. ~~Moreover,~~ The pandemic brought together major changes to the working conditions of employees at all levels, affecting many human resources parameters such as employee motivation, stress and anxiety, along with many employees switching to online and digitalised working methods with an immediate effect (Rapaccini et al. 2020). It will be an important future research avenue to further determine these complex influences, and facilitate the adaptation of the workforce to these rapidly evolving changes in job roles, and conditions.

Stemming from the evidence in this study that digitalisation and online interactions are at the forefront of our adaptation to the pandemic, further research on online communication tools and digital

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

---

operations management and intelligent manufacturing technologies such as the ~~i~~Internet of ~~T~~Things, ~~(Belhadi et al. 2021)~~; big data analytics, ~~(Li et al. 2020)~~; digital twins, ~~(Ivanov and Dolgui 2020)~~; are highly noteworthy avenues to support the organisations and our society in our fight against the pandemic ~~(Zimmerling and Chen 2021)~~.

**Funding:** This research received no external funding.

**Acknowledgements:** The valuable contributions of the industrial interviewee participants are sincerely acknowledged.

**Disclosure Statement:** The authors declare no conflict of interest.



## References

- Aday, Serpil, and Mehmet Seckin Aday. 2020. "Impact of COVID-19 on the Food Supply Chain." *Food Quality and Safety* 4 (4). Oxford University Press (OUP): 167–180. doi:10.1093/fqsafe/fyaa024.
- Anderson, Roy M., Hans Heesterbeek, Don Klinkenberg, and T. Déirdre Hollingsworth. 2020. "How Will Country-Based Mitigation Measures Influence the Course of the COVID-19 Epidemic?" *The Lancet*. Lancet Publishing Group. doi:10.1016/S0140-6736(20)30567-5.
- Bastas, Ali, and Kapila Liyanage. 2018a. "ISO 9001 and Supply Chain Integration Principles Based Sustainable Development: A Delphi Study." *Sustainability* 2018, Vol. 10, Page 4569 10 (12). Multidisciplinary Digital Publishing Institute: 4569. doi:10.3390/SU10124569.
- Bastas, Ali, and Kapila Liyanage. 2018b. "Sustainable Supply Chain Quality Management: A Systematic Review." *Journal of Cleaner Production* 181 (C): 726–744. doi:10.1016/j.jclepro.2018.01.110.
- Bastas, Ali, and Kapila Liyanage. 2019. "Setting a Framework for Organisational Sustainable Development." *Sustainable Production and Consumption* 20. Elsevier B.V.: 207–229. doi:10.1016/j.spc.2019.06.005.
- Belhadi, Amine, Sachin Kamble, Charbel Jose Chiappetta Jabbour, Angappa Gunasekaran, Nelson Oly Ndubisi, and Mani Venkatesh. 2021. "Manufacturing and Service Supply Chain Resilience to the COVID-19 Outbreak: Lessons Learned from the Automobile and Airline Industries." *Technological Forecasting and Social Change* 163 (May 2020). Elsevier Inc.: 120447. doi:10.1016/j.techfore.2020.120447.
- Bogner, Alexander, Beate Littig, and Wolfgang Menz. 2009. "Introduction: Expert Interviews — An Introduction to a New Methodological Debate." In *Interviewing Experts*, 1–13. Palgrave Macmillan UK. doi:10.1057/9780230244276\_1.
- Boyce, Carolyn, and P Neale. 2006. *Conducting In-Depth Interviews: A Guide for Designing and Conducting in-Depth Interviews for Evaluation Input, Monitoring and Evaluation*. Vol. 2. Pathfinder International.
- Castleberry, Ashley, and Amanda Nolen. 2018. "Thematic Analysis of Qualitative Research Data: Is It as Easy as It Sounds?" *Currents in Pharmacy Teaching and Learning* 10 (6). Elsevier: 807–815. doi:10.1016/j.cptl.2018.03.019.
- Chinazzi, Matteo, Jessica T. Davis, Marco Ajelli, Corrado Gioannini, Maria Litvinova, Stefano Merler, Ana Pastore y Piontti, et al. 2020. "The Effect of Travel Restrictions on the Spread of the 2019 Novel Coronavirus (COVID-19) Outbreak." *Science* 368 (6489). American Association for the Advancement of Science: 395–400. doi:10.1126/science.aba9757.
- Deshmukh, S. G., and Abid Haleem. 2020. "Framework for Manufacturing in Post-COVID-19 World Order: An Indian Perspective." *International Journal of Global Business and Competitiveness* 15 (1). Springer Singapore: 49–60. doi:10.1007/s42943-020-00009-1.
- Eikenberry, Steffen E., Marina Mancuso, Enahoro Iboi, Tin Phan, Keenan Eikenberry, Yang Kuang, Eric Kostelich,



- and Abba B. Gumel. 2020. "To Mask or Not to Mask: Modeling the Potential for Face Mask Use by the General Public to Curtail the COVID-19 Pandemic." *Infectious Disease Modelling* 5 (January). Elsevier: 293–308. doi:10.1016/J.IDM.2020.04.001.
- Farthing, Trevor S., and Cristina Lanzas. 2021. "When Can We Stop Wearing Masks? Agent-Based Modeling to Identify When Vaccine Coverage Makes Nonpharmaceutical Interventions for Reducing SARS-CoV-2 Infections Redundant in Indoor Gatherings." *MedRxiv*, April. Cold Spring Harbor Laboratory Preprints. doi:10.1101/2021.04.19.21255737.
- Galvin, Ray. 2015. "How Many Interviews Are Enough? Do Qualitative Interviews in Building Energy Consumption Research Produce Reliable Knowledge?" *Journal of Building Engineering* 1. Elsevier: 2–12. doi:10.1016/j.jobe.2014.12.001.
- Gates, Bill. 2020. "Responding to Covid-19 — A Once-in-a-Century Pandemic?" *New England Journal of Medicine* 382 (18). Massachusetts Medical Society: 1677–1679. doi:10.1056/nejmp2003762.
- Gigauri, Iza. 2020. "Influence of Covid-19 Crisis on Human Resource Management and Companies' Response: The Expert Study." *International Journal of Management Science and Business Administration* 6 (6): 15–24. doi:10.18775/ijmsba.1849-5664-5419.2014.66.1002.
- Haleem, Abid, Mohd Javaid, Raju Vaishya, and S. G. Deshmukh. 2020. "Areas of Academic Research with the Impact of COVID-19." *American Journal of Emergency Medicine*. W.B. Saunders. doi:10.1016/j.ajem.2020.04.022.
- Haraguchi, Nobuya, Charles Fang Chin Cheng, and Eveline Smeets. 2017. "The Importance of Manufacturing in Economic Development: Has This Changed?" *World Development* 93 (May). Elsevier Ltd: 293–315. doi:10.1016/j.worlddev.2016.12.013.
- Herrmann, Christoph, Christopher Schmidt, Denis Kurle, Stefan Blume, and Sebastian Thiede. 2014. "Sustainability in Manufacturing and Factories of the Future." *International Journal of Precision Engineering and Manufacturing - Green Technology* 1 (4). Korean Society for Precision Engineering: 283–292. doi:10.1007/s40684-014-0034-z.
- Ivanov, Dmitry, and Alexandre Dolgui. 2020. "A Digital Supply Chain Twin for Managing the Disruption Risks and Resilience in the Era of Industry 4.0." *Production Planning and Control*. Taylor and Francis Ltd. doi:10.1080/09537287.2020.1768450.
- Juergensen, Jill, José Guimón, and Rajneesh Narula. 2020. "European SMEs amidst the COVID-19 Crisis: Assessing Impact and Policy Responses." *Journal of Industrial and Business Economics* 47 (3): 499–510. doi:10.1007/s40812-020-00169-4.
- Kumar, Aalok, Sunil Luthra, Sachin Kumar Mangla, and Yiğit Kazançoğlu. 2020. "COVID-19 Impact on Sustainable Production and Operations Management." *Sustainable Operations and Computers* 1 (July): 1–7. doi:10.1016/j.susoc.2020.06.001.

- Li, Xingyu, Baicun Wang, Chao Liu, Theodor Freiheit, and Bogdan I. Epureanu. 2020. "Intelligent Manufacturing Systems in COVID-19 Pandemic and Beyond: Framework and Impact Assessment." *Chinese Journal of Mechanical Engineering (English Edition)* 33 (1). Springer: 1–5. doi:10.1186/s10033-020-00476-w.
- Loey, Mohamed, Gunasekaran Manogaran, Mohamed Hamed N. Taha, and Nour Eldeen M. Khalifa. 2021. "A Hybrid Deep Transfer Learning Model with Machine Learning Methods for Face Mask Detection in the Era of the COVID-19 Pandemic." *Measurement* 167 (January). Elsevier: 108288. doi:10.1016/J.MEASUREMENT.2020.108288.
- Metters, Richard. 1997. "Quantifying the Bullwhip Effect in Supply Chains." *Journal of Operations Management* 15 (2). Elsevier: 89–100. doi:10.1016/S0272-6963(96)00098-8.
- Mogaji, Emmanuel. 2020. "Financial Vulnerability During a Pandemic: Insights for Coronavirus Disease (COVID-19)." *SSRN Electronic Journal*, April. Elsevier BV. doi:10.2139/ssrn.3564702.
- Nicola, Maria, Zaid Alsafi, Catrin Sohrabi, Ahmed Kerwan, Ahmed Al-Jabir, Christos Iosifidis, Maliha Agha, and Riaz Agha. 2020. "The Socio-Economic Implications of the Coronavirus Pandemic (COVID-19): A Review." *International Journal of Surgery*. Elsevier Ltd. doi:10.1016/j.ijisu.2020.04.018.
- Okorie, Okechukwu, Ramesh Subramoniam, Fiona Charnley, John Patsavellas, David Widdifield, and Konstantinos Salonitis. 2020. "Manufacturing in the Time of COVID-19: An Assessment of Barriers and Enablers." *IEEE Engineering Management Review* 48 (3): 167–175. doi:10.1109/EMR.2020.3012112.
- Paul, Sanjoy Kumar, and Priyabrata Chowdhury. 2020. "A Production Recovery Plan in Manufacturing Supply Chains for a High-Demand Item during COVID-19." *International Journal of Physical Distribution and Logistics Management*, June. Emerald Group Publishing Ltd. doi:10.1108/IJPDLM-04-2020-0127.
- Petrosky-Nadeau, Nicolas, and Robert G. Valletta. 2020. "Unemployment Paths in a Pandemic Economy." *Federal Reserve Bank of San Francisco, Working Paper Series*, 01–20. doi:10.24148/wp2020-18.
- Rapaccini, Mario, Nicola Saccani, Christian Kowalkowski, Marco Paiola, and Federico Adrodegari. 2020. "Navigating Disruptive Crises through Service-Led Growth: The Impact of COVID-19 on Italian Manufacturing Firms." *Industrial Marketing Management* 88 (May). Elsevier: 225–237. doi:10.1016/j.indmarman.2020.05.017.
- Sanders, Karin, Phong T. Nguyen, Dave Bouckennooghe, Alannah Rafferty, and Gavin Schwarz. 2020. "Unraveling the What and How of Organizational Communication to Employees During COVID-19 Pandemic: Adopting an Attributional Lens." *The Journal of Applied Behavioral Science* 56 (3). SAGE Publications Inc.: 289–293. doi:10.1177/0021886320937026.
- Saunders, Mark N. K., Philip Lewis, and Adrian Thornhill. 2015. *Research Methods for Business Students (7th Ed)*. Pearson.
- Shen, Huayu, Mengyao Fu, Hongyu Pan, Zhongfu Yu, and Yongquan Chen. 2020. "The Impact of the COVID-19

- 1  
2  
3  
4  
5 Pandemic on Firm Performance.” *Emerging Markets Finance and Trade* 56 (10). Routledge: 2213–2230.  
6 doi:10.1080/1540496X.2020.1785863.  
7  
8 Slack, Nigel, Alistair Brandon-Jones, and Robert Johnston. 2016. *Operations Management*. 8th Editio. Pearson.  
9  
10  
11 Spsychalski, Piotr, Agata Błażyńska-Spsychalska, and Jarek Kobiela. 2020. “Estimating Case Fatality Rates of  
12 COVID-19.” *The Lancet Infectious Diseases*. Lancet Publishing Group. doi:10.1016/S1473-3099(20)30246-  
13 2.  
14  
15  
16 Statistics, U.S. Bureau of Labor. 2019. “Industries at a Glance: Manufacturing: NAICS 31-33.” *U.S. Depart of*  
17 *Labor Website*. <https://www.bls.gov/iag/tgs/iag31-33.htm>.  
18  
19  
20 Tukamuhabwa, Benjamin R., Mark Stevenson, Jerry Busby, and Marta Zorzini. 2015. “Supply Chain Resilience:  
21 Definition, Review and Theoretical Foundations for Further Study.” *International Journal of Production*  
22 *Research* 53 (18). Taylor & Francis: 5592–5623. doi:10.1080/00207543.2015.1037934.  
23  
24  
25 United Nations. 2020. “Infrastructure and Industrialization – United Nations Sustainable Development.”  
26 <https://www.un.org/sustainabledevelopment/infrastructure-industrialization/>.  
27  
28  
29 van Kasteren, Puck B., Bas van der Veer, Sharon van den Brink, Lisa Wijsman, Jørgen de Jonge, Annemarie van  
30 den Brandt, Richard Molenkamp, Chantal B.E.M. Reusken, and Adam Meijer. 2020. “Comparison of Seven  
31 Commercial RT-PCR Diagnostic Kits for COVID-19.” *Journal of Clinical Virology* 128 (July). Elsevier  
32 B.V.: 104412. doi:10.1016/j.jcv.2020.104412.  
33  
34  
35 Yu, Xingxia, and Rongrong Yang. 2020. “COVID-19 Transmission through Asymptomatic Carriers Is a Challenge  
36 to Containment.” *Influenza and Other Respiratory Viruses*. Blackwell Publishing Ltd. doi:10.1111/irv.12743.  
37  
38  
39 Zimmerling, Amanda, and Xiongbiao Chen. 2021. “Innovation and Possible Long-Term Impact Driven by  
40 COVID-19: Manufacturing, Personal Protective Equipment and Digital Technologies.” *Technology in*  
41 *Society* 65 (May). Elsevier Ltd: 101541. doi:10.1016/j.techsoc.2021.101541.  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60