

# THE 2022 WORLD MANUFACTURING

## REPORT

REDESIGNING SUPPLY CHAINS  
IN THE NEW ERA  
OF MANUFACTURING



WORLD  
MANUFACTURING  
FOUNDATION

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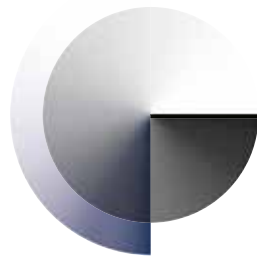
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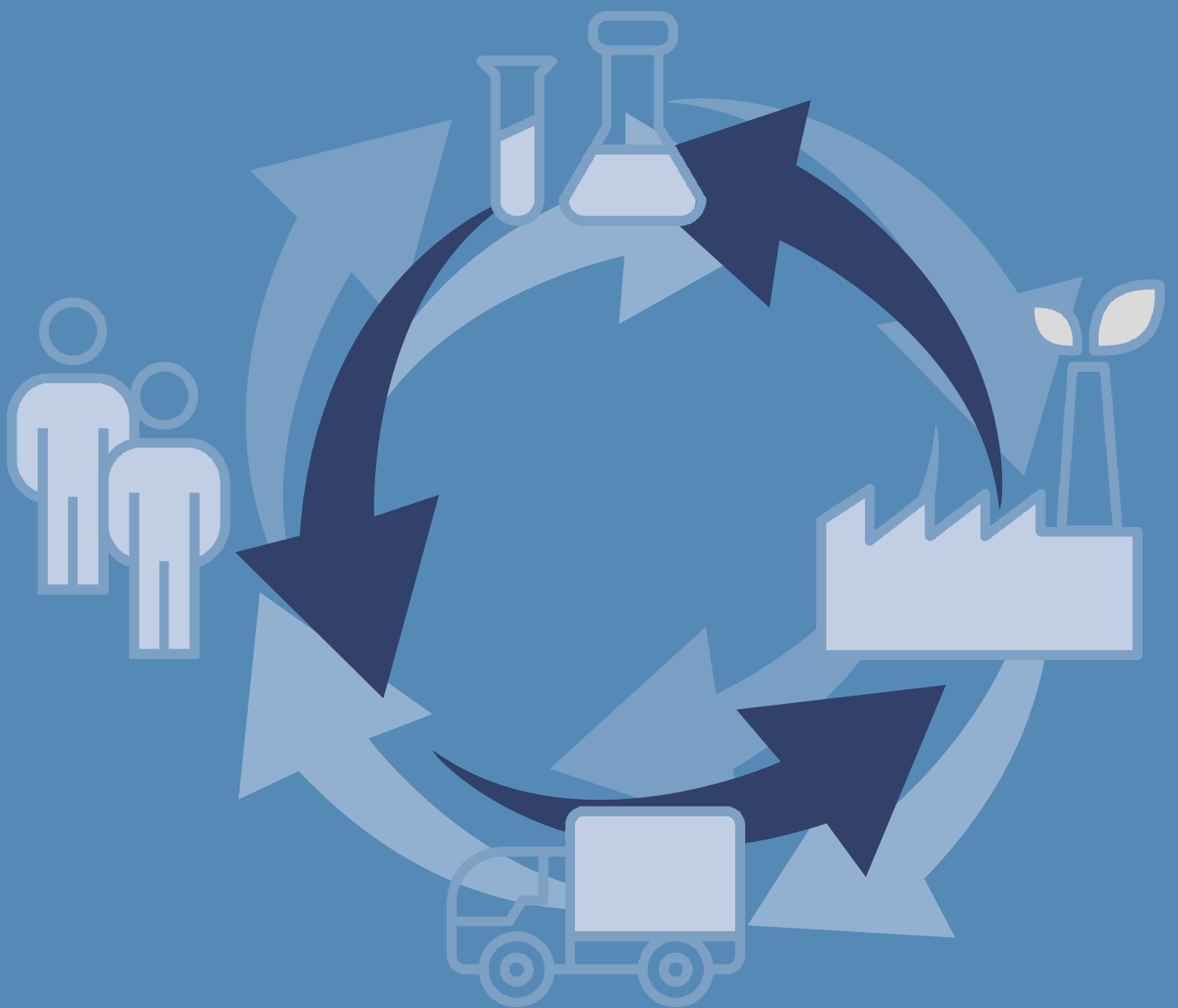
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**WORLD  
MANUFACTURING  
REPORT**

**2022**

**REDESIGNING SUPPLY  
CHAINS IN THE NEW ERA  
OF MANUFACTURING**



# Foreword

## Dear Readers,

With the mission to spread industrial culture worldwide, the World Manufacturing Foundation (WMF) organises several activities, among which the World Manufacturing Forum, where this Report is presented and discussed by the speakers from industry, policymakers, and academia. The WMF can be considered a dynamic platform where representatives of countries, organisations, and institutions can hold discussions, share their visions, initiatives and current actions addressing the evolving paradigms of manufacturing.

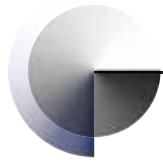
The Editorial Board of the World Manufacturing Report, composed of a selected group of experts, exploits its expertise and knowledge for the elaboration of the Report itself, which is also enriched by feedback and suggestions from the International Advisory Board. The yearly topic of the Report is aligned with that selected for the Forum. In this regard, the past reports are worth a mention. The first *World Manufacturing Forum Report: Recommendations for the Future of Manufacturing*, published in 2018, presented our vision for the future of manufacturing. The *2019 World Manufacturing Forum Report: Skills for the Future of Manufacturing* analysed the skills gaps phenomenon in the sector. The *2020 World Manufacturing Report: Manufacturing in the Age of Artificial Intelligence* provided insights into the successful and sound adoption of artificial intelligence in manufacturing. Last year, the *2021 World Manufacturing Report: Digitally Enabled Circular Manufacturing* highlighted the key potentialities of the technological advancements in undertaking a circular transition.

This year's edition will focus on *Redesigning of Supply Chains in the New Era of Manufacturing*, a highly relevant topic for the complex geopolitical situation that the global economy is experiencing. The Report first analyses the economic, social and political global megatrends from a high-level perspective; attention then focuses on the key implications of these megatrends on manufacturing companies and on their supply chains. Finally, the Report proposes the Ten Key Recommendations, developed with a global group of experts and addressing the manufacturing community and society at large, to suggest the undertaking of urgent actions to enhance the resilience of manufacturing companies and supply chains worldwide.

The World Manufacturing Foundation, through the World Manufacturing Report, commits to producing high-quality and non-partisan content on relevant themes and issues in manufacturing. I hope that this whitepaper will be useful for companies, for policymakers, for academia, and for society at large, to promote the redesigning of supply chains by valuing their key resources, among which the workforce, enhancing the potentialities of small and medium enterprises, and fostering the ecological transition relying on current technological advancement.

I thank the *2022 World Manufacturing Report Editorial Team and Advisory Board* for their valuable contribution.

Prof. Marco Taisch  
*Scientific Chairman, World Manufacturing Foundation*



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6 Executive Summary

---

7 Project Methodology

---

8 Chapter 1  
**Manufacturing in an Age of Disruption:  
Finding the Silver Linings in a  
Changing Global Landscape**

---

28 Chapter 2  
**Supply Chain Transformation  
towards Resilience and  
Innovative Value Creation**

---

60 Chapter 3  
**Vision for the Future of Manufacturing  
and Relevance to Supply Chains**

---

68 Chapter 4  
**Ten Key Recommendations by the  
World Manufacturing Foundation**

---

79 Conclusion

---

80 **Young Manufacturing Leaders**  
Case Studies

---

94 References

---

98 The World Manufacturing Foundation

---



# Executive Summary

The *2022 World Manufacturing Report: Redesigning Supply Chains in the New Era of Manufacturing* aims to provide the whole picture of the state of play of our society from the perspective of the manufacturing sector, considering the recent disruptive events. To address this purpose, the current global megatrends have first been explored, to then dig deeper in evaluating their implications for manufacturing companies and their value chains, finally delineating the trends of future manufacturing in this changed context. To conclude, key recommendations for policymakers, manufacturing companies and society at large are proposed, suggesting how to face this new era.

The manufacturing industry plays an essential role in the economy, contributing to economic growth (representing 17% of global gross domestic product), boosting demand in other sectors, providing employment opportunities (directly employing 13% of workers), and representing a considerable share of global trade. At the same time, economic and geopolitical factors can significantly impact manufacturing companies and their operations in both the short and long term. Understanding how emerging global trends will impact our lives and future generations is an important exercise for governments and businesses trying to boost their competitiveness and ensure their ability to respond to citizens' and consumers' needs.

Among the key megatrends characterising the new era, we can see the shift from globalisation, which started to rise in the 15th century, towards the so-called "slowbalisation", i.e. the slowdown in the process of global integration which has recently emerged. Globally soaring inflation levels and protectionist policies are also impacting manufacturers. At the same time, sustainability has become the new status quo and from a social perspective, consumers' habits and behaviours are evolving over time, while changes in the workforce have been registered in terms of skills needed, benefits, and working conditions. Therefore, given the multidimensional systems that supply chains are today, they are impacted in a variety of ways by the global ecosystem of which they are a part. The challenges and risks faced by today's manufacturing supply chains are manifold and diverse. Not all are new or unexpected; however, the rapid succession of significant disruptions within a short period of time is unprecedented in recent history.

The future-oriented model of manufacturing relies on the new industrial vision formed by a multidirectional focus to reinforce sustainable growth and increase global societal wealth as developed and presented in the *2018 WMF Report*. This vision has been enriched by information that was gathered from scientific and grey literature, combined with input from a panel of worldwide experts, among whom leading representatives from manufacturing firms, prestigious institutions, and both governmental and non-governmental organisations. As a result, the following six disruptive trends for the future of manufacturing are presented in this Report, underlining the immense opportunities in the transformation of manufacturing, which are: cognitive manufacturing, circular manufacturing, global risks-resilient manufacturing, hyper-personalised manufacturing, rapidly responsive manufacturing, and inclusive manufacturing. These trends are likely to play out simultaneously and not alternatively.

Finally, ten key recommendations are proposed, addressing policymakers, manufacturers and society at large, with the intention of suggesting actions and behaviours to be undertaken in order to face, and in the future anticipate, disruptive events. Among them, it is suggested that iterative and continuous improvement in the redesigning of supply chains be adopted, that products be created for an agile redesign of supply chains, and that Small and Medium Enterprises be supported by including them in the redesigning of supply chains, leveraging on their capabilities and addressing their needs.



# Project Methodology

The *World Manufacturing Report* is a yearly whitepaper discussing key trends in the manufacturing sector and this year, the focus has been directed towards the disruptive events which have impacted on this sector as well as on society as a whole.

The *World Manufacturing Report* was developed by an *Editorial Team* which is heterogeneous in terms of gender and country, and which was supported by an *Advisory Board* composed of members of universities and organisations from more than ten countries. The Report was built upon both scientific and grey literature through an extensive review of the state of the art. This process led to the analysis of the global megatrends and the key implications of these trends on manufacturing companies and their supply chains. In addition to that, specific case studies were also reported to highlight the key changes and outcomes of disruptive events.

Scientific publications, policy magazines and the other written sources were complemented by a series of interviews with experts. The experts involved are representatives of manufacturing firms, of prestigious institutions and universities and of both governmental and non-governmental organisations. In light of their personal background and expertise, during the interviews the experts were asked to provide their personal views on the main topics addressed in the Report. These interviews were therefore also fundamental for the delineation of the ten key recommendations.

Finally, the *World Manufacturing Report*, as previously, in 2020 and 2021, includes a set of case studies written by the *Young Manufacturing Leaders*, which were selected as winners from among the participants in the call. The *Young Manufacturing Leaders* initiative, co-funded by the European Union under the EIT Manufacturing Initiative, is a global network of students and young workers interested in a career in the manufacturing sector. In relation to the *World Manufacturing Report*, the *Young Manufacturing Leaders* Network issued an Open Call for case studies that highlight the redesign of supply chains in the new era.

# **Manufacturing in an Age of Disruption: Finding the Silver Linings in a Changing Global Landscape**

# Manufacturing in an Age of Disruption: Finding the Silver Linings in a Changing Global Landscape

Over the last few years, black swan events have become the norm. From the COVID-19 pandemic and the war in Ukraine to increasingly frequent extreme weather events, these external shocks have jeopardised the global economy and contributed to the acceleration of global trends already visible in society and shaping our future.

Although the manufacturing industry has shown incredible resilience and is now building back quickly, to maintain momentum, manufacturers need to accelerate the pace of industrial transformation and design supply chains fit for an age of economic, geopolitical, and societal disruptions.

This chapter contributes to the discussion by underscoring the centrality of manufacturing and the interconnections underpinning it in our daily lives, taking stock of the state of the global economy and its short-term prospects in light of the most recent headwinds and describing emerging global trends that are likely to shape the economy and society moving forward. Far from being exhaustive, the silver linings highlighted in the last section of the chapter are meant to invite manufacturers and supply chain managers to move past current challenges and focus on the opportunities identified in the forward-looking, visionary part of the report (Chapters 2, 3 and 4).

## Nothing Happens without Manufacturing

**Recent supply chain disruptions have made apparent that our way of life and economies depend on the health of the whole manufacturing ecosystem.**

Nothing happens without manufacturing. This is one key lesson from the ongoing COVID-19 pandemic and other geopolitical shocks playing havoc with supply chains. While it was easy for consumers to take manufacturing for granted when they were able to get any product they wanted when they wanted it, the shortage of personal protective equipment in the early stages of the pandemic – or the humorous case of the missing toilet paper – acted as a potent reminder that we depend on manufacturing to carry out even the most mundane tasks.

Manufacturing is also essential to governments for achieving public policy objectives, from preserving public health to ensuring national security. Pharma manufacturers were – and still are – at the forefront of the fight against COVID-19, developing test kits, new vaccines, and treatments and quickly scaling up production to meet urgent and unprecedented demand. And countries' ability to ramp up arms production in times of conflict is now a strategic concern<sup>1</sup> and a factor capable of determining the outcome of the war in Ukraine<sup>2</sup>.

Manufacturing is not only a key enabler of statehood of our

way of life, but also the backbone of the economy. Without manufacturing:

- **Our economies would grow at a slower pace.** Manufacturing value added represents 17.0% of the global gross domestic product (GDP)<sup>3</sup>. Furthermore, the sector turbocharges the economy by spurring demand in related industries (e.g. retail, warehousing), providing the equipment needed for running their operations (e.g. airline, telecommunications), and enabling technological progress. According to estimates made using US data, every \$1.00 spent in manufacturing adds another \$2.68 to the economy<sup>4</sup>.
- **There would be fewer – and lower-paying – jobs.** The manufacturing sector directly employs 13.6% of workers, ranging from 6.2% in low-income countries to 16.9% in upper-middle-income countries<sup>5</sup>. Empirical research and anecdotal evidence show that these jobs tend to provide a higher wage, especially for low-wage workers. For example, a recent study on US workers by the Brookings Institute found that “workers at all wage levels, men and women, and those in all racial/ethnic, educational attainment, and occupational groups earned more in manufacturing than in other industries.”<sup>6</sup> The same study also suggests that low-wage workers benefit highly from manufacturing jobs. This becomes particularly relevant as, according to the Global

Wage report 2020-2021, minimum wage salaries have the potential to reduce relative poverty.

- **There would be less innovation.** In an era where there is a race for competitiveness, companies must accelerate their efforts to stay afloat. The manufacturing industry represents a segment in which significant investments are made to integrate new technologies and develop new, better, and smarter products. As such, manufacturing is the primary source of commercial innovation and is essential for innovation in the service sector. In the USA, the leading country for R&D spending<sup>7</sup>, manufacturing accounts for about three-fifths of private-sector R&D spending<sup>8</sup> and 55% of patents<sup>9</sup>. Notably, the three main manufacturing regions – i.e. the United States, Europe, and East Asia – are also making the most significant investments in Industry 4.0 technologies, thereby raising their long-term leadership prospects<sup>10</sup>.

- **Countries would have a higher trade deficit.** According to the World Trade Organization (WTO), trade in manufactured goods represented 71% of world merchandise exports in 2020, equal to US\$12.1 trillion

out of a total of US\$17 trillion<sup>11</sup>. With trade in goods representing the lion's share of global trade, countries that do not export manufactured goods and rely on trade in services, natural resources, and agricultural products have difficulty achieving a trade surplus and reducing their indebtedness to other nations.

While this data makes it apparent how essential individual manufacturing companies' economic, environmental, and social health is for the world's functioning, there is an element of interconnection that is equally crucial and should not be ignored. For example, the absence of well-thought-out contingency plans due to a lack of synchronisation between managerial and technological fluency among firms during the pandemic led manufacturing companies to have a firefighting approach to problems such as material shortages stopping everything, from the production of computers to home renovation supplies, and even caused many companies to shut down their operations altogether. In an era where has become the new normal, manufacturing firms must be able to collaborate and form connections that cannot be easily disrupted.

# Manufacturing Tested by Geopolitical Disruptions

As observed, the manufacturing industry plays an essential role in the economy and society, contributing to economic growth, boosting demand in other sectors, providing employment opportunities, and representing a considerable share of global trade. But today, the COVID-19 pandemic, Russia's war in Ukraine, the increased frequency of extreme weather events, and their second-round effects are posing new threats to the sector.

An important exercise for governments and businesses trying to respond to emerging challenges and ensure their ability to meet people's evolving needs and aspirations is understanding how the current geopolitical shocks are impacting the economy in the short run and shaping trends already visible in our society.

## Global Economic Outlook

**Old and emerging threats are casting a shadow over the economic recovery.**

Almost three years since the onset of the COVID-19 pandemic, Russia's invasion of Ukraine and prolonged shutdowns in China due to its zero-COVID policy are

weighing on the global economy, **dampening its growth prospects and increasing uncertainty.**

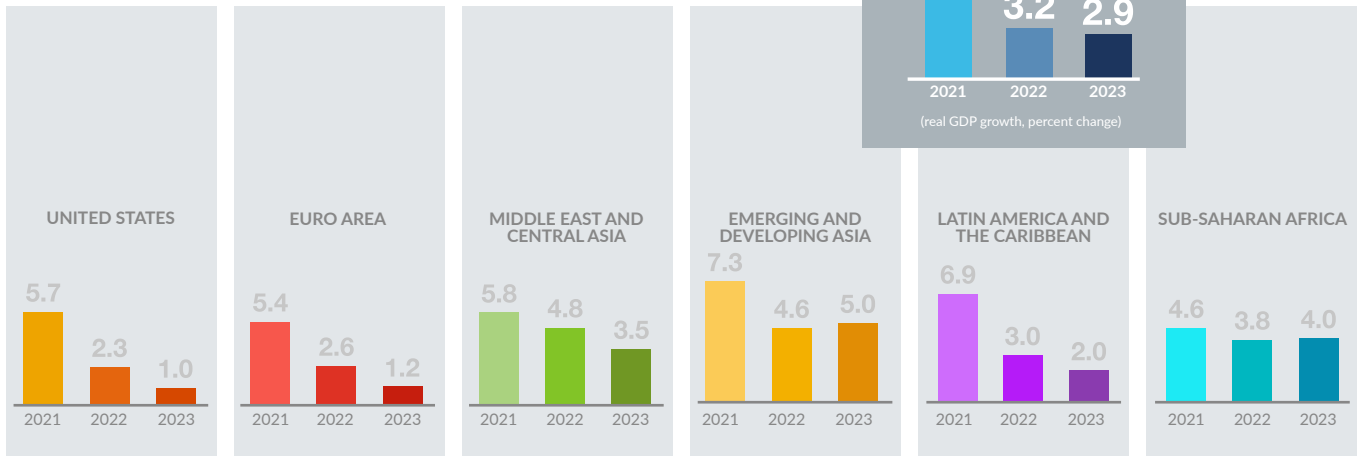
**Global economic growth is slowing...**

**Global economic growth** contracted in the year's second quarter and is expected to slow from 6.1% in 2021 to 3.2% in 2022, with no rebound projected in 2023<sup>12</sup>. Although slower growth is projected in almost all countries Europe and Central Asia are projected to be hit the hardest, as the Ukraine war's repercussions are felt through commodity and financial markets, trade and migration flows, and business and consumer confidence<sup>13</sup>. (Figure 1).

Figure 1

## Real GDP growth by region (percentage change)

(Sources: IMF, World Economic Outlook Update, July 2022)



### ... and inflation is rising, fuelling stagflation fears.

At the same time, **inflation** has reached new highs, tightening financial conditions, eroding real disposable income, and raising costs for enterprises. Inflation expectations have also risen further in both advanced economies (AEs) and emerging market and developing economies (EMDEs) due to surging food and energy prices, lingering supply bottlenecks, and tight labour markets in AEs (Figure 2).

Figure 2

## Longer-term inflation expectations

(Sources: IMF, World Economic Outlook Update, July 2022.)

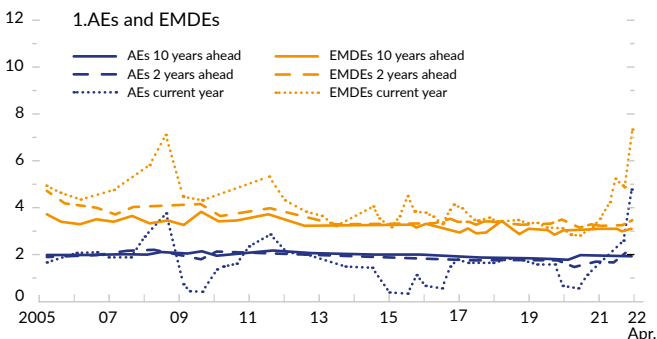
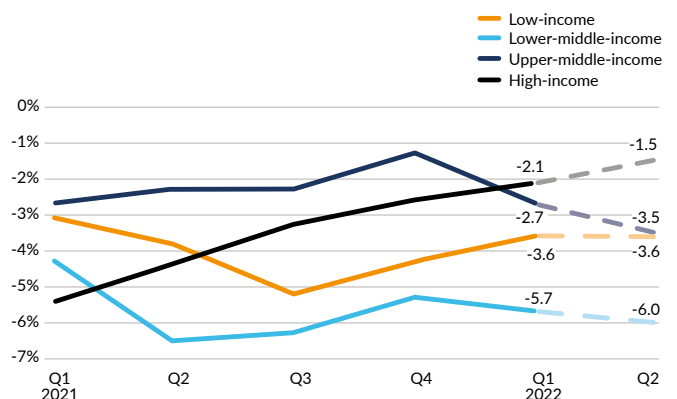


Figure 3

## Change in global hours worked relative to 2019 Q4, by country income group (percentage)

(Sources: ILO Monitor on the world of work, Ninth Edition)



### Global labour market recovery is equally at risk, disproportionately affecting poorer economies and women.

The multiple threats endangering economic growth and causing inflationary pressure are also putting the **global labour market** recovery at risk and widening existing inequalities between and within countries<sup>14</sup>. While high-income economies are experiencing a steady recovery in hours worked compared to pre-crisis levels, upper-middle-income, low-income, and lower-middle-income economies are still far from reaching their pre-crisis benchmarks with a 2.7, 3.6, and 5.7% gap respectively when compared to the fourth quarter of 2019. Furthermore, these diverging trends are likely to worsen (Figure 3)<sup>15</sup>.

Consistent with these diverging trends in hours worked, advanced economies are also experiencing a strong rebound in employment. In contrast, middle-income and low-income countries are still dealing with a considerable pool of unemployed and underutilised labour. Notably, employment recovery has generally been faster for men than women, increasing the gender employment gap.

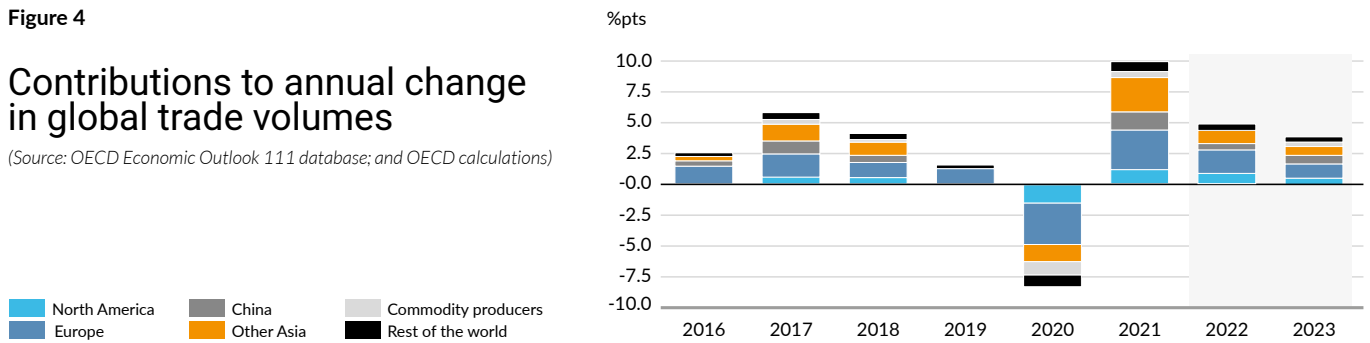
**Further clouding the economic outlook is the expected deceleration of world trade.**

Making things worse, **global trade volumes** are projected to moderate, decreasing from 10% in 2021 to about 5% in 2022 and 4% in 2023 (Figure 4)<sup>16</sup>. As stressed by the OECD, key factors underpinning this slowdown include supply chain disruptions amid new COVID-19 shutdowns affecting major Asian ports, weaker demand in Europe as a result of the war in Ukraine, and US consumers' shift in spending from goods back to services<sup>17</sup>.

**Figure 4**

**Contributions to annual change in global trade volumes**

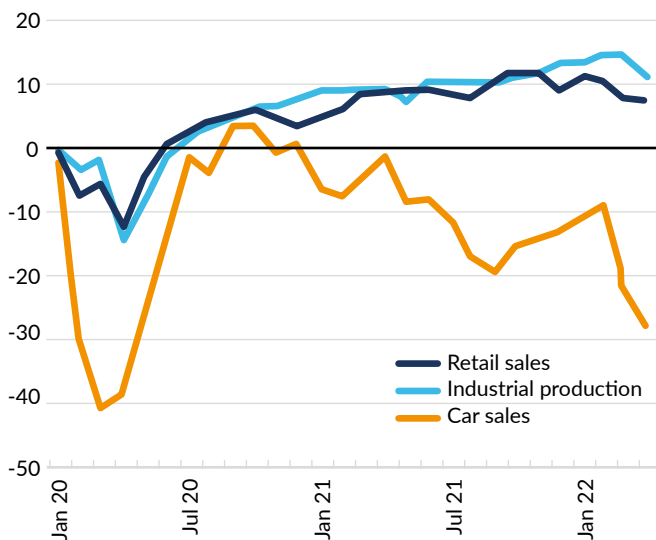
(Source: OECD Economic Outlook 111 database; and OECD calculations)



**Figure 5**

**Global activity indicators (percent change from same month in 2019)**

(Sources: OECD Economic Outlook, Volume 2022 Issue 1)



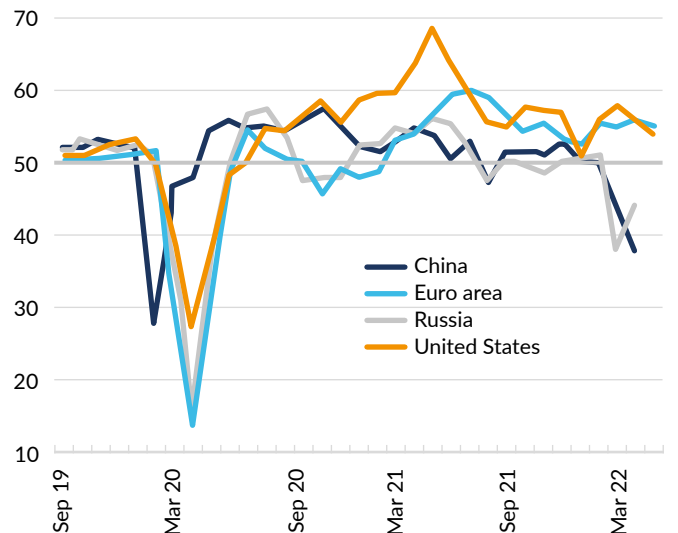
**Inevitably, the war in Ukraine and COVID-related restrictions are also taking a toll on business activity and confidence.**

Ukraine's conflict and COVID-related restrictions also weigh on business activity and confidence. **Global industrial production, retail sales, and car sales all declined** in March and April (Figure 5), and business confidence and output indicators have worsened, albeit with significant country differences (Figure 6).

**Figure 6**

**Composite output PMI**

(Sources: OECD Economic Outlook, Volume 2022 Issue 1)



Consumer confidence indicators – which measure consumers’ confidence in the state of the economy and their own financial stability – are experiencing a similar trend (Figure 7)<sup>18</sup>, probably due to a squeeze in real household disposable income and increased uncertainty<sup>19</sup>.

Figure 7

### Consumer confidence (OECD standardised indicator, long-run average = 100)

(Sources: OECD Economic Outlook, Volume 2022 Issue 1)

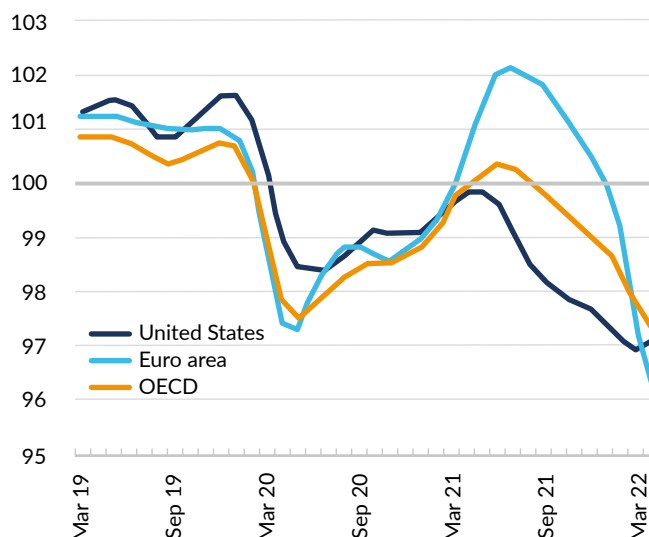
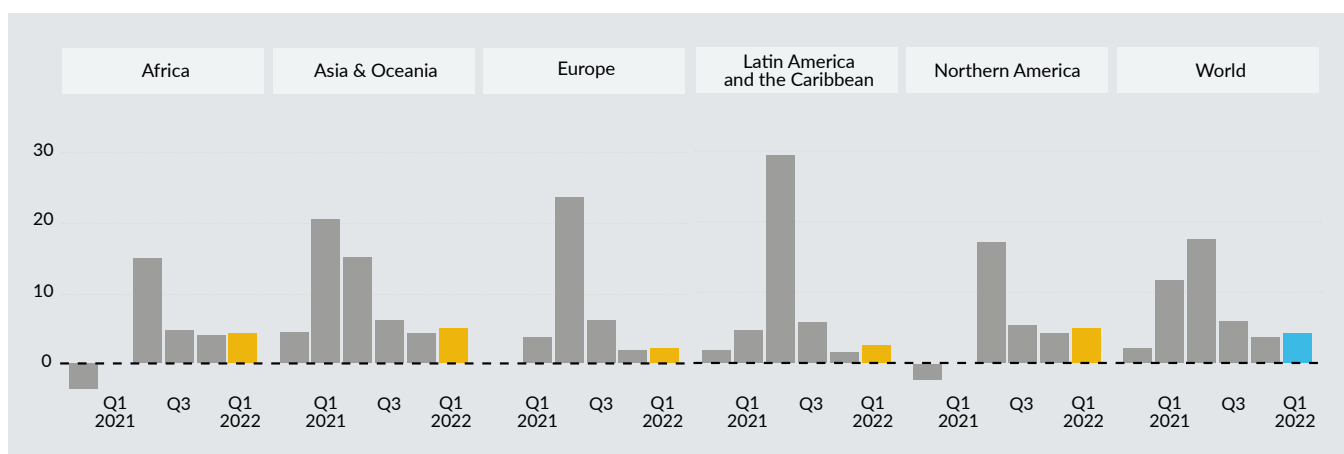


Figure 8

### Year-over-year growth rates of regional manufacturing output

(Source: UNIDO World Manufacturing Production, Quarter I 2022)



**Yet, the manufacturing sector is showing incredible resilience despite regional and sectoral differences.**

Despite a worsening outlook, the latest data provided by The United Nations Industrial Development Organization (UNIDO) confirm the **resilience of the manufacturing sector**.

Global manufacturing production registered year-on-year output growth of 4.2% in the first quarter of 2022,

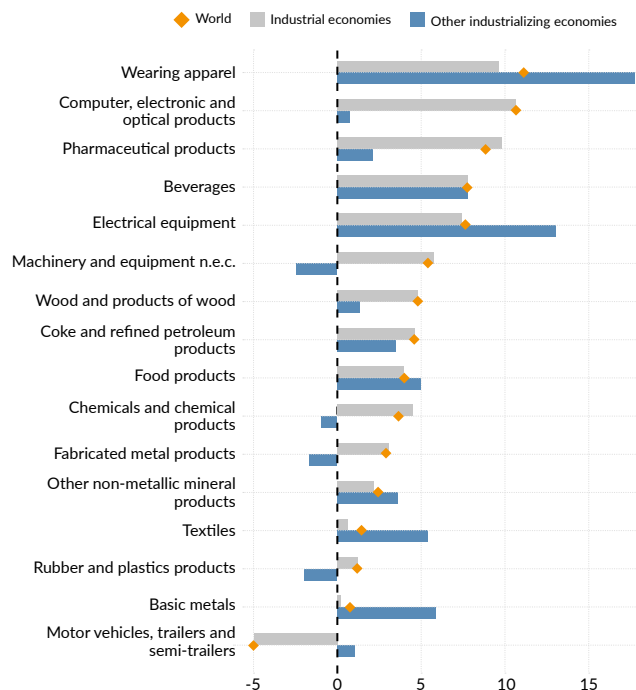
following an increase of 3.3%, 5.8%, and 17.8% in the previous three quarters. Thanks to the United States and China’s dynamism, Northern America and Asia & Oceania were the best performers, showing stable growth rates of more than 5% and 4.8%, respectively. In Europe and Latin America, manufacturing output growth stabilised at around 2% after registering a sharp rebound in the second quarter of 2021, whereas limited data on African manufacturing production indicate year-on-year growth of 4.2% (Figure 8)<sup>20</sup>.

Disaggregated data by sector provide additional insights. While the production of motor vehicles in industrialised economies is still hampered by supply chain disruptions and the production of machinery, chemicals, and fabricated metals in industrialising economies continues to register losses, the production of wearing apparel, computer, electronic and optical products, pharmaceutical products, beverages, and electronic equipment is experiencing strong growth in both industrial and other industrialising economies (Figure 9) <sup>21</sup>.

Figure 9

## Growth rates by industry in percentage change compared to previous year, Quarter I 2022

(Source: UNIDO World Manufacturing Production, Quarter I 2022)



Nonetheless, new developments in the pandemic, the economic toll of the war in Ukraine, policy failures, and other external shocks may worsen the economic outlook, jeopardising manufacturing growth.

Although UNIDO projects world manufacturing value added to grow by 3.9% in 2022 after a 7.2% rebound in 2021 from COVID-19<sup>22</sup>, risks are on the downside. In particular, new developments in the pandemic, an escalation in the war in Ukraine and surging energy prices, monetary policy failures, tighter financial conditions, and other external shocks, such as trade wars and extreme weather events, may further worsen the economic outlook, jeopardising manufacturing growth.

## Global Trends Shaping the Economy and Society

Weathering the short-term economic effects of geopolitical shocks is the first line of defence for governments and companies trying to survive the storm. However, assessing these shocks' long-term political and societal implications is equally important for ensuring continued relevance.

To help policymakers and manufacturers build awareness and navigate uncharted waters, this section provides an overview of emerging global trends that are likely to shape the economy and society and their long-term implications:

the end of hyperglobalisation; rising protectionism; the emergence of a new global order; the increasing relevance of climate change and sustainability; the emergence of new consumer needs; and profound changes in the workforce supply and demand.

### The End of Hyperglobalisation

**Over the last fifteen years, world economic integration has been faltering. While the global financial crisis triggered the process, the rise of nationalist politics and the COVID-19 pandemic have consolidated it.**

Since the global financial crisis of 2008-2009, the hyperglobalisation of the post-Cold War era has been receding, compounded by the rise of nationalist politics and prevention measures put in place by governments to respond to the COVID-19 pandemic.

World trade has fallen from about 60% of global GDP to 52% in 2020 (Figure 10). At the same time, exports of goods and services as a share of GDP have remained roughly constant after two decades of steady growth (Figure 11). The slowdown in trade integration was equally visible in the realm of trade governance, where the stockpile of import restrictions in force has grown steadily since 2009, both in value terms and as a percentage of world imports (WTO, 2022)<sup>23</sup>.



Figure 10

## World trade (% of GDP)

(Source: World Bank national accounts data, and OECD National Accounts data files.)

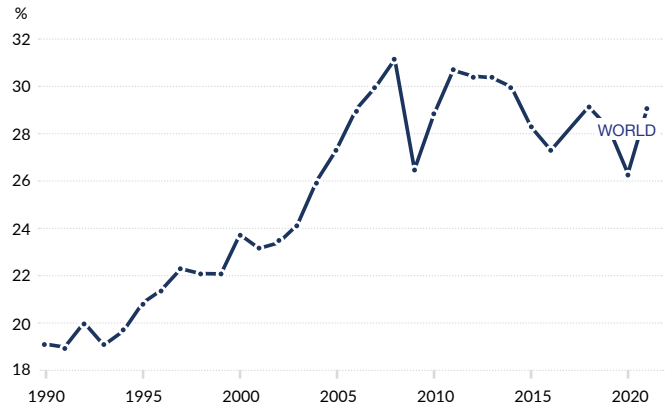
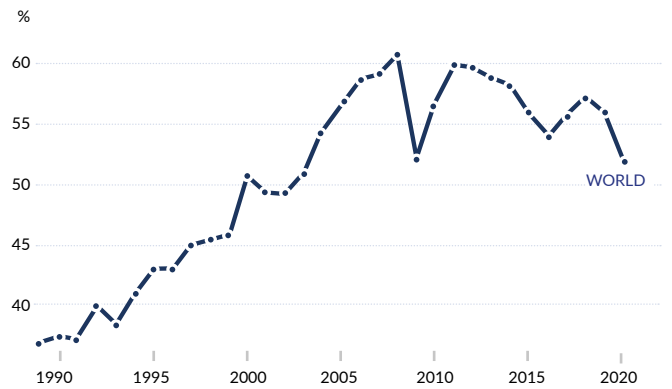


Figure 11

## Exports of goods and services (% of GDP)

(Source: World Bank national accounts data, and OECD National Accounts data files.)



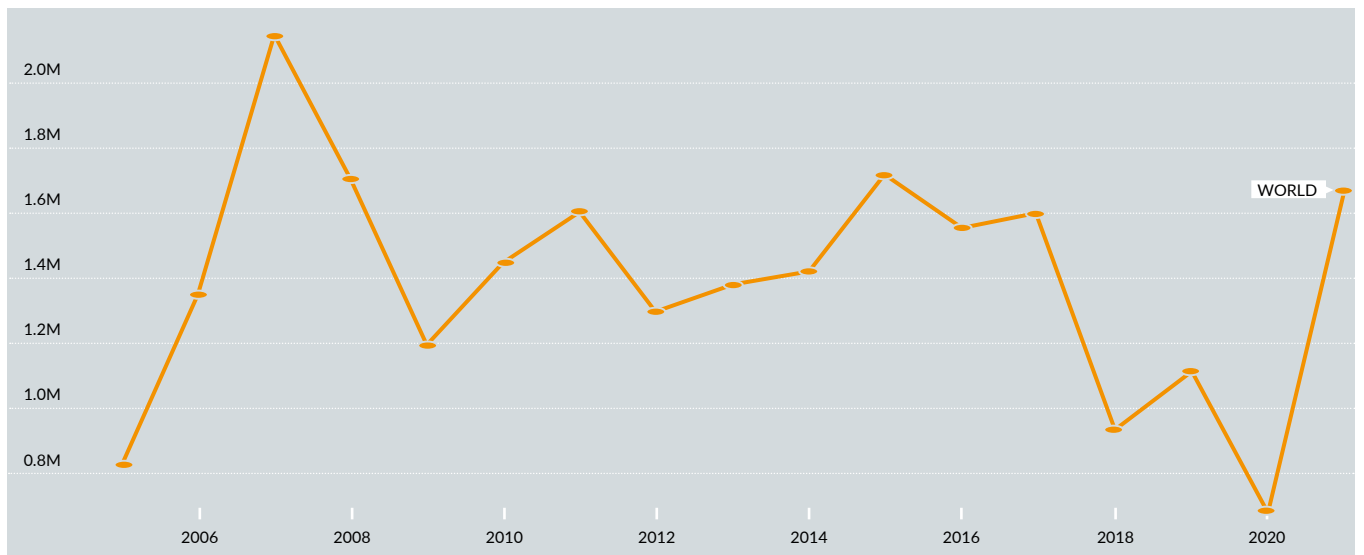
The sudden shocks experienced since 2008 have also hurt global financial linkages. While the latest measures of financial integration point to a recovery, this data also suggests that the pace of financial integration is unlikely to go back to its pre-crisis level, at least in the short term. For example, foreign direct investment (FDI) flows – a commonly used measure of financial integration which records the value of cross-border transactions related to direct investment during a given period –<sup>24</sup> are still below

their 2008 peak (Figure 12)<sup>25</sup>, despite a strong rebound from the dramatic fall in 2020 caused by the pandemic.

Figure 12

## FDI flows

(Source: Benchmark definition, 4th edition (BMD4): Foreign direct investment: financial flows, main aggregates)



The recent ballooning of cross-border capital flows – another common measure of financial globalisation that comprises FDIs, portfolio investment in debt and equity securities, and cross-border lending by banks – also provides mixed evidence. While cross-border capital flows have now exceeded the level which existed before the Lehman Brothers’ collapse, the trend is driven by a huge increase in market-based finance rather than a strong pickup in FDIs or bank loans (The Economist, 2022)<sup>26</sup>. With foreign investors, especially staid institutions (e.g. insurance companies, pension funds, etc), often underestimating the riskiness of their investments, these new financial interlinkages may threaten global financial stability (The Economist, 2022) more than they further its integration.

### **Most recently, the slowdown in globalisation patterns has also extended to information and people flows.**

The slowdown in globalisation patterns was not limited to commerce and financial integration but also extended to the movement of information and people.

According to a recent report by DHL and the New York University Stern School of Business, “data on internet traffic, voice calls, scientific collaboration, and payments for the use of intellectual property all suggest that the major upswing in the globalisation of information flows has slowed in recent years,” despite a temporary surge in digital information flows as personal interactions went online to curb the spread of COVID-19<sup>27</sup>. At the same time, the pandemic had a disruptive impact on the international flow of people. But while international travel fell sharply in 2020 due to travel restrictions implemented to curb the spread of COVID-19, the growth of international migration only slowed. In addition, the deceleration in student mobility which started in 2019 appears to have continued in 2020, although the full impact of the pandemic remains uncertain<sup>28</sup>.

### **These developments do not support current deglobalisation claims but provide evidence of a “slowbalisation.”**

The developments in trade, capital, information, and people flows described so far point to a “slowbalisation” – i.e. a slowdown in the process of global integration – rather than providing evidence of a reverse in the integration process. Furthermore, they show the resilience of global interconnectedness in the face of major shocks.

### **With the future of globalisation in the balance, some factors are going to play a key role, posing both threats and opportunities: the role of data-driven technologies, the need for international cooperation in the face of global challenges, the push towards regionalisation, and**

### **how the poorest countries are going to be integrated into the redrawing of global trade maps.**

While it is premature to assess where globalisation is heading, with pundits having made different assumptions – from the end of globalisation to the bifurcation into two economic blocks, one aligned with the USA and the other with China –, <sup>29</sup> there are some additional factors to consider when thinking about the future of globalisation.

First, receding waves in the process of globalisation that started with the Age of Discovery in the 15th century are not a new phenomenon. This assumption has led the World Economic Forum (WEF) and others to preconise a new wave of globalisation dominated by the USA and China, enabled by data-driven technologies and centred around sustainability – what the WEF calls Globalisation 4.0<sup>30</sup>. Second, the global financial crisis and the COVID-19 pandemic exposed the risk of interconnectedness but also emphasised the need for more international cooperation. Although not discussed in this section, similar considerations apply to other external shocks with global implications, such as extreme weather events triggered by climate change. Third, as global interlinkages wither away, China, the USA, and the European Union are trying to strengthen regional links via trade deals, regulatory action, and direct investments. Finally, some of the world’s poorest countries – especially in Africa and South America – are falling behind in the globalisation recovery, with trade and FDI flows still below their pre-pandemic levels<sup>31</sup>, and they are at risk of being once again excluded from the redrawing of international trading maps.

The hyperglobalisation wave that’s behind us has brought incredible benefits in terms of economic growth, innovation, and efficiency but it also created winners and losers. Moving forward, the new globalisation patterns that replace it can also be an opportunity to rethink how the benefits that come with global economic integration are redistributed.

## **Rising Protectionism**

### **The rise of protectionism dates back to the global financial crisis when the backlash against globalisation brought the re-emergence of nationalist politics.**

Protectionism is on the rise. Although trade tensions came into focus with the COVID-19 pandemic when governments started implementing a protectionist agenda in support of critical supply chains, the rise of nationalist politics can be dated back to the global financial crisis. At that point, the public backlash against neoliberal globalisation and its distributional consequences led some politicians to embrace nationalist politics, with substantial implications for international trade and multilateralism.

This new political vision was well summarised years later by former US President Donald Trump when he argued in front of the United Nations General Assembly that “The future does not belong to the globalists. The future belongs to the patriots.”<sup>32</sup>

**Since 2009, world governments have implemented almost 8,000 interventions to discriminate against foreign commercial interests. Among them the “buy American” clause, EU countries’ bail-out measures in support of their automotive industries, and new import licensing systems in Argentina and India.**

Examples of nationalist trade measures adopted in the aftermath of the global financial crisis included the “buy American” clause in the Recovery and Reinvestment Act of 2009 to encourage the purchase of domestic products; bail-out measures implemented by European countries such as Germany, France, and the United Kingdom to support their automotive industries; the new import licensing systems introduced in Argentina, India, and Indonesia; and higher tariffs in Ecuador, Russia, and

Ukraine on imported products, including automobiles, electrical goods, iron and steel, and machinery.<sup>33</sup>

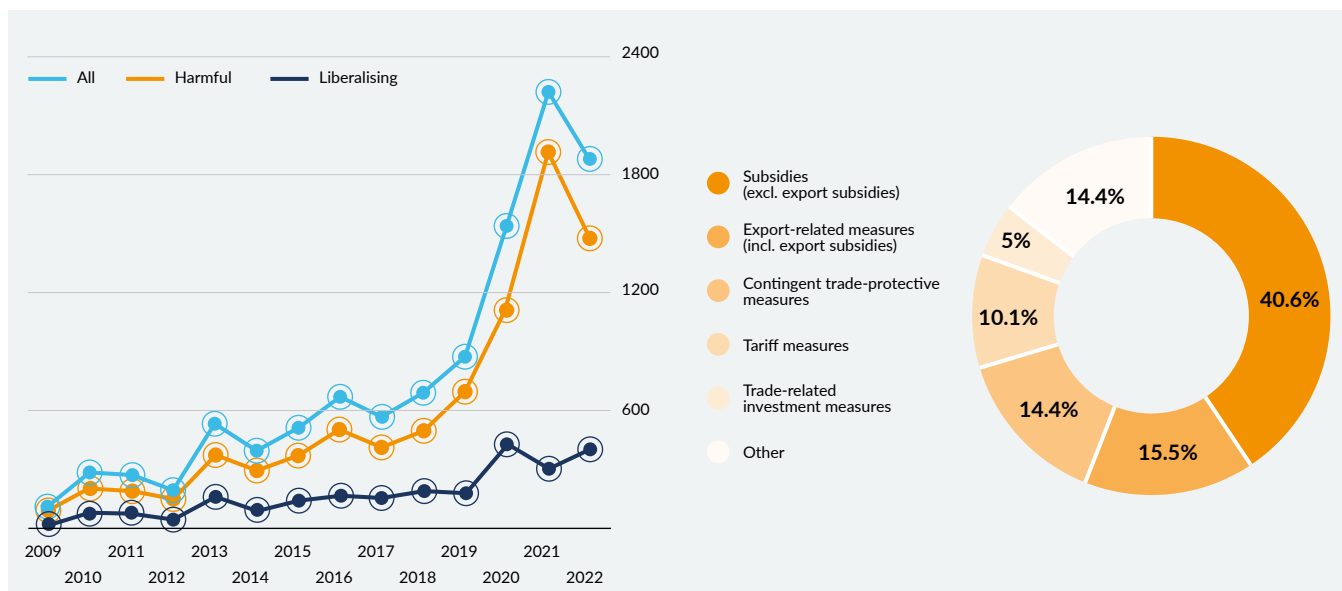
Although far removed from the onset of the crisis, the collapse of the Transatlantic Trade and Investment Partnership (TTIP), the Trump administration’s withdrawal from the Paris Agreement and attacks on the WTO and NATO, the US-China trade conflict, the renegotiation of NAFTA to reduce the US trade deficit and bring back manufacturing jobs,<sup>34</sup> increased trade barriers between the US and the EU, as well as Brexit, were also among the consequences of this new political zeitgeist.

Data from the Global Trade Alert database show that since 2009, world governments have implemented at least 7,899 interventions to discriminate against foreign commercial interests. More than half have been adopted since the onset of the COVID-19 pandemic. Of these, 40.6% were subsidies, 15.5% export-related measures, 14.4% contingent trade-protective measures, and about 10% and 5% tariffs and trade-related investment measures, respectively (Figure 13).<sup>35</sup>

**Figure 13**

### New harmful trade interventions per year and policy instruments uses

(Source: Global Trade Alert database)



China has been the main target of protectionist measures due to its dominance in strategic sectors, continued supply chain disruptions, and underlying political tensions that heightened the risks of dependence on Chinese suppliers. While the USA was the most active jurisdiction, followed by India, Russia, and the EU, China was the most affected country, with major EU economies (e.g. Italy, Germany, and France) and the USA immediately behind (Figure 14).

The rationale for China being the main target of protectionist measures is straightforward: the country enjoys a dominant position in strategic sectors such as semiconductors and the supply of all 16 strategically critical rare-earth metals, which are necessary for the production of technological equipment.<sup>36</sup> With China having already used this supremacy strategically, new COVID-19 outbreaks posing a threat to supply chains, and escalating tensions between the USA and China over Taiwan, several governments have intensified their efforts to decrease the dependency on Chinese suppliers.

For example, the USA has recently approved more than US\$50 billion in support for American semiconductor research, development, manufacturing, and workforce development.<sup>37</sup> Furthermore, it has invested US\$35 billion to address rare earth supply vulnerabilities.<sup>38</sup> Similarly, Japan approved a US\$6.8 billion package for semiconductor investments in November 2021<sup>39</sup> and added rare earth to the list of industries subject to tougher restrictions on foreign investment. EU institutions are currently negotiating a Chips Act, which would provide billions in support to strengthen Europe's semiconductor ecosystem<sup>40</sup> and has created a European Raw Material Alliance (ERMA) to secure European industry's access to sustainable raw materials, advanced materials, and industrial processing knowhow. South Korea is seeking to pass legislation providing US\$450 billion in investment in semiconductor production over ten years. Most recently, Japan and the United States announced the creation of a joint research centre for advanced semiconductors, open to other "like-minded" nations.<sup>41</sup>

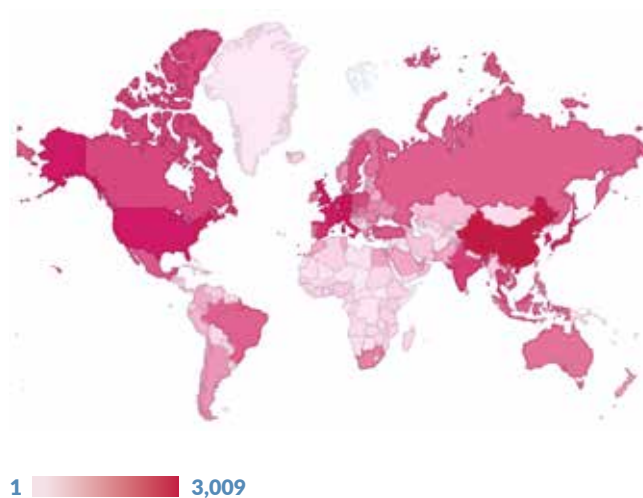
**With data and digital services gaining importance, countries have started erecting barriers to digital trade and including rules on data regulation in FTAs.**

Protectionist measures are not limited to trade in goods. As data and digital services play an increasingly crucial role in the economy and international trade, countries have started sheltering their tech industry through barriers to digital trade (e.g. censorship, forced localisation requirements, privacy regulations, filtering, discrimination against foreign digital products), or the inclusion of rules on data regulation in free trade agreements that prohibit members from adopting protectionist policies.<sup>43</sup>

Figure 14

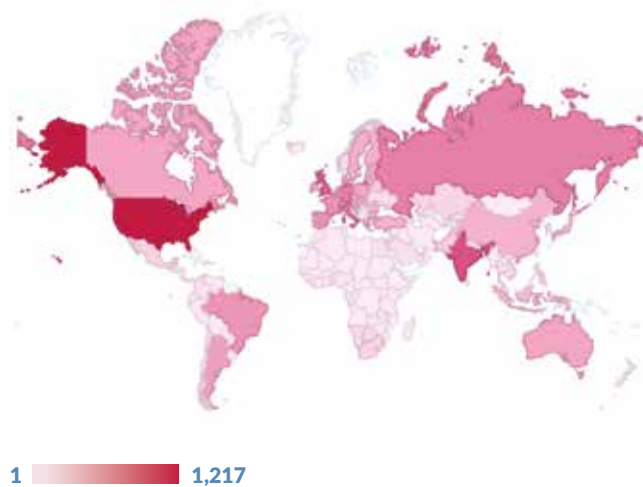
## Country exposure to harmful interventions<sup>42</sup>

(Source: Global Trade Alert database)



## Country contribution to harmful interventions

(Source: Global Trade Alert database)



As the war in Ukraine and other geopolitical conflicts, such as the escalation of the tensions between the USA and China over Taiwan, risk further exacerbating protectionist tendencies, the possibility of a broader trade war looms large over the prospects of the global economy.

## The Emergence of a New Global Order

**In recent years, the post-Cold War global order dominated by the USA and its allies has been slowly fading.**

In the West, Trump's rejection of multilateralism on the global scene and disregard for democratic values at home have upended US leadership of the free world after two decades of unchallenged economic, political, and military supremacy. Meanwhile, China and the other BRICS countries (i.e. Brazil, Russia, India, and South Africa) have been pushing for a new global system that better reflects existing economic and political realities. Despite G7 countries making up 44% of global GDP against the 23% of BRICS, the latter represent a larger share of the world population, and their relative importance in the global economy is expected to grow.<sup>44</sup>

**The US-led world order is faltering. Although the war in Ukraine has reenergised Washington's leadership of the free world, it has also strengthened the ties between China and Russia and escalated the tensions between China and the US over Taiwan's future.**

Although the Ukrainian conflict has recently reenergised US leadership on defence and energy security issues and strengthened NATO, it has also aligned Chinese and Russian interests in their quest to redraw the world's geopolitical map to reaffirm the supremacy of autocracy over democracy and reignited dormant geopolitical rivalries with Beijing over the future of Taiwan.

As highlighted by Edoardo Campanella, "the West's sweeping sanctions against Russia were designed not only to punish the Kremlin but also to send an early warning to China's leaders who may be contemplating an attack on Taiwan."<sup>45</sup> US Speaker of the House Nancy Pelosi's trip to the island triggered a further escalation of these tensions,<sup>46</sup> raising fears of a fully-fledged conflict.

While the outcome of this process is still unpredictable, most analysts agree that the geopolitical rivalry between

the USA and the People's Republic of China will dominate international politics in the 21st century.

## Climate Change and Sustainability

**The climate crisis, a consequence of unmeasured human activity, is causing unprecedented destruction around the globe.**

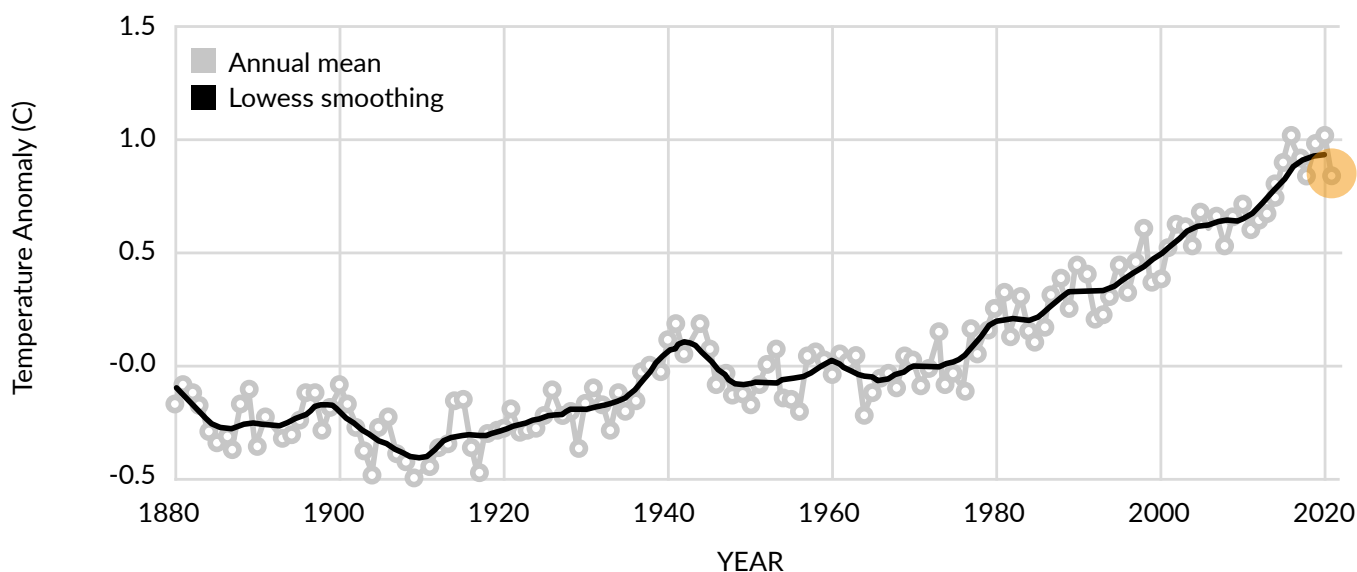
Climate change is accelerating, posing a challenge to sustainability and increasing the urgency required to respond to the current state of global warming. In recent months, China's longest and warmest heatwave has combined the most extreme intensity with the most extreme length. To cope with such extreme heat, the country has had to deal with unexpectedly high power demand, leading to electricity outages, which have been addressed by powering up the Sichuan Guang'an Power Generation, the region's biggest coal-fired power plant. This plant has been operating at full capacity for 21 consecutive days. Its electricity generation for August is expected to jump 313% from a year earlier.<sup>47</sup>

Meanwhile, Europe experienced one of the worst droughts in 500 years, together with the Horn of Africa and across great extensions of the USA and Mexico.<sup>48</sup> In Pakistan, months of heavy monsoon rain and flooding have left the country below water,<sup>49</sup> claiming over 1,000 lives, with the government reporting US\$10 billion in damage. Furthermore, the USA was gripped by the consequences of changing global conditions (Fig. 15) in a combination of hurricanes, droughts, and wildfires that extend to over 15,000 acres.

Figure 15

### Global land-ocean temperature index<sup>50</sup>

(Source: NASA)



**Sustainability cannot be an “innovative” add-on to regular strategy, it is a mandatory priority for all industrial sectors.**

Although our earth has for a long time experienced cycles, the frequency and intensity of these extreme weather events are unprecedented, increasing the urgency to change the status quo of daily lives, starting from the large industrial sectors that contribute the most to greenhouse gases (GHGs), particularly CO2 emissions.

Therefore, it is not surprising that sustainability, the concept that once seemed to be an innovative approach to the status quo, with investors, corporate boards, senior executives, and government leaders is now naturally embedded on Environment, Social, and Governance (ESG)<sup>51</sup> factors and on their inclusion in long-term policy and planning strategies.<sup>52</sup> Further encouragement derives from the views of many, where corporate integrity can impact ESGs (Fig. 16), considered essential to achieving the energy transition and mitigating the inequalities in our society.

Also, with less than ten years remaining to deliver on the decade of action<sup>53</sup> towards the 2030 Agenda, the international community is urged to step up its actions. For companies, this poses an unprecedented call to rethink the way inclusion and sustainable development belong in their strategies, including socioeconomic resilience and prioritising sustainable growth.

**Firms that fail to place sustainability as a core value and comply with regulations risk becoming incapable of creating and retaining competitive advantage, and losing their place in global markets.**

Recent reports have brought attention to the importance of the sustainable governance element in the ESG equations.<sup>54</sup> Failing to comply with ESG principles places companies at risk of reputational damage, compliance costs, the potential loss of business, and the lack of a company’s ability to attract and retain talent.<sup>55</sup>

It could be expected that non-compliant manufacturing companies could find it challenging to secure funding and attract investment. In response, firms are jumping on the sustainability bandwagon in an ever more conscious manner, with 88% of publicly traded companies in 2020 having an ESG strategy in place, and 80% of the world’s largest companies reporting exposure and taking actions to face the physical or market transition risks associated with climate change.<sup>56</sup>

Many companies face growing consumer demand for better, more sustainable products and transparent processes. Beyond the demand pull for such transformations, many firms have begun to identify value opportunities in such transitions, noticing and optimising their activities to the point that more sustainable products and services become more profitable and addressing previously neglected customer needs.

**Figure 16**

## ESGs and integrity<sup>57</sup>

(Source: WEF)

**The various ways in which corporate integrity impacts ESG performance and reporting**



## Evolving Consumer Needs

Almost by definition, consumer needs are constantly in flux, with individual and collective demand changing to reflect disposable income, new life circumstances, aspirations, preferences, trends, and values.

**The endless series of shocks experienced in the last 15 years, coupled with unprecedented technological advancements, have triggered the most radical revolution in consumer preferences since the post-World War II period.**

Nonetheless, the crises and sudden shocks that disrupted the global economy over the last few years have redefined geopolitical equilibria and triggered the most radical revolution in consumer needs since the post-Second World War period.

In particular, as the COVID-19 pandemic changed the way consumers live and work, it also affected consumption patterns due to increased uncertainty, practical barriers to consumption (e.g. store closures), and the emergence of new habits (e.g. increased time spent at home, less reliance on public transport). While some of these changes were imposed upon consumers, others accelerated ongoing trends and are likely to be permanent.

**Recent surveys have identified six emerging trends that are here to stay: the increased use of online shopping; the mainstreaming of the metaverse; a push towards low-carbon lifestyles; a focus on authenticity and social issues; support for local business and services; and a rising demand for health-related products and services.**

A review of consumer surveys carried out in the past two years highlights the emergence of six trends that are going to have a lasting impact on demand:

**- Increased use of online channels to buy goods and services.** While this trend was initially forced upon consumers due to lockdowns, closures, and safety concerns, a consumer survey conducted by Deloitte<sup>58</sup> suggests that this change in behaviour patterns will stick for all product and service categories, especially among users who had already purchased them online before the pandemic. In addition, data provided by McKinsey show that, contrary to some predictions, the rise in e-commerce doesn't necessarily harm brick-and-mortar retailers. In fact, 75% of US consumers now say they research and purchase goods online and in stores. Furthermore, many participate in omnichannel activities, with social media influencing their purchasing decisions.<sup>59</sup> As observed by Euromonitor, the pandemic also acquainted older consumers with online shopping, virtual solutions for socialising, and digital services, opening up new business opportunities.<sup>60</sup>

**- Mainstreaming of the metaverse.** With consumers spending more time online, the distinction between the physical and the virtual world blurred, creating fertile ground for the mainstreaming of the metaverse<sup>61</sup> – i.e. an immersive online experience that mimics real life thanks to features like virtual reality (VR), avatars, non-fungible tokens or NFTs (i.e. digitised products that users own in the metaverse), geo-enabled virtual locations, and virtual commerce.<sup>62</sup> While both the development and the uptake of the metaverse are still in their early stages, the metaverse is likely to reshape our lives and open up endless business opportunities.<sup>63</sup> Notably, companies like Facebook, Gucci, and Disney have already invested in the space.

**- Green activism and low-carbon lifestyles.** Although consumers' push towards sustainability has been relevant for some time, a survey by Euromonitor shows that the COVID-19 pandemic further raised consumers' awareness of their contribution to climate change through purchasing decisions.<sup>64</sup> There are two different dimensions to keep in mind when considering this trend. On the one hand, climate-aware consumers are changing their consumption behaviour to reduce their carbon footprint, for example, by reducing waste, improving their recycling habits, and embracing second-hand shopping. On the other hand, they are also demanding brands invest in low-carbon innovation and climate-friendly products and enhance environmental transparency through tech tools, such as digital labels and mobile apps. However, affordability still stands in the way of mainstreaming the demand for sustainable products.<sup>65</sup>

**- Prioritisation of authenticity and social issues by younger consumers.** A survey conducted by McKinsey shows that while older consumers interested in rewarding brands and products that promote values tend to prioritise health and environmental considerations, Millennials and Gen Z are more likely to reward brands that are transparent about what they make or do or that put people over profit.<sup>66</sup> Diversity, equity, and inclusion (DEI) considerations are also top of mind for younger generations, whereas only one in four older consumers seems to consider them a priority.<sup>67</sup>

**- Support for local products and services,** motivated by health, environmental, and economic considerations. Although this trend emerged before the pandemic, it was accelerated by changing economic conditions and regulations put in place in response to the crisis. According to Deloitte, the support for local producers, retailers, and service providers will remain important, especially to older and wealthier groups.<sup>68</sup>

**- Rising demand for activities and products that can support mental and physical health.** As the pandemic forced people to change their habits radically, it also triggered "drastic personal changes and a collective

reboot of values, lifestyles, and goals.”<sup>69</sup> With consumers increasingly invested in their personal growth and wellbeing, products and services that can support physical and mental health (such as business casual attire and mindfulness apps) will continue seeing an increase in popularity.

Although the impact of Russia’s invasion of Ukraine on consumer behaviour is likely to trigger new changes in this, these trends show an urgent need for companies to restructure their offerings to match a fast-changing demand.

## Workforce of the Future

The highly dynamic last couple of years have completely redefined employees’ values and priorities, forcing companies to reevaluate the benefits and conditions in their work environments to attract new talent and retain their existing expertise. The most significant trend that has reshuffled employment and hiring structures receives the name of the Great Resignation; although accelerated by the global pandemic and the work-from-home conditions this brought, economists from the Wall Street Journal<sup>70</sup> argue that it has been apparent since the beginning of this century. This term, along with the Big Quit and the Great Reshuffle, refers to a widespread phenomenon whereby employees have voluntarily resigned from their jobs due to the confidence that they can get higher-paying jobs, incentivised by virtually low unemployment rates. According to the Harvard Business Review, nearly 57 million Americans quit between January 2021 and February 2022<sup>71</sup>, further visualised in Fig. 18.

**The Great Resignation has been pinpointed as the name for the empowering movement of employees who pose increasing requirements on job selection and prioritise the alignment of their personal values with those of their employers.**

Workers have increasingly rethought their careers, work conditions, and long-term goals, and further, to act through leaps of faith, questioning the power dynamic relating to whether employers or employees have the final say. Such shuffling impacts firms’ strategies, since if the workforce cannot be recruited in a certain geographical location, then a corporation has no alternative but to locate its facilities elsewhere, even if that implies not adopting a reshoring or onshoring strategy which they might desire.

However, there are challenges other than those involved in workforce restructuring. According to Deloitte, organisations can leverage alternative roles to tap into new markets, meet seasonal demand, discover new expertise and talent, and, of course, save resources.<sup>72</sup> Further, it gives companies an opportunity to try to better understand the motivation behind their employees, which is often misaligned between employers and the workforce, as illustrated by McKinsey<sup>73</sup> (Fig 18).

Figure 17

## Relevant factors to employees vs employers<sup>74</sup>

(Source: McKinsey)

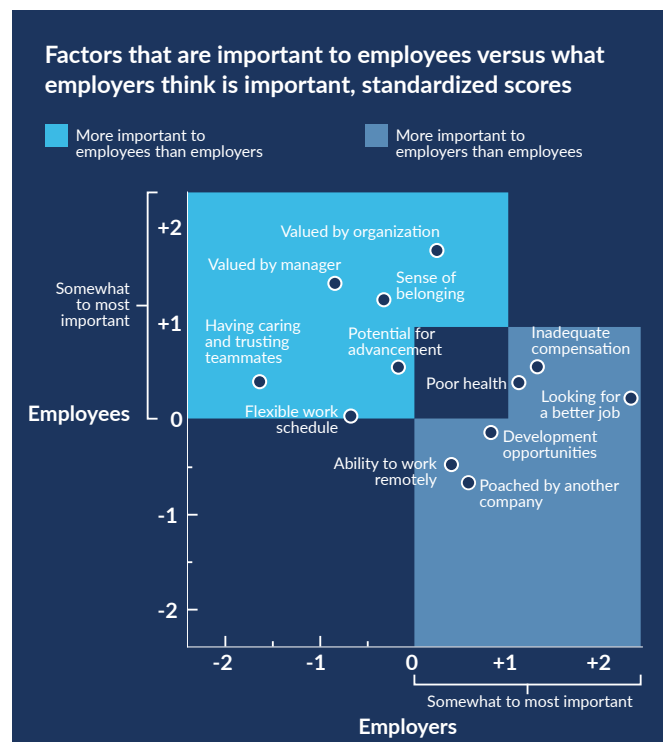
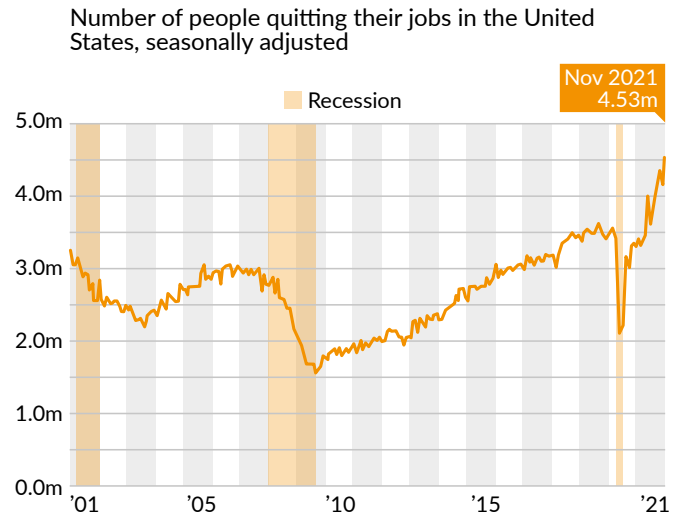




Figure 18

## The great resignation<sup>75</sup>

(Source: Statista via WEF)



The entire job market is undergoing a complete transformation. In an MIT Sloan article<sup>76</sup>, two simultaneous evolutions are seen in the redefinition of the nature of work. In the first, employees are transforming the execution of tasks to increase efficiency and reduce costs. In contrast, the second approach includes redefining work to take advantage of the changes in the system. Both approaches are important, as strategy redefinition is essential to learn how to capture long-term and sustainable value.

**Skill definition is complex, as it combines tangible and intangible elements of the requirements for a job. However, firms must learn to do this soon, as the “war for talent” will require increased competitiveness in recruitment processes.**

Updating the definition of work and the skills required becomes very difficult, particularly when organisations do not clearly understand the current skills of their workforce and how they will change in the near future<sup>77</sup>. According to a report by the Society for Human Resource Management<sup>78</sup> in the USA, the top three missing technical skills are (1) trade skills (carpentry, plumbing, machining, welding, etc), followed by (2) data analysis and data science skills and (3) those of scientists, engineers and doctors.

Further, the concept of “war for talent,” which was already predicted at the beginning of the century, has forced firms to look at their capabilities to develop stronger leadership skills, address the quality and quantity of the time where they are listening to their workforce, and reflect on the varying needs of their employees (i.e. remote workers), among other techniques to become more competitive while recruiting.<sup>79</sup> On the other hand, an increasing number of employees have been reported to reconsider jobs and employment positions based on the alignment of human values between their beliefs and those of their employers.

While concerns about the future of the workforce are mainly noticed in advanced and ageing economies, in the coming decades, they are expected to gain relevance also in middle-income countries. For instance, Europe’s ageing population has raised challenges for policymakers in relation to employment, working conditions, living standards, and welfare, leading to concerns over the sustainability of pension systems and the supply of labour<sup>80</sup>. Also, ageing workers will most likely experience increasing pressures to upgrade their digital and technology-related skills to continue to be employable. The need to reskill and upskill is an undeniable response to fast-changing labour market needs and evolving skills gaps and mismatches. All these changes create an increasing relevance for the integration of digital and transferable skills in skills development and removing barriers to learning for adults.<sup>81</sup>

**Transferring women into a balanced workforce is yet to be achieved. The global pandemic increased the complexity of the many efforts addressed to cover this gap.**

Some key features of demographic and occupational change in Europe over the last 25 years include the ageing of the working-age population, the increasing participation of women in the labour market, educational upgrading, and, in many cases, an increase in the migrant population. On the occupational side, against the background of generally expanding employment rates, there have been two dominant patterns of change across European countries: polarisation and upgrading, which could otherwise be described as the expansion of employment in high-paying jobs simultaneous with varying trends in mid- and low-paying jobs.<sup>82</sup>

After the COVID-19 pandemic, data from the World Economic Forum brings light to the challenges that the

future of work faces. By developing the Global Gender Gap Index benchmarks the evolution of gender-based gaps among four key dimensions (Economic Participation and Opportunity, Educational Attainment, Health and Survival, and Political Empowerment) is addressed and monitored. On its current post-pandemic trajectory, it is estimated that it will now take 135.6 years to close the gender gap worldwide<sup>83</sup>. The aforementioned gender gap is more likely to be found in sectors that require disruptive technical skills. For example, in Cloud Computing, women make up 14% of the workforce; in Engineering, 20%; and in Data and AI, 32%<sup>84</sup>. Adding to the challenges, data from the ONS has shown that the number of unemployed women aged 65 and over has tripled since the onset of the pandemic<sup>85</sup>, leaving a question mark over whether this will become a long-term trend or how to easily predict the underlying factors.

## **Increasing Relevance of Equity, Diversity, and Inclusion**

In recent years, diversity, equity, and inclusion (DEI) considerations have taken centre stage in the social, political, and business arenas. Spurred on by the #MeToo and Black Lives Matter (BLM) movements, which exposed the systemic sexism and racism permeating our society, the trend was further accelerated by the COVID-19 pandemic and its disparate socio-economic impacts on women, racial and ethnic minorities, and people in low-income households.

Although there is no shared definition of DEI, and the three terms are often used interchangeably, each word stands for a different but complementary goal. “Diversity” aims to ensure a proportionate representation across all dimensions of human differences, such as age, class, ethnicity, gender, health, physical and mental ability, race, sexual orientation, religion, physical size, education level, job, function, and personality traits. “Inclusion” strives to make everyone feel included, visible, heard and considered. Finally, “equity” aspires to eliminate existing inequalities and barriers that impede so as to overcome past inequities.<sup>86</sup>

**With diversity, equity, and inclusion considerations taking centre stage, governments, investors, workers, and consumers are increasingly asking companies to deliver social value.**

The push toward DEI aims, first and foremost, to rebalance current socio-political structures and the system of power underpinning them. Yet, its relevance also has direct implications for business.

First, as highlighted by Saadia Zahidi, Managing Director at the World Economic Forum, “building truly diverse, equitable and inclusive workplaces, value chains and products” is integral to the development of the social pillar of the ESG paradigm discussed previously.<sup>87</sup>

Second, several governments around the world are introducing legislation to ensure that businesses and investors are delivering social value. For example, the California Corporations Code, as amended by Assembly Bill 979, requires corporations to have at least one director from an underrepresented community – a number that goes up to three for corporations having more than eight directors.<sup>88</sup> Besides legislators, regulators and standard-setting organisations are also promoting disclosure rules around DEI. For example, Nasdaq’s Board Diversity Rule, which was approved by the SEC last year, requires companies listed on our US exchange to include disclosures around board diversity,<sup>89</sup> and the Chartered Financial Analyst (CFA) Institute has developed a voluntary code to guide DEI in the investment industry, beginning in the USA and Canada.<sup>90</sup>

Third, with DEI considerations increasingly influencing workers’ choices, embedding DEI in the workplace has become essential to preserve an organisation’s ability to grow, innovate, and compete for talent. Compounding this trend is a growing consensus that diverse teams benefit a company’s profitability.<sup>91</sup> One tangible outcome of this push towards DEI in the workplace has been the steep rise in the number of people with the title “head of diversity,” “director of diversity,” and “chief diversity officer” between 2015 and 2020, as evidenced by LinkedIn data.<sup>92</sup>

Finally, as discussed earlier in the chapter, embedding DEI principles in business decisions has also become imperative for companies trying to improve their reputation with increasingly socially conscious consumers.

# Silver Linings in a Changing Global Landscape

The changing landscape described so far poses many challenges to governments and business leaders, but it also hides silver linings that deserve consideration.

For example, the deceleration in the pace of globalisation is leading to fragmentation and protectionism, and it has heightened tensions between countries. Still, it also provides an opportunity to rethink the integration process in a way that promotes equitable and sustainable outcomes.

Similarly, while the current protectionist impetus is hampering economic growth and increasing tensions between countries, it is also forcing policymakers to build internal capabilities to enhance resilience and strengthen their economies in the face of shocks.

Further, awareness of the fragility of current supply chains, where many weaknesses were exposed, also highlighted the false sense of control that many companies have over their operations, bringing light to the need for firms to strengthen their leadership approaches and become increasingly agile to react to potential threats.

Although firms cannot control global phenomena, they can secure their internal pillars by focusing on creating a sense of purpose that works as a backbone for their operations, while reigniting their workforce and creating a sense of belonging to the company, even during hard times. Also, creativity and reimagination of the firm's differentiation and competitive advantage become essential to retain space in ever-changing markets.

## Global Manufacturing Transformation: the South American & Brazilian Perspective

### Enzo Morosini Frazzon

Associate Professor of Production Engineering, Federal University of Santa Catarina

The future of manufacturing and the ongoing redesign of global supply chains are intertwined. The current transformation is characterised by increasing dynamics, bloc-oriented strategic decisions (proximity sourcing) and the quest for an economically, socially and environmentally sustainable future. South America and Brazil have the opportunity to increase their participation in manufacturing networks due to favourable structural changes. Several challenges persist for South American countries, but a clear strategic vision along with hands-on actions can overcome them and provide long-term benefits.

### The era of dynamic manufacturing

Manufacturing systems are subject to dynamics due to operation-level influences (e.g. machine breakdowns, demand oscillation) and context changes (Frazzon et al., 2018). Both are challenging, whilst the impact of abrupt modifications in the *contour* conditions of production systems is more difficult to predict and long-lasting. The manufacturing context is impacted by several megatrends such as supply chain shortages, environmental issues, pandemics, escalating conflicts, political polarisation and uncertainty, stagnation and inflation, ubiquitous digitalisation, and new decision-making methods. We are witnessing the end of an era of equilibrium, which has lasted for several decades. At the present moment, from where we stand, a new equilibrium is not yet in sight. Surviving in the new era of continuous change will demand new wisdom.

Supply chain robustness is defined as a proactive strategy for dealing with turbulence, change, or disruption. Questions about how to improve the robustness of supply chains are at the top of the manufacturing agenda. How are global megatrends shaping the new era of dynamic manufacturing and what challenges and opportunities will they bring? Firstly, the redesign of global manufacturing supply chains in the context of this evolving scenario and megatrends will create *bloc-oriented supply chains*. Secondly, digitalisation allows for production control based on the current state of the manufacturing system, commonly described as data-driven decision-making approaches. Indeed, supply chains have been experiencing technological transformations

on a scale unlikely seen before (Frazzon et al. 2021). Last but not least, there is a shared understanding about the relevance of manufacturing, the growing complexities of supply chains and the quest for an economically, socially and environmentally sustainable future. It is on the news: *Manufacturing matters and people care!* Thus, manufacturing industries must pursue evidence-based clarity and dialogue with an ever-increasing number of impacted agents and stakeholders. The intertwined relation between newly redesigned supply chains, data-driven decision models, and evidence-based dialogue will define the era of dynamic manufacturing.

### South America & Brazil must have a central role in the new era of bloc-oriented supply chains

Diversification begets resilience. When diversification is impaired by a lack of trustworthy locations to source raw material, parts and services, organisations must turn to new frontiers. Despite not being the best example of successful democratic liberal societies, South America (SAM) shares the worldview and the long-term objectives of both sides of the North Atlantic.

SAM also displays comparative advantages based on a century-old manufacturing industry, as well as world-class agrobusiness, biotech and energy sectors. Furthermore, SAM countries have an increasingly favourable balance of workforce skills and costs. Due to its still young population and openness to new technologies, the workforce can easily be prepared for a tech-oriented future, in which the role of digital technologies leverages the creation of resilient manufacturing supply chains. Indeed, the handling of continuous change on a daily basis is already at the centre of SAM industry. Inflation, changing rules, scarcity, fluctuating demand, political and economic instability do not comprise a scenario that is new to us. The flexibility to handle the new era of dynamic manufacturing abounds in our countries. Surely, all SAM countries still need to cope with the basics and improve their competitiveness indexes, mainly by investing in education, infrastructure and public security.

Regarding cultural and historical proximity, it is important to note

that SAM and Brazilian local industry is closely tied to Germany, Italy, Europe in general, and North America. Since absorptive capacity relies on shared knowledge, existing awareness is paramount for the success of foreign direct investments in services (Frazzon, 2009) and manufacturing industries. On the demand side, the region is also unquestionably relevant due to the growing population and purchasing power. Along with that, there is an increasing and impactful awareness regarding the relevance of achieving balanced economic, social and environmental sustainability.

Four long-term characteristics support the claim on the relevance and centrality of South America and Brazil in the new era of bloc-oriented supply chains: shared democratic liberal values, a historic industrial connection with players in the bloc, a readiness for dynamic scenarios and a comparative advantage in a variety of sectors and segments (including manufacturing). Actively fostering a shoulder-to-shoulder integration of South America into bloc-oriented manufacturing networks will provide mutual long-term benefits.

## Vision and agenda

To that end, SAM countries need to be aware of their comparative weakness and strengths. Several challenges persist, but a clear strategic vision along with hands-on actions can overcome them. Governmental decisions with direct impact on manufacturing industry have long-term impact, posing an even more relevant role in a bloc-oriented global reality. Alignment between trade agreements, policy planning and implementation, and fiscal incentives needs to consider the manufacturing industry's technological capabilities, maturity level and strategy. This alignment can be achieved with the support of a scientific, evidence-based approach. It is paramount to build a shared vision based on the rational analysis of data and evidence, avoiding the polarisation trap and promoting the transformative leadership of industry.

In this context, manufacturing companies in the region must actively embrace the ongoing transformation, assuming a relevant role in structurally changed supply networks. For that, they must leverage the comparative advantage of SAM countries, which are based on the availability of raw material, resources and capabilities. Furthermore, the industrial base must connect with the agrobusiness, biotech and energy sectors, ensuring the emergence of a reliable manufacturing cluster for supplying equipment and other capital resources. Finally, it is paramount to replace the export of raw materials to added-value products, by means of a strong transformation industry. Current digital transformation offers a unique opportunity to leap forward if companies properly apply it to ease the integration into aforementioned networks. Finally, manufacturing in SAM countries must pursue a clear communication strategy,

evidencing its sustainable contribution to the overall society and economy.

The adoption of policies that are unfit for (existing and forthcoming) industrial realities can damage the survivability of whole economies. Examples of such policies would be the adoption of restrictions in dissonance with feasible industrial setups, creating economically unsustainable societies. Another example of biased policy with limited positive impacts is the hand-picked promotion of national champions. Instead, SAM countries need reality-oriented policymaking. Such a transition to evidence-based policymaking is now possible due to increasing data availability facilitated by emerging digital technologies. An effective and urgent policy is the adoption of clear and consistent cross-sector actions favouring the whole productive sector: tax cuts, infrastructure improvements, the simplification of bureaucracy, the availability of credit, the promotion of long-term education and research and development (R&D) incentives.

The still-existing demographic bonus of SAM countries needs to be leveraged. A new generation of engineers capable of leading the digital transformation will contribute to industrial evolution and national development, acting as catalysers of (accelerated) technological change. Their education relies on proper collaboration between industry, civil society and academia at a strategic level and a more approximal dialogue between industrial organisations and educational institutions at the operational level (Tortorella et al., 2022). Thereof, more effective formation practices for engineering education can be fostered, such as project-based and research-based learning approaches.

There are plenty of opportunities for including SAM countries in the positive transformation of global manufacturing supply chains. Currently, Brazil stands out as the country taking more consistent decisions favouring the manufacturing industry. In more industrialised parts of the country, the benefits of this unique opportunity can already be seen. The performance of a well-integrated manufacturing industry is supporting economic, social and sustainable development. The road ahead involves embracing this transformation and strategic integration into reordered manufacturing supply chains.

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# **Supply Chain Transformation towards Resilience and Innovative Value Creation**

# An Outlook on the Current Situation of Supply Chains

Supply chain disruptions have continuously dominated evening news, magazine front pages, and newspaper headlines. Although not a surprise to industry and manufacturing professionals around the globe, supply chains and their associated challenges have arrived in the mainstream as their impacts have been felt across the board by business and private consumers alike. Leaders of the major economies are alert and have made supply chain a priority topic<sup>93</sup>. We have observed a rapid succession of events over the past years – from new tariffs and trade barriers to a global pandemic – all of which impacted manufacturing supply chains globally (see Figure 19).

Manufacturing supply chains have taken matters into their own hands. Many found themselves in a position where their supply chain required some significant adjustments. Others realised that some of their strategies had strengths and provided them with differentiation. Regardless, this learning and reflection period has led many manufacturers to integrate their insights into a process of supply chain redesign. Increasingly, supply chain managers are considering how people, process, and technology can be balanced better to ensure effective supply chain networks. Since then, strategies such as smarter digitisation led by roadmapping, considerations on how to bring manufacturing and distribution closer to customers to stay flexible in case of a new disruption, along with concerns over how to avoid spikes from responses to temporary demands, have guided many firms towards supply chain innovation.

Manufacturing firms are increasingly including the term of resilience in their goal definition. This can sometimes represent the fact that short-term costs are harder to control, particularly when private and public sectors develop an increased approach to domestic production, whereas efficiency and low costs have been prioritised over security, sustainability, and finally, resilience<sup>94</sup>.

At a global level, many supply chain partners, particularly large and leading companies (OEMs), realised that their own partners, many of a different size (SMEs), faced different challenges. Some companies saw the necessity to integrate SMEs, who act as suppliers of critical components and services, and help them solve some of the struggles they were experiencing at different scales to jump back into operations after global disruptions.

In this chapter, we present an overview of supply chains in manufacturing, the dominant challenges and opportunities,

discuss the impact of the digitisation of supply chains, and take a bold look at sustainable supply chain transformation.

## Changes in the Global Eco-system Relevant to Supply Chains

Given the multi-dimensional systems of supply chains today, they are impacted in a variety of ways by the global ecosystem of which they are an essential part. The global megatrends depicted in Chapter 1, such as COVID-19, global economic growth, severe inflation driven by a surge in energy and food prices, particularly since the start of the war in Ukraine, and the arising pressures to become more sustainable, all influence manufacturing supply chains in one way or another.

The understanding and awareness of the large-scale changes and adaptations that supply chains have had to embrace is addressed in this Report as a potential opportunity for companies to transition into a better version where they maximise their potential. This way, although global circumstances like the recent COVID-19 pandemic disrupted supply chains globally, from toilet paper to construction materials, many non-functional elements of previous supply chain arrangements were brought to light, giving companies an opportunity to address them rapidly and simultaneously, along with their collaborators and competitors.

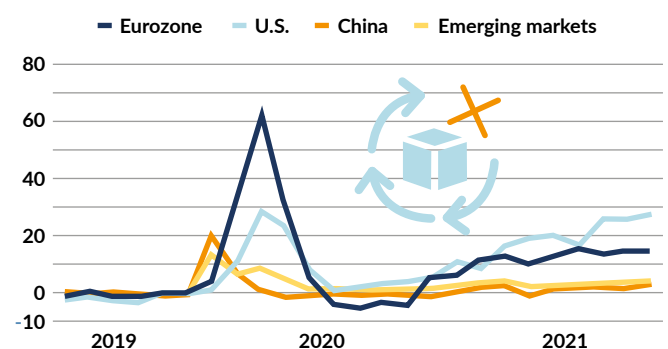
Figure 19

### Supply chain disruptions around the globe<sup>95</sup>

(Source: IMF. Image: Statista)

Index of global supply chain disruptions (100=most disrupted)

Based on the difference between the supply delivery times subindex and the supply delivery times based on manufacturing output subindex (both part of the PMI)



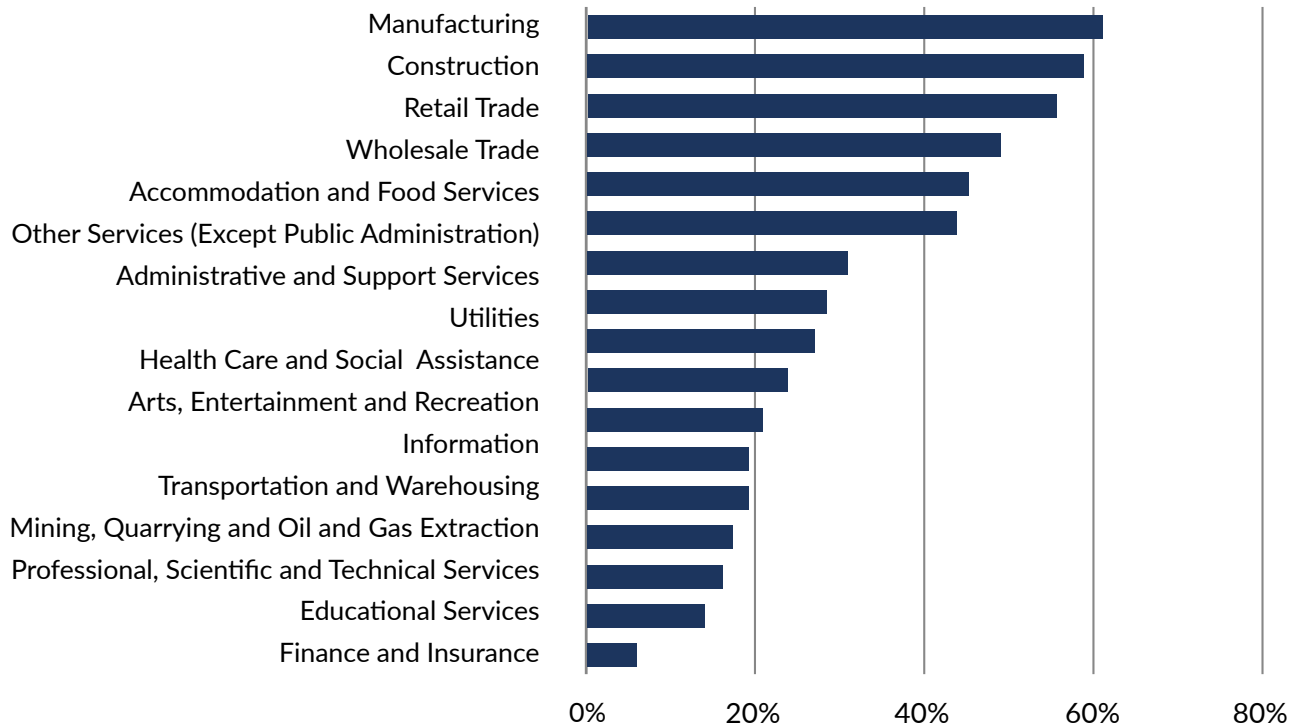
The manufacturing sector has been particularly hard hit by these black swan events as is evident looking at long supplier delays (see Figure 20).

Figure 20

## Supply chain disruptions by sector

(Sources: U.S. Census Bureau, CEA Calculations)

In the last week, did this business have domestic supplier delays? (Percentage saying yes)



The effects of such events are manifold and impact supply chains through lockdowns and local restrictions seen recently in Shanghai and the Los Angeles harbour, but also through demand shifts and labour force availability. Other singular events including the blockage of the Suez Canal by the Ever Given obstructing a major global shipping route added to these effects. Shifts in global politics impact the ability of supply chains to source internationally and trade restrictions further amplify these impacts.

## Modern Supply Chains and their Boundaries

Before we dive deeper into the topic, we will briefly provide a recap of what today's supply chains entail. Today, most products are multipart systems that are a product of complex supply chains. Hence, many scholars and practitioners postulate that companies rarely compete with other companies, but it is supply chains that compete on the marketplace. Supply chains are no longer a simple determination of linear material flows, but complex networks that provide value beyond logistics.

These modern supply chains are often deeply integrated and include coordination of design, development, and

engineering tasks during the beginning of life involving various stakeholders. Spanning multiple companies, geographic locations, time zones, and political systems, modern supply chains are intricate systems themselves. In this Report, we have consciously decided to use the term supply chain with the intent to reduce unnecessary complexity that might alienate interested readers and ensure alignment with the most recent news coverage. We are aware that the field is continuously developing, and terminology must reflect that. To ensure transparency in our approach, we briefly discuss three terms that we commonly refer to with the overarching term "supply chain" throughout the Report. Each has a distinct meaning and many of the detailed discussions throughout the Report reflect viewpoints that experts might associate with either or both of these terms: value chains and digital supply networks (DSN).

In principle, supply chains focus on the efficient delivery of a product or part to a customer. Supply chains have evolved over time and grown in complexity. However, the principle of organising material and information flow is dominant. The Supply Chain Operations Reference Model (SCOR) is an industry reference that highlights the focus on the flow of material and information.<sup>96</sup>



Value chains have been around for decades, first introduced by Michael Porter in 1985. Value chains expand the system boundaries of the supply chain towards all activities involved in the creation and delivery of a product or service. This is especially relevant with regard to the introduction of digital services in conjunction with physical products, as well as new non-ownership business models heavily reliant on data and data analytics. Value chains place emphasis on how commercially interconnected businesses deliver value to customers and customers' customers. Value chains have received considerable attention including the increasing reshoring pressure many manufacturers feel.<sup>97</sup>

Digital Supply Networks (DSN)<sup>98</sup> or the Digital Capabilities Model for Supply Networks<sup>99</sup> acknowledge that today, the flow of materials and information is no longer one-directional and addresses this increased complexity by focusing on interconnected capabilities that are technology-enabled instead of flow-related. Especially with regard to Industry 4.0 and Smart Manufacturing technologies, DSN emphasise a holistic perspective to addressing processual issues and digital technology opportunities in conjuncture. This enables more rapidly reconfigurable innovation networks to keep pace with innovation and change in the ecosystem.

## Relation to Previous Reports

Looking back at key topics highlighted in prior WMF Reports, including skills, technology, AI, and sustainability, we can see how supply chain is at the intersection of the previous Reports. In the inaugural 2018 WMF Report, we formulated ten key recommendations on the future of manufacturing. The recommendations highlighted the need to support SMEs in their transformation, a topic that was found to be instrumental for supply chain operations. Furthermore, across the recommendation, the global

nature of manufacturing was visible – a topic that causes much tension and stress on today's supply chains.

The following 2019 WMF Report focused on skills for the future of manufacturing. The impact of the shortage of skilled workforce in manufacturing operations is impacting supply chains, but this expands to other related trades such as truck drivers, harbour operators, and warehouse workers. We will see in the following sections that the shortage of skilled workforce turns out to be a particular challenge for supply chains.

In 2020, the WMF Report focused on AI and highlighted recommendations around data sharing, privacy, and quality. AI and data are considered a potential mechanism to address supply chain issues moving forward, but the challenges depicted in the prior Report remain and become of particular interest for future supply chain transformations.

The latest Report in 2021 addressed the circularity problem and focused on tech-enabled sustainability in manufacturing. Sustainability and climate change are driving change in supply chains along with the rest of society. A topic that we will discuss in terms of transformation is the transition to supply chains where circularity provides a business opportunity.

In the following, we relate several topics from the previous Reports to current challenges in manufacturing supply chains, while we differentiate between challenges that the supply chain partners have to handle and keep under control as they are influenced by external effects and challenges that supply chain partners can deal with and prepare for.

# Challenges Faced by Manufacturing Supply Chains

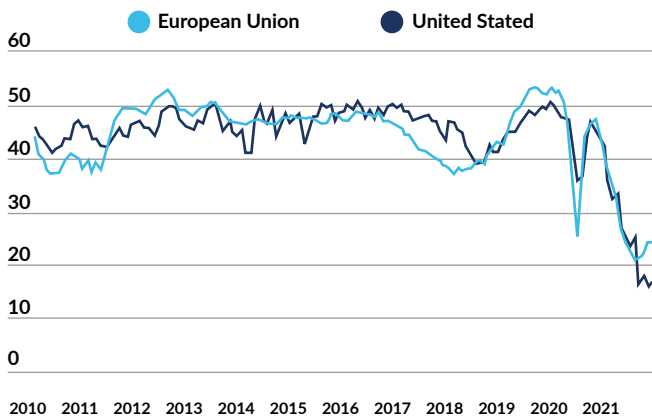
The challenges faced by today's manufacturing supply chains are manifold and diverse. Not all are new or unexpected; however, the rapid succession of significant disruptions within a short period of time, as experienced in the last few years, is unprecedented in recent history. The effects of those disruptions led to several backlogs and bottlenecks that clearly reflect in the suppliers' delivery times, which increased nearly twofold in 2020 and 2021 as shown in Figure 21. Several challenges led to these backlogs and bottlenecks.

In the following section, we will discuss major challenges clustered around whether they are within the realm of control of the company and supply chain, or external, with limited control. As always, there is a large grey area between internal and external and many of the challenges discussed are not independent of one another. Nevertheless, this represents a major factor in how companies and supply chains can prepare and react to them, and thus seems like a practical and appropriate form of clustering.

Figure 21

## Average suppliers' delivery times in the US and EU in recent years<sup>100</sup>

(Sources: IHS Markit)



Suppliers' delivery times in the US and EU have slowed considerably – a lower index reflects longer delivery times.

(Manufacturing PMI, suppliers' delivery times)

Note: PMI=Purchasing Managers' Index. Readings above 50 indicate faster delivery times, readings at 50 signal no change and readings below 50 indicate slower.

## Challenges out of the Supply Chain's Control Global Phenomena

We have witnessed a plethora of global phenomena with direct impacts on supply chains worldwide. Some are considered black swan events that are difficult-to-impossible to predict, such as COVID-19. Others, such as climate change, have been on the radar of companies and governments for longer periods, yet the indirect impacts (e.g. floods, wildfires) are again difficult to predict.

These global phenomena are not directly under the control of companies and supply chains respectively. Hence, the challenge is to prepare, manage risk, and predict these events and their impacts on the particular supply chain. When we look at the global phenomena of climate change, it drives a variety of impacts that have supply chain implications, in both the short and the long term. Short term, the flooding in Pakistan may interrupt supply from this region and thus impact supply chains with partners there. Long term, climate change drives the price of (fossil) energy and the transition towards the electrification of the automotive and trucking sectors. This, again, has a plethora of implications on the supply chain across the board. On the other hand, some factors relating to climate change have not (yet) received significant attention in

supply chains today. For example, carbon emissions are not considered a cost factor in optimisations as they should be from a supply chain standpoint. This is slowly changing with early-stage planning and increasing information requests from suppliers, but not to the extent the public conversation may indicate.

Social phenomena are also impacting supply chains significantly. One socially-driven aspect that is propelling supply chain change is the fact that consumers are becoming more demanding – often called the Amazon effect – expecting everything to be available within days or even hours. In this instance, it is important to distinguish between the 'served' and 'underserved' populations globally, but also locally, within a country or region. While certain products and services are only available to the 'served' population, information and visibility on what such access looks like is available to all – driving unrest and phenomena like migration.

It can be safely said that most global phenomena that impact supply chains are not independent of each other and companies and supply chains that are resilient and agile in adapting are best prepared to navigate the changing environment moving forward.

## Critical Materials Availability

A major factor why supply chains have received significant media attention over the past few years is rooted in the fact that both consumers as well as companies have experienced critical materials shortages. This is noteworthy, as prior to this, supply chains were not discussed outside of circles directly involved. On the consumer side, almost everybody remembers the shortage of toilet paper, garlic, and Christmas presents, as well as masks, PPE, hand sanitiser, and drugs at the height of the pandemic.

On the company side, the semiconductor (or chip) shortage wreaked havoc on a wide variety of industries, including automotive, defence, and aerospace. A semiconductor, also called an integrated circuit, a microelectronic chip, or a computer chip, is a small electronic device composed of billions of components that store, move, and process data. Semiconductors are crucial for cars, appliances, and phones, but also a key source of military competitive advantage. They represent and showcase how single components (other examples include wire harnesses) can bring down a whole complex supply chain and interrupt the production of a complex product (e.g. a car or a fighter jet). Currently, the leading countries in the semiconductor global supply chains are the USA, Taiwan, Japan, and South Korea. Semiconductors are a crucial component of modern defence systems, and as such the implications of the shortages on the defence supply chain makes this

a highly political topic, as leading countries fear lack of self-sufficiency in terms of components and materials for industrial independence and technological innovation. Both the USA and China have put measures in place to address this moving forward (e.g. the American Frontier Act). Taking to consideration the tensions between the USA and China, along with the susceptibility of international supply chains to external crises, which are expected to increase with the grow pressure to address the effects of climate change, it can be assumed that countries might decrease their interest in economic international cooperation, striving to be more self-sufficient, particularly in critical sectors.

Now, while some of these shortages are connected to the COVID-19 pandemic directly or indirectly, it is more complex than that. The semiconductor shortage is not only impacted by plant closures and shipping issues in the wake of COVID-19, but also by the lack of skilled labour, critical raw materials (e.g. availability of neon from Ukraine after the Russian invasion), as well as political trade restrictions.

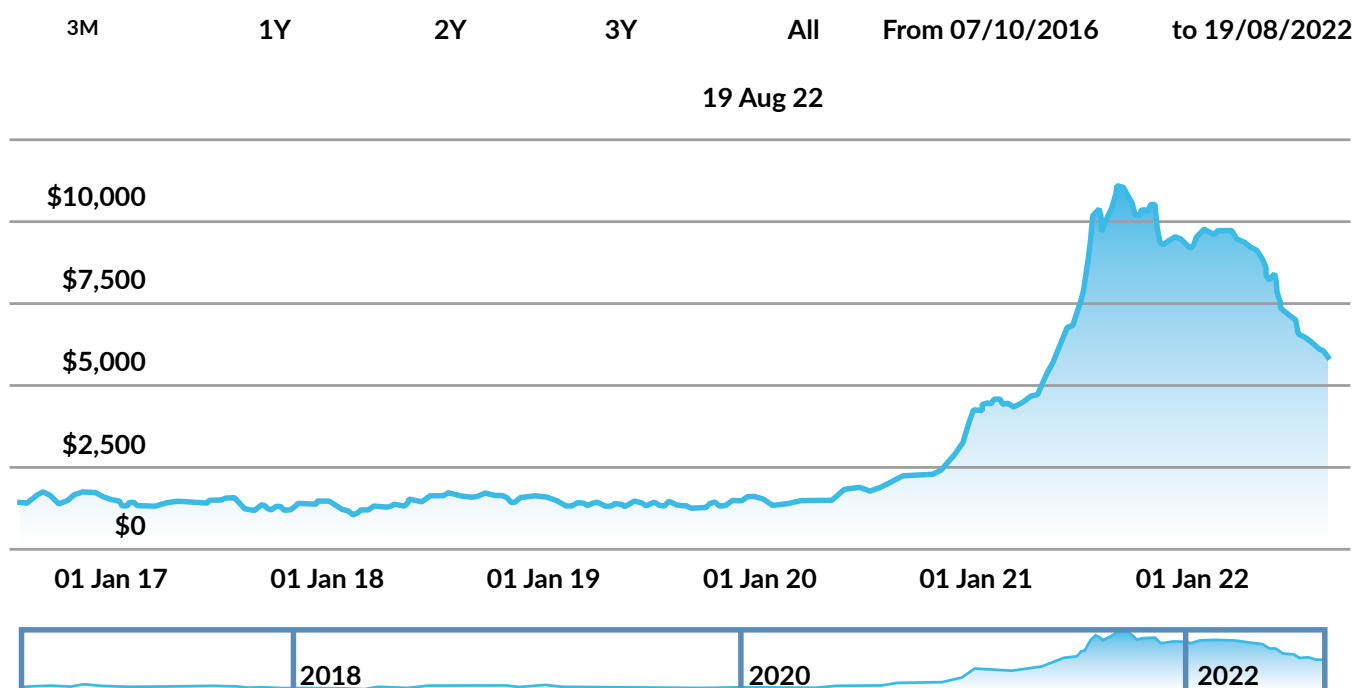
We have to differentiate between materials and components that are unavailable globally due to manufacturing capacity issues (such as semiconductors) and materials and components that are unavailable due to

logistics and related issues. The latter amplified the former in recent years with a succession of interruptions of transportation modalities. The ability to ship was further hindered by events such as the Suez Canal blockage, shutdown of harbours, and the shortage of truck drivers. Multimodal systems became a bottleneck due to container unavailability and lockdowns that caused major disruption to the circular flow of containers resulting in major price increases (see Fig. 22) and the high unreliability of predicted arrival times for intermodal transport.

These events are leading to behaviour on the marketplace that amplifies the problem. For example, many companies started stockpiling materials and components once they became available, further squeezing the markets. As it is still expected that the unreliability of arrival times in multimodal transports will prevail, this causes companies to increase their safety stocks. To date, the perspective is very company centric and does not take the needs of the supply chain holistically into account. Hence, the short-term action of stockpiling might cause further issues for the overall supply chain when similar materials and/or components are needed by different tiers of the same supply chain. Transparency and an exchange of data could address this and incentivise collaboration.

Figure 22

### Freightos baltic index (FBX): global container freight index<sup>101</sup>



## Supplier Availability

After the slowdown from COVID-19, many businesses recognise the need to improve their supply chain resilience by diversification and identifying alternative trading partnerships. However, it turns out to be complicated, leaving manufacturing companies increasingly concerned about their strategies for sourcing and procurement. Even multinational organisations faced issues sourcing from their own subsidiaries abroad due to trade restrictions, container capacity and shipping cost/delays. Torn between developing several partnerships or focusing on a few strong and reliable relationships, along with the lack of availability in critical materials and parts that support manufacturer's quality goals, companies must find the right balance in their suppliers portfolio and mitigate risks. A major factor influencing accessibility and availability is the politics-driven trend to regionalisation. We can observe more localisation and building 'independent blocks' (e.g. building their own supply chain to serve the Chinese market, with another to serve the EU/USA) to overcome the expected hurdles set by trade restrictions, tariffs, etc.

Companies are not only actively seeking to broaden their suppliers to match the goals and values of their organisation, such as prioritisation of sustainability and ethical sourcing, with minimal changes to transport and logistics providers. Supply chain leaders are also focusing on risk monitoring to address inherent and residual risks in near-real time and cyber risks.

Manufacturers can build agility and resilience by working on the diversification of their supply chains, which can include working with providers who have adopted servitisation and other business models that support sustainability. This means that new and more modern technologies, which can include trading systems, planning and analytics as capabilities and imposing new logistical requirements for suppliers can provide better operational flexibility and allow them to reduce costs. Some of the resulting scenarios can include stronger and more diverse supply chains where risks related to costs are easier to mitigate.<sup>102</sup>

## Employee and Workforce Shortages

The manufacturing sector, which has been exposed to the many disruptions from our world's geopolitical situation in recent years, continues its journey to recovery. This recovery is far from smooth and homogeneous, instead seasonal, regional and sectoral differences persist. As business is recovering, the industry is experiencing a shortage of workforce. A major example is the workforce shortage of security staff at airports as tourism has picked up again. Having released 2.3 million jobs globally in the aviation sector during the pandemic, airports had

difficulties recouping the workforce on time. However, the effect distribution of these trends has not been even throughout the manufacturing industry. According to the latest UNIDO report on World Manufacturing, the high-tech industry is recovering faster than other sectors. On the other hand, non-durable goods, semiconductors, automotive, electronics and aircraft sectors have been among the most affected by this trend.

Further, terms like "The Great Resignation" and "Quiet Quitting" have been front and centre in business trends reports in the last year. The Great Resignation trend, describing the large number of employees who have left their current positions, adds to the already revealed need for skilled workers. On the contrary, fuelled by stress and burnout effects due to working from home during COVID-19, Quiet Quitting describes a trend of employees remaining in their jobs but just doing what is requested and prioritising their work-life balance. Along with remote working, employees discovered the flexibility to enjoy their passions, which reflects in pursuing new opportunities for jobs on the side or in taking time off. It is also described as the 'art of not taking work too seriously'<sup>103</sup>, often connected to Gen-Z employees. Having experienced the option of the remote office, current employee behaviour exemplifies that companies need to adapt to employees' preferences, which reflects in having more trust and being allowed to choose their workplace, be it working from home as well as from the office.

Accordingly, the company structure and internal policies can pose a challenge for supply chains as a whole. Strongly connected to the skills shortage and remote work phenomenon, companies need to balance the demands of their workforce for certain accommodations so as not to risk losing their talent. On the other hand, they must retain the ability to react quickly to disruption, for example, and to interact with information systems securely. This may be contradictory at times and companies must navigate this challenge carefully. Coordinating with partners within the supply chain and transparency regarding decisions to decline remote working requests are key. In some instances, flexibility with remote working policies might even be beneficial from a supply chain standpoint given, for example, the ability to access talent across various time zones which might improve response time in the event of disruption.

## Skills Crisis

Skilled labour beyond manufacturing directly impacts supply chains, and the current shortages are felt across the board, making companies realise they have to 'make do with the people they have'.

## Shortages of skilled staff in manufacturing

Ironically enough, in an industry where automation has been feared by many when it comes to the role of automation in job replacement, today companies are experiencing a large gap in skills, struggling to cover all the employment positions required to run their organisation smoothly. More specifically, they are facing difficulties in finding candidates who have the skills required to contribute to the solving of industrial challenges.

In public statements, companies working with semiconductors and chip supply have expressed their concerns and called the current job market a “candidate” market, with more demand for skilled manufacturing workers than available supply.

The manufacturing skills gap is much more than a buzzword within this industry. According to an extensive report developed by Korn Ferry, 8.5 trillion dollars are at risk for the US manufacturing sector due to the skills gap.<sup>104</sup> Adding to such concern, the increased use of digital technologies at operational levels, including the use of AR, VR and XR, has increased data collection and the wish for analytics; the pervasiveness of computer-controlled machinery, among other things, will require employees to increase their knowledge of and skills in:

- mathematics and logical thinking
- intuition and systems thinking
- stamina for agile, fast-paced working methods
- a high-tech skill set

## Differentiating between soft and technical skills

Leading analysts agree that soft skills, like critical thinking, interpersonal relationship building, the ability to manage others, persuasion, and empathy will only grow more important in the years to come. Further, there is a need for communication skills, emotional intelligence, collaboration capabilities and problem solving. Many think that the greatest leaps forward will come to manufacturers who learn how to amplify workers’ soft skills with digital tools. Managing complex human relationships has become one of the most important manufacturing skills today.

From a technical perspective, some of the skills required include, but are not limited to, an understanding of platforms, new coding languages, new hardware and devices, new datastreams, big data and business applications, technology building blocks (IoT) software, infrastructure, cybersecurity, Artificial Intelligence, blockchain, robotics, Machine Learning, mobile application development, web development, and digital skills.<sup>105</sup>

Especially within management, the need to have both skill sets, soft skills and technical skills, becomes apparent. This

is posing more and more of an issue, as most employees focus on either one or the other due to their work environment. Therefore, companies need to further engage to enable their employees to gain both skill sets to ensure future trust in their management.

## Cybersecurity

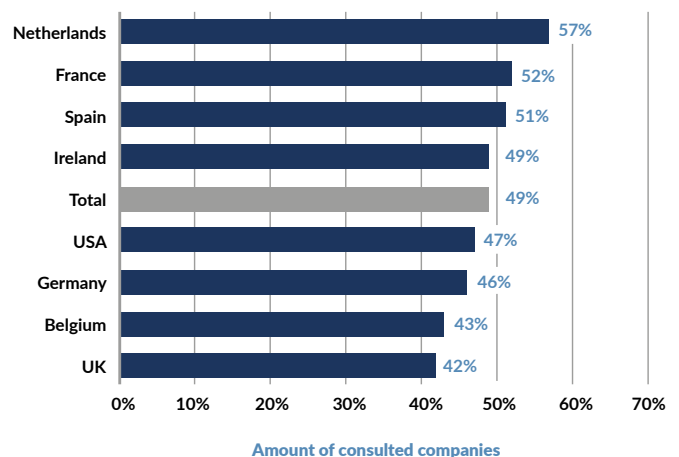
The many conflicts at geopolitical level in the last few years have brought the threat of cyberattacks on individuals, businesses, and nations into sharp focus. Cyber risks are higher than ever and their impacts increasingly severe, meaning that every organisation needs to take steps to respond accordingly (see Figure 23).

The lack of alignment of cybersecurity strategies with external frameworks, failing to create response plans, a lack of information and skills in companies’ employees regarding how to respond to a cyberattack, and the lack of clarity over regulations and compliance obligations aggravate the potential negative impacts of such attacks. Some consequences and losses of cyberattacks include, but are not limited to:

- theft of corporate information
- theft of financial information (e.g. bank details or payment card details)
- theft of money
- disruption to trading (e.g. inability to carry out transactions online)
- loss of business or contract

Figure 23

## Number of companies experiencing cyberattacks in selected countries in 2022<sup>106</sup>



Further, while dealing with the breach, businesses will most likely be exposed to costs associated with repairing affected systems, networks and devices<sup>107</sup>. In this sense, the effect of cyberattacks should not be underestimated as shown in Figure 24. The total value at risk in the last four years for the industry by direct or indirect attacks amounts to US\$5.2 billion, a figure that is nearly equal to the size of the economies of France, Spain and Italy together. Figure 24 shows the distribution of the value of risk per country (in US\$ billion)<sup>108</sup>.

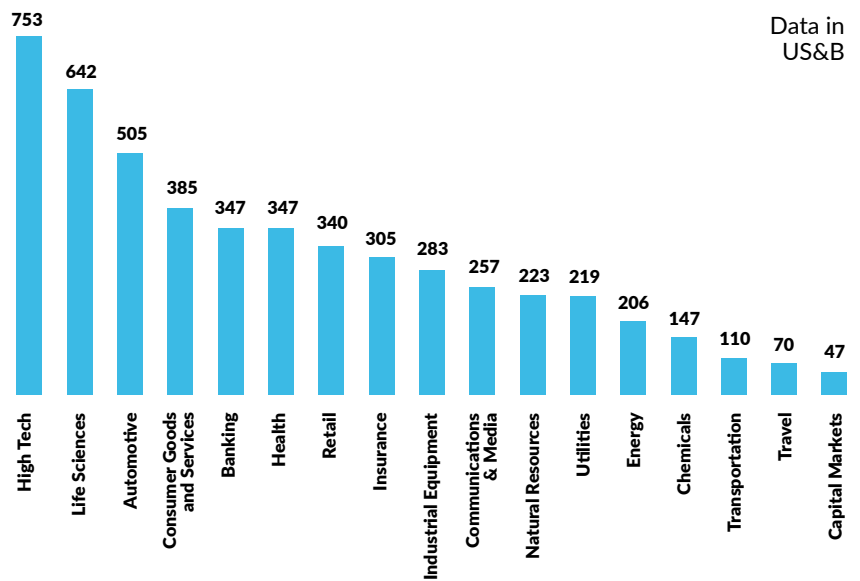
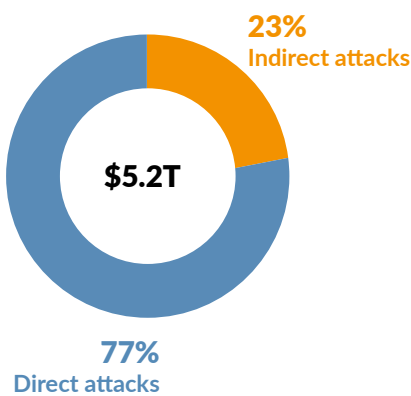
Figure 24

## Value at risk\* by industry between 2019-2023<sup>109</sup>

(Source: Accenture Research)

### Direct and Indirect Attacks

(Cumulative 2019 to 2023, US\$ Billion)



\*Expected foregone revenue cumulative over the next five years. Calculations over a sample of 4,700 global public companies.

## Challenges within the Supply Chain's Control

### Digital Infrastructure and Data Exchange

In order to achieve the previously stated goals of provisioning supply chain partners with quality data for planning, risk assessments, etc, companies must first have a strong handle on their internal digital data infrastructure and management. To date, the digital infrastructure is often an evolving compilation of different services and platforms, legacy systems, and a large number of individual, dedicated applications.

This setup poses a significant challenge for companies themselves and for their role in the larger supply chain context. Given the diversity of systems in place and the lack of clear data-exchange policies and protocols, companies struggle to determine the next step towards a more integrated, secure, and transparent digital infrastructure.

The increasing availability and use of digital platforms with composable apps can be seen as an agent of change, yet the transition is hindered by the diversity of applications in place and the lack of transparency where data is generated, stored, and used today. This is further augmented by trends such as remote working, cybersecurity concerns, and the competitive nature of production data.

Another pathway towards digital infrastructure and data exchange beyond the company borders is made up of trusted third party brokers that enable the anonymous sharing of confidential data with supply chain partners while retaining the sensitive and competitive data. These broker systems are still at an early stage. Early examples of broker systems are the Eclipse Data Space Connector that includes the International Data Spaces (IDS) standard and relevant protocols and requirements associated with Gaia-X<sup>110</sup>. It has to be noted that this strongly depends on the type of data and the industry and thus cannot be generalised. In some cases, relevant supply chain data is already shared freely among partners today.

## Interoperability between Different Systems

Building on the prior challenge of digital infrastructures and data exchange, the lack of interoperability between different systems across IT and OT can be considered a major challenge of digital transformation that impacts relevant supply chain data. Given the nature of supply chains to encompass different processes, including logistics, manufacturing, and business, the interoperability issue is elevated by the diversity of systems generating and consuming relevant supply chain data. Interoperability is already considered a major challenge internally when attempting to connect similar systems with full control and access. In a supply chain context, this is amplified by interoperability towards external systems that heighten the risk of exposure, introducing cybersecurity risk and dependency on external partners, to name just two examples.

However, this challenge even goes beyond the interoperability issues faced when dealing with different digital (software) systems. It includes different policies and rules when dealing with supply chain that encompass country, state or block borders, such as different tax rules, customs, currencies (e.g. US\$, EUR), units (e.g. miles, km, mm, in, etc) that further impact and complicate interoperability.

Interoperability is a multifaceted challenge, with technical and organisational facets. Technically, advances in cloud platforms, semantics, standards, and broker platforms are advancing rapidly. Research focuses on enabling higher-level semantic interoperability<sup>111</sup> moving forward, that addresses some of the current challenges. On the organisational side, it is necessary to develop a holistic understanding of interoperability impacts on risk and revenue sharing within supply chains.

## Communication between Supply Chain Entities

Building on the prior two challenges, the mode of communication between manufacturing units (supply chain participants) is currently rarely systems based, integrated, and digital (e.g. EDI). Even in supply chains that are considered among the most advanced, such as aerospace or automotive, communication between partners is still dominated by phone calls, emails (with attachments), and MS Excel. Especially in times of disruption, many feel the standardised systems offer too little flexibility and timeliness to troubleshoot effectively.

Various initiatives aim to address this issue and develop standards to allow automated messaging and data exchange (e.g. OAGI), often driven by the OEMs in larger supply chains. Incentives and resources availability at different levels of the supply chain hamper the fast

progression of this transition (see section on SME challenges).

The diversity of communication means used today in a supply chain context poses a challenge for data integrity and quality. When other systems (outside of the automated systems, such as EDI and ERP) are used in case events occur, the data collected may no longer reflect reality, as the 'official' systems are not updated based on the emergency measures discussed via phone. While the priority of the supply chain stakeholders at this crucial point in time may be to deliver a quality product at the agreed-upon time, circumventing the based IT systems may cause issues later on, e.g. when the historic data is used as training input for decision support AI models.

## Challenges particular to Small- and Medium-sized Manufacturers in Supply Chains

The opportunities for Small and Medium Enterprises (SMEs) in global value chains are huge. Their participation in value chains provides them with exposure to a large customer/buyer base, giving them the opportunities to learn from large firms and from engaging and surviving in the hotly contested sectors of the global marketplace. However, the rapid growth of global value chains also presents huge and often daunting challenges for SMEs: with global opportunities come global risks.<sup>112</sup>

Some of the most common challenges faced by SMEs come with the increased competition in changing markets, rapid technological changes and the reduced access they inherently have to knowledge and resources. They are experienced in terms of <sup>113</sup>:

- facing a lack of resources
- lack of economies of scale
- higher costs due to smaller number of transactions
- lack of information, knowhow and experience due to lack of networks
- inability to compete with large partners at R&D level
- lack of entrepreneurial capacity

## Resource and Skills Constraints

The crisis experienced due to lack of ability to cover employment positions is a multifaceted global problem that also impacts SMEs across many axes. A 2021 report by Deloitte and the Manufacturing Institute found that 500,000 jobs remain unfilled in US manufacturing alone<sup>114</sup>. Also, manufacturers and particularly SMEs report that it is harder to find talent today.

Needless to say, manufacturing workers of any age group feel increasingly motivated by digital environments. However, particularly today's younger manufacturing

workers are digital natives. This creates expectations around digitisation and automation that are hard for SMEs to fulfil due to the cost and complexity of traditional automation and digitisation solutions.<sup>115</sup>

In a recent research publication where SME-focused case studies were conducted, two main skill sets arose from the data as essential for SMEs<sup>116</sup>:

**(1) Personal attributes:** commitment, competence, confidence, creativity, dedication, enthusiasm, flexibility, intelligence, leadership, maturity, motivation, perception, personality, professionalism, qualifications, and reliability.

**(2) Business needs:** commercial competence, communication, IT competence, language ability, loyalty, market awareness, organisation, planning, product knowledge, sector knowledge, social ability, teamwork, management, technical ability, and work experience.

## Pressure to Provide Data in Real-time and Automated Using Specific Standards

SMEs are an integral part of almost all supply chains and as such must exchange data with the other supply chain entities. In cases where the supply chain is coordinated by a large OEM, SMEs still provide essential components and materials at different tiers. In many cases the OEM requires supply chain participants to provide data and information in specified standards and formats in an automated way. For SMEs this may pose a challenge given the documentation and requirements of adopting an automated messaging standard (e.g. EDI, UBL, OAGIS).

The previously mentioned resource constraint extends to the IT resources that are required to implement and maintain a messaging standard. This leaves SMEs with limited options including acquiring knowledge in-house (e.g. through upskilling), outsource implementation, integration, and maintenance of solutions to third parties – which is often cost prohibitive – or rely on solutions that are user friendly and do not require domain knowledge beyond what can be expected of an SME.<sup>117</sup>

## Cybersecurity

While digitisation proves to be an advantage, SMEs, especially, lack investment in appropriate IT-systems and IT-competences for a sophisticated collaboration. One of the major issues concerns the identification of relevant datasets for the exchange between partners, but also the adherence to data privacy and cybersecurity strategies are topics which are difficult for SMEs. There are an increasing amount of cyberattacks and SMEs are especially affected<sup>118</sup>.

## Little Support for Investment

SMEs often experience the fact that growth rarely comes easily. Most of them have modest and tight IT budgets which represent a huge challenge when they want to achieve levels of digitisation that enable visibility of data flows through supply chains. Lagging on their data-sharing strategies can represent a risk for their competitive advantage.

Many firms are struggling to transition from the initial solutions into deciding which of the latest cloud platforms they should adopt, but for SMEs disconnected and inefficient systems and applications are sometimes part of their day-to-day operations. In this sense, larger companies are encouraged to consider modernising their supply chain systems and investing in automation to help SMEs realise significant cost savings over the long term<sup>119</sup>. OEMs and leading innovators in supply chains must share their expertise and resources with their partners, building long-term, trusting relationships that elevate the overall supply chain and mitigate the resource constraint at the SME partner level.

## Missing Incentives to Digitally Transform

From a holistic supply chain point of view, transparency and provisioning data across the tiers and supply chain partners is crucial for resilient and agile operations. However, at the same time, the rewards and risks are not always fairly distributed and transparent. SMEs, often at a lower tier in the supply chain, are frequently required to provide data, adopt data exchange technologies, and provide other relevant insights. However, the incentive to invest in smart digital technologies to provide such data that will benefit the supply chain is missing in many cases. The main beneficiaries of advanced notice are often the OEMs that can adapt their sourcing, for example. A major challenge for SMEs today is the uneven risk-reward structure of such supply chain provisions as they internalise many of the risks and costs, yet do not adequately participate in a share of the added value this provides to the overall supply chain. In order to incentivise SMEs to capture, analyse, and share relevant data with the supply chain partners, the incentive structure needs to be reenvisioned with a fair reflection on the SMEs' contribution.

Ultimately, OEMs must take responsibility to support and guide SMEs in their supply chains and ensure that incentives to innovate are present.



# Examples of Responses to Challenges and Risks

Manufacturers have employed several responses to the challenges and risks they have experienced of late, depending on their organisational structure and their particular network settings. A common aim during the last few years concerned the general material availability that demanded collaboration and options to discuss stock and capacity availability. This tied up a lot of FTEs that are needed quickly in such situations and difficult to employ within the required timeframe.

Several responses have been deployed, some of them of technical nature and some integrating a change of mindset. Technical responses predominantly build upon digital transformation to enable early insights by better forecasts, predictive analytics and risk detection, more flexibility with data sharing, and added value by creating transparency in the supply chain (e.g. Digital Supply Chain<sup>120</sup>). The solutions enable manufacturers to be faster, more flexible, more precise, more sustainable and to engage in new business models.

Figure 25

## Digital solutions enable the manufacturing industry<sup>121</sup>



## More Balanced Approach to Lean

Over the last two decades, most companies followed lean approaches that frequently applied just-in-time and just-in-sequence deliveries, low inventory and warehouse-on-wheels concepts. This mindset has changed recently. While capital tied up due to inventory plays a minor role, it is of more importance to have critical material available. This mindset reflects in new approaches of 'Just-in-Case' instead of the famous 'Just-in-Time'. As this mindset propagates throughout the tiers of a supply chain, it creates a bullwhip effect, and the stock pipeline of the supply chain contains severalfold of inventory compared to before COVID-19. This results in exorbitant rents for external warehouses<sup>122</sup>. As internal and external warehouse capacities are occupied with additional stock, companies reported issues in operative process flows due to the creation of waste as is usually the case if space is scarce. At the same time, companies reported that wherever material is still scarce, the effects of missing parts and material has an immediate effect on the production of finished goods as the pipeline of the supply chain has emptied over the past risk events.

Accordingly, it is important to differentiate critical parts from generally available parts. This requires a detailed analysis of the supply chain and increased transparency. A general approach companies have applied as a more balanced approach to lean can be summarised in the following action points:

### Tailored inventory holding for specific material, parts, and components.

The setting up of a timely buffer for critical parts or those from overseas is more likely to be exposed to logistics issues. This increase in buffer contains an increase in days of supply without any effects on safety stock. It is important to communicate this increase to the supply chain partner in order to avoid bullwhip effects.

### Just-in-time processes remain important.

Parts that follow a just-in-time approach pertain to specific characteristics like bulkiness or a high number of part variants. Parts in just-in-time chains have undergone an optimised calculation according to their storage and supply costs and material availability. An adaptation of this calculation is necessary in case of changing circumstances, e.g. increased transportation rates.

### Increased timelines for approval of material purchases at the supplier.

Especially if just-in-time processes remain relevant, increased timelines for approval of material purchases can become a valuable option. Suppliers can purchase materials for future production for a period of up to 4 to 12 months in advance (depending on the industry and the underlying supply chain). Accordingly, the supplier has the opportunity to buy parts for the envisaged production cycle and has a guarantee from the producer that material will be paid for.

### Shortening of timelines for production approvals to ensure correct versioning of parts and components.

While timelines for material purchase allowances increased, those for production approval decreased to keep up flexibility for final production and ensure the right versioning of a part.

### Enhanced supplier development with focus on parts availability.

While supplier development was originally concerned with quality and process improvement, the focus has now changed now to the availability of parts. Currently, this process involves even top management.

At corporate level, general approaches are emerging for new purchasing and logistics strategies to ensure resilience considering long-term crises<sup>123</sup>. In some cases, an increase in stock level is discussed in the sense of an increased coverage of days of inventory or dual sourcing. By assessing the strategies of an increased stock level, additional variable and fixed costs like additional warehouse areas, inventory management systems and additional staff have to be evaluated well against the background of efficiency and pricing for final products. Often this strategy adds value for critical components and for specific supply chains that contain unstable and disrupted processes. Specifically for critical components, manufacturers review regional supply chains and a reshoring of production capacities as a strategic improvement.

## Change of Supplier Relationship and Integration to gain Transparency

Prior to COVID-19, most purchasing teams selected new suppliers mainly based on costs, including logistics and purchasing costs. However, nowadays the supply chain and potential partners are reviewed with respect to parts availability integrating different risk factors. This review of the supply chain includes an identification of critical components and bottlenecks. Depending on the

underlying network, companies change critical chains within the supplier network whenever an improvement and risk hedging option is available.

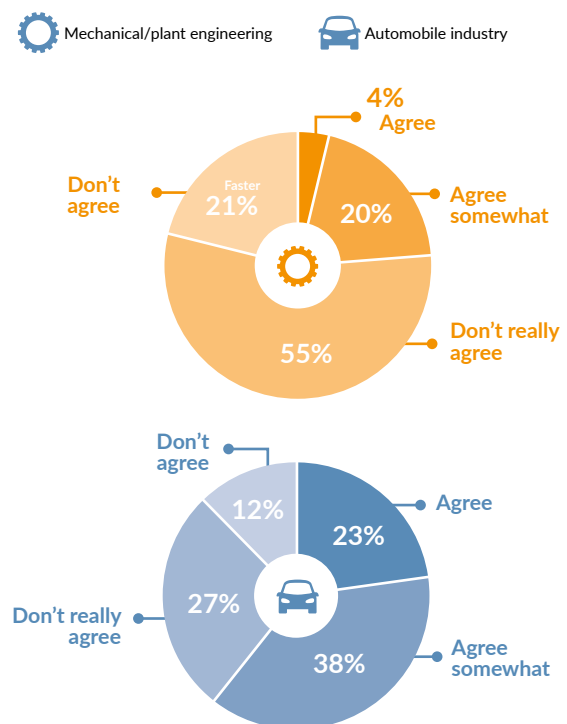
Additional regulatory requirements and awareness of natural catastrophic events in consequence of climate change enforce the integration of ecological and social criteria into the supplier selection. While the automotive industry already includes these criteria in most companies (61%), companies in the manufacturing industry are more hesitant, with 24% of companies including the ecological criterion (see Figure 26)<sup>124</sup>.

Figure 26

### Sustainability as an awarding criterion for supplier selection<sup>125</sup>

(Source: Staufen AG.)

Need to catch up: Only one mechanical engineering company out of four selects its suppliers according to ecological criteria.



A particular focus, due to the European Sustainability Act, lies in implementing ecological criteria like CO2-neutral production and adhering to social standards. Accordingly, the selection of suppliers integrates these new criteria while buying costs remain the most central criterion. But the general consensus is that next to cost optimisations, medium- and long-term supplier selection, and changes in a supply chain need to consider the optional increase in resilience to enable each partner in the supply chain to

adapt rapidly with appropriate responses to the event of a crisis. A strong support to establish adaptiveness lies in the digitisation of supply chains.

In addition, manufacturers currently integrate their suppliers along the supply chain more closely. This includes a general identification of first- second- and even third-tier suppliers as it becomes necessary to identify potential bottlenecks along the supply chain. Specified task force managers, as well as material requirements planners became very closely involved in supply chain planning where earlier, companies contacted first tiers only. In the period of the last two to three years, close contact with frequent meetings has been established. Especially with critical electronic components, these meetings have been extended to second-tier suppliers.

## Focus on Global Supply Chains to Increase Resilience

As one further option to ensure material availability, the topic of regional or even local supply chains arises frequently. This option is considered as a more reliable and sustainable alternative to global supply. Thereby, reshoring activities are considered as an iterative supply chain improvement process integrating overall supply chain risks (supply, product, design, etc), instead of a general strategic change. The discussion is further enhanced on the one hand by increased transportation costs, be it sea freight and container rates or costs for overland deliveries, and by the expectation of geopolitical blocks on the other hand.

Regional supply can reduce disturbances in transport, provide further reliability and support circular economy concepts, as has been recognised by the automotive industry that implemented regional clusters. Close cooperation due to continuous exchange stimulated by the short geographical distance between those regional partners is an additional advantage of regional clusters. The close and direct exchange facilitates the work of taskforces that were frequently mentioned as a response to the COVID-19 pandemic.

It has to be considered though, that on the contrary, regional supply chains are also prone to collapse at the same time in cases of regional risk events, e.g. floods or hurricanes. In general, along with the change in mindset of material availability in the times of COVID-19, the euphoria of purchasing on Asian markets has reduced and is more strongly evaluated under additional risk aspects. The latest research has considered reshoring more closely in different literature streams. As a constraint for reshoring, authors mention the high total landed cost as a particular constraint which is due to high costs in energy. More frequently than not it is also an issue of available capabilities in the respective markets<sup>126</sup>. The major reasons

for reshoring included flexibility and quality increase. While still considering total landed costs, reshoring has often been coupled with technology development and digital transformation that allowed high automation and implementation of Industry 4.0 concepts<sup>127</sup>.

## Adaptation to Changing Market Conditions

While COVID-19 forced companies to realign and adapt their supply chains, it also enabled companies to change suppliers in cases where it was necessary. Regarding different political trends, companies will adapt their supply chains to eventual political block building. This will further push the regionalisation of supply chains due to the incorporation and calculation of geopolitical risks. With further expectations of a recession on the horizon, some manufacturers envisage a further pooling and concentration of activities to certain regional hubs that again lead to a stronger regionalisation of supply chains. In essence, companies must continuously monitor and evaluate their supply base and work with their suppliers to build trusting relationships to be able to navigate changing market conditions. An example of such relationships are OEMs that have developed suppliers in one region of the globe in the direction of diversity and now new suppliers are expanding into other regions, building on the lessons of close collaboration with the OEM.

## Expanding and Diversifying Supply with Dual- and cross-sourcing Options

In several industries, the option of dual- or cross-sourcing has been discussed to increase the resilience of the supply chains. It involves flexible adjustments of delivery volumes. The dual-sourcing strategies often split the volume to 80% of the parts delivery from the main supplier and 20% from a secondary supplier<sup>128</sup>. The strategy mostly involves suppliers from two independent regions to cover regional risks like flooding, volcano eruption or political instability. This strategy supports efficiency by obtaining major parts of the delivery from one supplier that offers low costs and another that is offering flexibility. If a supplier is unable to deliver, the volumes are shifted. This provides the advantage of increased resilience. The downside of this strategy involves higher costs per part as volume orders decrease. This type of strategy might get implemented with an additional local or regional supplier to avoid complicated certification and quality checks. But the major volume will remain with the cost-effective supplier to keep up efficiency. For the selection of the second supplier during any of the latest risk events, material managers used historic data wherever possible to identify suppliers from which they had ordered earlier. If this had not been the case, a detailed search for a potential supplier followed.

This is an area wherein digitised solutions can support and facilitate matchmaking.

As one provision within COVID-19, some companies even restructured part of their supply chain and changed their suppliers to integrate further resilience into their supply chain. Next to the integration of more regional suppliers, this restructuring integrated the development of transport prices into the total cost calculation for parts supply. A quick change of suppliers integrates quality checks, and in many industries, specific certifications impede a change. This is particularly true of manufacturing industries in the medical sector. Some research projects from the European Union consider this fact and identify approaches to ease the certification processes (e.g. CO-VERSATILE)<sup>129</sup>. In addition, a quick change between suppliers is confined by technical developments in the product, too. Often, different IT systems in a product are finely adjusted and coupled. This impedes the integration and quick adaptation of optional suppliers. An approach to platform solutions can overcome this impediment (see also section on Common Platform Concept).

## Strategic Partnerships to Deal with Resource Scarcity and Support Sustainability

A change in supply chain structures is also triggered by strategic development. The automotive industry adapts their models to electric vehicles that require additional demand for electrochemical cells. Production capacities for cell production no longer count as a bottleneck, even more because of the supply reliability for the raw materials. Especially reserves of cobalt and lithium can become scarce due to geopolitical interests<sup>130</sup>.

At the same time, the automotive industry plans an adaptation to autonomous vehicles for trucks and cars with respective digital and electronic components, while other industries producing AGVs and autonomous industrial trucks and forklifts require further sensorics and digital components. In parallel, the construction industry continues towards the application of Building Information Modeling (BIM) and smart homes, resulting in further sensorics and electronic component requirements. Accordingly, the demand for semiconductors will further increase in future and has a high potential to cause a major bottleneck.

Different industries, amongst them the automotive industry, reacted to this future resource scarcity with strategic partnerships including supply agreements (e.g. Audi with Umicore and BMW with Glencore)<sup>131</sup>. In addition, regarding lithium-ion battery development, strategic partnerships or joint ventures are about to be established with technology partners. In some cases, agreements are made with several technology partners to profit from

different technological developments and capabilities<sup>132</sup>. In other cases, the insourcing of raw materials suppliers is envisaged, amongst them BMW, which plans to buy cobalt and lithium directly from the source with the additional advantage of supply chain transparency<sup>133</sup>.

A similar situation can be applied to the development of hydrogen energy solutions. Strategic partnerships are currently being set up with international, political partnerships, e.g. with South and West Africa, Canada and Australia to ensure future production of hydrogen energy<sup>134</sup>. Strategic partnerships are of major relevance with regard to sustainability aspects as well. Along with the political and social developments in Europe and the USA in particular, climate-neutral production is gaining in importance. To enable climate-neutral recycling concepts, Northvolt and VW have initiated a strategic partnership. Based on a production with renewable energy, the partnership ensures climate-neutral production of electrochemical cells coupled with recycling concepts<sup>135</sup>. Other sustainability concepts focus on product development to enable an emission reduction for the end user. Or the integration of reusable packaging material or returnable packaging, which is also one major implementation goal for SMEs. It is apparent though, that recycling processes require long-term strategic partnerships that allow for continuous work on the recycling process throughout the lifespan of a product.

In the case that several manufacturers produce similar products, standards and transparency support the recycling process. Especially regarding resource scarcity, a transparent tracking and tracing of integrated resources in a product facilitate the recycling process and enable different market players to have an increased interest in this process. If available, this transparency makes the recycling process attractive for SMEs, too, in order to regain necessary and valuable resources.

This approach is closely connected to data streams and common availability of the data. It is one of the areas where data creates actual value that we estimate that companies will be willing to pay for.

## Developing Trust-based Communication Relationships among Supply Chain Partners

The last few years have transformed supply chains into an increasingly complex web of interconnectivity between partners. Although the rapid digitisation of many companies has brought light to the need for new and more advanced digital technologies, and the skills to exploit them, many firms have come to realise that many of their challenges lie in more human elements of the connections between firms. For instance, the role of trust is increasingly discussed from two perspectives, both from the point of

view of data transparency, but also through the alignment of values and the reliability one has in the industrial partners of the supply chains to which one belongs.

The role of trust in supply chain management is a widely explored topic among academics and practitioners, and its complexity lies in the nature of the term, which is often based on perception rather than hard facts. For example, it is often assumed that every member of a supply chain is competent to deliver the tasks it claims it can deliver. Some reassurance can be secured from referees, but ultimately, partners are requesting companies to trust them. In a similar vein, the belief of the integrity of every member leads to the assumption that they will fulfil their promises. This is based on experience, and whilst this is good, past performance is no guarantee, leading to some unavoidable level of risk.

One of the ways in which companies can develop trust with their partners is by improving the communication process. Some of the strategies to do this include:

- Prioritise stakeholders/suppliers – consider the impact it would have on your business if they stopped supplying and how strategic they are.
- Regularly meet up with stakeholders and suppliers: get together with them on a regular basis and make sure they are regularly updated and offer constructive feedback to the supplier as well as asking for it yourself.
- Always offer options. After negotiations, produce a list of options and relevant cases that back up each situation.
- Use the right communication tool and be clear about your communication strategies.
- Tailor your communication, consider the stakeholders you are addressing and adapt your strategies to show how you will tackle their own individual concerns.

A personal and pragmatic approach will get faster and better results when aiming to implement change<sup>136</sup>.

## Attracting and Retaining Skills

Although many manufacturing firms report that recruiting in the first place is tough, the high volatility of the market also suggests that companies must work hard on strategies to retain the talent they have today. To do this, the manufacturing industry can help its workers become lifelong learners, especially in an era where skills and knowledge are becoming obsolete faster than ever before due to the shorter development processes of digital technologies, which require continuous training and updating to match new ways of working. Therefore, to meet challenges and achieve success in Industry 4.0 and 5.0, business leaders must invest in their workers by retraining and upgrading them.

Manufacturers must invest and work on<sup>137</sup>:

- Defining the capabilities and skills, instead of the job descriptions they require to succeed.

- Understanding the nature of the work.
- Emphasising the need and desire of employees to keep pandemic practices in their daily lives, such as flexibility and remote working.
- Innovating in managerial practices, involving agile practices, innovation hubs and taking advantage of multidisciplinary teams.
- Defining and reinventing the culture when needed. Build a culture that reinforces agile working.
- Working on closing the gender gap. The involvement of women in manufacturing represents worrying numbers, as they hold only 27% of positions, posing a need for covering skills gaps and improving equality throughout your workforce.

## Staying Competitive as a Small and Medium Enterprise

The large-scale events were tough on everyone, but for SMEs the effects were potentially more devastating. Beyond attempting great success, SMEs are struggling to just retain their place in the market.

It is unclear how to support SMEs and also who is best-placed to do it. However, OEMs are highly dependent on SMEs as suppliers and as supply chain partners, but there is not always a clear structure for how they can and should assume responsibility to help SMEs digitise and develop their businesses in a systematic way. If one missing component can completely stop an automotive assembly production line, it is most likely worth it to invest in developing SMEs to avoid such shortages.

When SMEs take action for development into their own hands, they might be tempted to think they require comprehensive and expensive software, but this is most likely not to be the right fit. Instead, SMEs can embrace their flexibility and the lack of bureaucracy which means they can adopt systems in a shorter timespan. Although strong leadership and a well-defined vision are prerequisites for success, they can truly benefit from their small size and avoid attempting to replicate the efforts of large companies, instead, identifying their niche and investing in innovation that supports their identified source of competitive advantage in a lean way.

The initial steps of digitisation of SMEs have huge impacts on the organisational culture of a company as they involve adopting new technologies, organisational culture, and learning skills, etc. The challenges previously mentioned in this chapter, such as cybersecurity, can mean becoming insolvent due to the lack of skills to prevent problems and the resources to respond rapidly. Further, self-assessment tools and maturity assessments across the supply chain are particularly useful to measure progress and take mitigation actions whenever required<sup>138</sup>.

# Digitisation of Supply Chains

Lately, with the COVID-19 pandemic, companies have recognised the value of the digitisation of supply chains. While being asked who was triggering digitisation in the company, the CEO, CTO or COVID-19, it remained a common joke that it was COVID-19 that had really initiated the big changes. As digitisation enables companies to gain transparency in their supply chain, COVID-19 acted as a catalyst for the digitisation of the supply chain. It remains a specific challenge that only a few partners of supply chains are digitised. Instead, it is necessary to achieve an end-to-end digitisation of the supply chains, covering Tiers 2, 3 and 4. Several initiatives to increase supply chain transparency in the sense of visibility started during that time and/or their services were in strong demand. Several startups couple blockchain solutions to enable real-time visualisation in the supply chain, including visibility of their ownership<sup>139</sup>, while other digital platform solutions enable a worldwide track-and-trace solution, including measuring the carbon footprint<sup>140</sup>. The economic potential and that for improving production processes between suppliers and manufacturers brought about by an efficient transfer, evaluation and utilisation of data within the supply chain has been recognised by several industries<sup>141</sup>. Cloud platforms play an important role for the digitisation of supply chains. Platforms enable a cross-company collection of data and a sharing mechanism for supply chain partners. In cases where near real-time data is shared, those platforms have the potential to act as digital twins. They enable a common information flow between supply chain partners and thus allow a quick reaction of supply bottlenecks or demand fluctuations<sup>142</sup>. They can even enable a first identification of supply chain partners within the network structure. In the coming years, several large automotive companies will be investing several billion euros in digitisation<sup>143,144</sup>.

Even though digitisation provides the technology to gain transparency that enables a quick reaction to disturbances and major disruption, it is still necessary to establish internal organisational structures that allow an agile reconfiguration of supply chains.

## Common Platform Concept

Most companies face the issue of using several IT systems in parallel that are not or only partly connected and interoperable. This makes it difficult to combine data and to trace relationships and dependencies between data. This concerns data that is required internally and is also relevant for the exchange with external supply chain partners. Knowing that it will be difficult to keep all IT solutions on one single IT system, large manufacturing companies plan to develop or employ dedicated platforms

with a common software architecture to integrate different data from production and logistics throughout the company and for different brands.

At the moment, companies establish different partnerships with external IT companies, for example, ZF Friedrichshafen cooperates with Microsoft Azure to connect all relevant data to optimise the connectivity of ZF components in cars<sup>145</sup>. Several companies prepare for new platform solutions by ensuring that each newly acquired software system provides an interface to their ERP systems, as ERP and MES service providers encourage their business development as being platform providers, too. As an example, Porsche establishes a strategic partnership with SAP to accomplish their digital transformation<sup>146</sup>.

These developments show that companies envisage higher success prospects with the establishment of independent and neutral platform companies<sup>147</sup>. In addition, the independence of these platform providers ensures neutrality towards all supply chain partners. Accordingly, suppliers to manufacturers have the choice to connect to a platform and use the same provider for their own operations or to simply establish an interface. A standardised platform solution for specific industry sectors, though, has not yet been established. As a consequence, as suppliers frequently deliver to different manufacturers, interfaces to several systems are still required. First solutions for an industry standard for an interface that can act similarly to a mobile app as we know it from our mobile phones are in discussion and being researched.

## Digitisation to Deal with Uncertainty

Collaborative planning tools that build upon data sharing facilitate planning by providing common approaches to deal with uncertainty. During COVID-19, several startups and sea freight service providers developed software to provide transparency on where a vessel is located, which containers are on the vessel, and the content of the container. A search function allows the tracing of ordered goods or a particular vessel to be located. Tradelink, Setlog, and Transporeon provide examples for this type of track-and-trace solution.

Due to the experience gained during the COVID-19 pandemic, several companies have invested strongly in the digitisation of their supply chain. A manufacturer of trailers and truck bodies, for example, is investing several double-

digit million euros in digitisation, allowing them to deal with uncertainty and volatility in demand and supply chain. Advances in digitalisation and cybersecurity are further supported by funding agencies as they are considered essential features for the GDP generation<sup>148</sup>.

In general, it is recommended that transparency be enabled in relation to the entire supply chain to ensure an end-to-end risk evaluation. By deploying simulation tools, risk effects can be evaluated, and perspective risk responses can be integrated into the supply chain design. This ensures an integration of resilience into the supply chain design<sup>149</sup>. The required transparency demanded by the European Supply Chain Act might prove to be an advantage when dealing with uncertainty. Data management throughout the supply chain or with core supply chain partners greatly allows flexibility and efficiency to be increased in the supply chain and ripple effects of risks due to early integration of risk responses to be reduced<sup>150</sup>. Data that needs to be exchanged on a real-time basis includes material, intermediate products, and current processing status.

Manufacturers who already had an early escalation of upcoming bottlenecks in the supply chain in place have benefitted well. The early escalation allowed them to discuss available capacities with their suppliers at an early stage and enabled them to reserve capacities with a timeline of three to four months earlier.

## Increased Willingness to Digitise and Share Data

One of the mindset changes that we have recognised during recent years includes an increased willingness to digitalise and to share data. The most evident reason for collaboratively sharing data includes the time-saving factor<sup>151</sup>. This was of particular relevance during COVID-19, since a vast number of discussions with suppliers and customers were required to coordinate capacities and prevent bottlenecks. Big companies as well as SMEs already digitalise or start digitalising operative process events including advanced shipping notifications or delivery notes, or planning parameters like delivery schedules. Several manufacturing companies envisage sharing operational data on transportation and goods receipt and sustainability datasets to enable compliance towards the German Supply Chain Act or the European Due Diligence Directive.

Recent events showed the importance of sharing additional planning data. Manufacturers who shared information on inventory and capacity planning during one of the latest risk events benefitted by streamlining their supply chain processes. With critical suppliers that can cause a halt in production, it proved furthermore essential to have a digital exchange of available stock data. Information about upcoming plant shutdowns (at the production site

and at the supplier) was of particular importance during COVID-19. Once this information was at hand, it enabled affected companies to start reducing inbound flows from other suppliers to prevent an overflow of warehouse capacities. As the world's geopolitical development is still causing great uncertainty about future economic development, partners throughout the tiers are increasing their stock levels. Sudden demand decreases or non-production ability due to lack of other resources mean that stock levels within the pipeline increase tremendously and cause typical bullwhip effects.

## The Blessing and the Curse of Data and its Value

Recent events have shown the value of data throughout the company for both operations and planning. This includes the acceptance of sharing data under aspects of cybersecurity. In parallel, it has increased the awareness of the value of additional data. While data can create value, it often represents a blessing and curse at the same time. Collecting data from several suppliers or customers or from internal datasets counts as an additional cost factor. Therefore, additional data has to be selected carefully and matched to the right data points within the company in order to be used effectively and to create additional value. Collaboration in relation to data transparency improves flexibility, but it is important to consider the amount of data creation. Sharing sales volumes and customer orders, production data, delivery and lead times or even further data can cause a data overload and issues concerning data privacy. It is hence important to limit the exchange of data. In addition, it is necessary to differentiate operational and planning data to be able to define frequencies for data exchange. As supply chains with several echelons contain a vast amount of data, it is important to reduce the necessary data to a minimum to avoid not only high data handling and storage costs, but also to reduce data interpretation and bundling time for staff<sup>152</sup>.

## Increased Supply Chain Collaboration via Digitisation

Interviewed manufacturers mentioned that, in general, data for demand forecasts from the producer is exchanged with the first-tier suppliers and suppliers reflect in return the expected demand they will be able to fulfil – again, highlighting the responsibility of OEMs to drive and support digitisation of SMEs in their supply chains. Further data throughout the supply chain, a digitalised overview of the supply chains (and their networks), or even digitised capacity data support the collaboration and enable a more adaptive approach towards unexpected risks.

During COVID-19, many manufacturers had to individually call their suppliers to request further capacities and to

coordinate future deliveries. Several manufacturers had to employ additional staff due to these coordination activities. The purchasing departments expressed the need for an automatism that provides further transparency in the supply chain. An automatism would be required that indicates available production capacity at a supplier and matches it with additional required demand from the producers. The digitalised context of this automatism will avoid frequent coordination calls between purchaser and supplier with intermediate rechecks with the production teams. This automatism then needs to integrate ATP mechanisms to check the realisability of integrating material on stock or in the pipeline. A first step is to set up this mechanism in one supply chain echelon, while the ideal future scenario would integrate an automatic check upstream until the raw material supplier. This automatic check requires a digitalised supply chain.

Digitisation serves to intensify the direct communication with the supplier and to integrate the supplier into the production planning. Thus, the automatism mentioned above can act as a decision support to facilitate decision-making during discussions between supplier and producer. Therefore, it is necessary to integrate first those suppliers that cover the majority of purchasing volume or deliver critical parts.

Digitisation enables a flexible adaptation of production planning with a daily planning of production sequences to integrate dynamic developments of the supply chain at an early stage. This necessitates that changes in production planning are directly passed to other planning entities, e.g. materials procurement. This requires a common platform concept or an ERP system that connects the planning entities internally and externally. It provides an adaptable supply chain for minor, mostly operational risks.

Interestingly, the construction sector might evolve as a pioneer for end-to-end digitisation of the supply chain. As the sector prepares for BIM, it establishes digitised processes in parallel. Those again trigger several new business models in the construction industry.

## New Business Models via Digitisation

Technological disruptions, along with changing global environments are changing the competitive landscape, fully impacting business structures and processes, while reducing the clarity around what is needed to innovate and creating variations across companies in the same industry, for instance manufacturing.

In response to the velocity and turbulence of the manufacturing environment and taking advantage of the increased availability of digital technology, firms

and groups of firms have increasingly established digital platforms for the combination of technologies and the delivery of services. In Europe, the Horizon 2020 programme launched several initiatives to advance the development of digital industrial platforms with a budget of more than 100 million euros<sup>153</sup>.

The use of digital technologies and platforms directly impact the supply chain design. As products get more digitised, it opens up the opportunity to postpone the variant decoupling point with a strong effect on variant prone industries. Prospectively, highly digitised products for the end consumer can have the same standard physical design, while software feature activation allows its customisation. Still, several physical designs might be available, but this reduces the vast number of individualised solutions, as is currently the case e.g. in the automotive industry.

Other business models result from the unavailability of parts during COVID-19 and the necessity for flexibility. If digitisation provides the possibility to communicate the production and delivery status of the product, it enables the provision of a delivery time interval to the end customer. Being based on a 'track and trace' solution, it enables a direct communication to the customer about the delivery status, similar to that with parcel deliveries. The solution is important for the receiving company in the case of cross-country relations.

In cases of non-availability of parts, a few companies had the idea to use the digitised supply chain processes for an adaptive price mechanism for the end consumer. One company faced issues with continuous price increases of total landed costs for parts. To transfer the prices to the customer, the company communicated an adaptive actual-cost-based price instead of a fixed price catalogue. This requires a digital price catalogue for the parts that includes total landed cost calculations per part. Others have applied buying incentives via price adjustments for specific products or product constellations.

In addition, digitised environments have enabled the rise of servitisation, as if companies are armed with a better understanding of the digital technologies available, and their application, they can transition from mere strategies to holistic business models where they can position the customers at the centre of their value proposition. This way, digital servitisation allows, for example, the accessing of information during the product lifecycle that can be applied to improve the product design or to have a radically different approach to maintenance, the management of spare parts, or even solving problems of resource scarcity by using digitalisation to facilitate and implement concepts of circular economy. Ideally, this transition will provide great opportunities to become more sustainable in the long



term through the collaboration of different stakeholders across supply and complete value chains.

## First Steps towards the Metaverse – Digital Twins to Analyse what-if Scenarios Based on Real-time Data

Once supply chain processes are digitised and real-time operational data available, technologies like digital twins provide further opportunities for quick supply chain adaptations. A supply chain real-time analysis of a digital twin predicts delayed deliveries and visualises risks and bottlenecks. If the digital twin technologies are coupled with what-if analysis with supply chain simulation, it allows the analysis of optional responses to the risks. This kind of decision-support in the form of self-monitoring and self-healing systems support adaptive supply chains. Most digital twin solutions integrate AI algorithms. But it should be kept in mind that digital twin solutions require sophisticated, robust, and if possible non-proprietary, and secure ICT supporting infrastructures to deal with the gathering, storing, integration architectures, and interoperation of real-time (often massive) information from different and distributed sources, especially when self-monitoring and self-healing systems are applied.

A broad application of digital twin solutions requires powerful and easy-to-deploy tools for the setup of digital twins. Current digital twin solutions include W2MO from Logivations and, with focus on the production perspective, from Unity and Omniverse from NVIDIA.

Further developments will link digital twins with real-time data, AI applications, supply chain simulations for what-if-scenarios with VR- and AR-technologies for creating a supply chain metaverse. The metaverse scenario of a supply chain shall provide interested stakeholders with a full overview of the transactions within a supply chain and merge the planning and execution of supply chain processes. With the visibility on transit times, shipping delays or real-time shipping costs, the metaverse enables a direct evaluation of supply chain transformations. The effects of a redesign on lead times, emission, and costs can directly be discussed with stakeholders.

## Integration of Staff in Digitised (AI) Processes

All digitisation processes need to be accomplished with change management in mind and in place. This allows the staff to be upskilled and for an understanding of the underlying technology to be provided. It is of particular importance to conduct relevant training when introducing AI algorithms to support decision-making. The staff needs to know which functions the AI supports and how it works, and especially, what the limits of the AI's inputs are. Then it remains a gradual process and the staff can support further improvement processes. But as the processes are often difficult to explain, especially in the case of decision-making on data, the training of the staff remains a challenge.

# Supply Chain Transformation - next Steps

The challenges of the last few years have amended the supply chains of most manufacturers. It is now important to keep up with the supply chain transformation by prioritising sustainability, especially with regard to the upcoming energy crisis, reenvision digitisation to support changes in the supply chain and make the most of upcoming technology advances. This is particularly necessary to integrate uncertainty into the supply chain and prepare for quick amendments and rapid reconfigurations. Those changes in supply chain operational and planning processes require different skill sets. Manufacturers need to address the topic of upskilling their staff, to give a true chance for the creation of value beyond material flow.

## Embracing sustainability priorities in supply chain transformation.

Global events and sustainability regulations bring more and more light to the need for more sustainable practices and transform the supply chains to fit the increasing standards, avoid social scandals and meet global goals. Many companies are increasingly imposing regulations on their suppliers to comply with their internal goals; therefore innovation in this sense might mean keeping partners. Incorporating supply chain sustainability considerations early in the product development process, e.g. product design for supply chain adaptations or even recycling processes, becomes increasingly important. Expanding this concept, adding agility and using redesign for supply chain as a means to

adapt to changing conditions and interruptions by changing materials, product features, or other levers to ensure a functional and sustainable supply chain becomes the next hurdle. At the same time, the design of the product lines and surrounding infrastructure needs to be flexible enough to incorporate the changes in product design.

Taking action calls for more comprehensive traceability models, systems, and indicators to allow both companies and customers to check items' origin, quality, certification process, and control ethics regarding labour. A holistic perspective to sustainability focuses on the triple bottom line, where economic, environmental and social sustainability are considered. Assessing tradeoffs among the three pillars of sustainability needs to be addressed as a priority in the future, as it was particularly challenging in the recently experienced disruptions. A proper definition of a company's purpose and approach to sustainability goals poses a requisite to efficiently implementing sustainability requirements, as well as attracting both workforce and customers.

The environmental perspective will play a major role in a mid- to long-term horizon. Increased sustainability awareness, the necessity to reduce emissions or to reuse raw materials will drive companies to a more sustainable approach and to develop products using recycled material. The need for setting up processes for recycling and the need for reduction in transport emissions to enable a product CO<sub>2</sub> neutrality will accelerate a transition to regional, circular supply chains. This reflects in several projects from manufacturers to reduce delivery time and to design short supply chains to reduce emissions, foremost by prioritising intermodal transport<sup>154</sup>.

These purpose-oriented regional supply chains can still be connected globally in cases where circularity is maintained. Some initial projects to reuse raw materials have started in areas that are spatially close. For example, Audi collects residues of aluminium from their production and reuses it in their pressing plants. This secondary aluminium consumes less energy in sheet production<sup>155</sup>. Further initiatives have been taken regarding product design, e.g. by using pentane as foaming material. Pentane has ecological advantages and can be used for isolation.

The European Sustainability Due Diligence Act but also the latest risk events have had a lasting effect on the supplier selection process. While costs remain the central criteria, adherence to human rights and social standards are becoming more significant. Overall, increasing resilience, agility and transforming towards more sustainable supply chains will require new setups that require work and a change of mindset. However, there are many incentives and positive signs of adaptation in the development of a new normal.

## Reenvision process for digitisation for true value gain.

The manufacturing industry needs to reenvision digitisation of the supply chain to effectively realise new opportunities to increase the resilience and flexibility of supply chains, to set up more climate-friendly production processes, and to gain market share by fulfilling customers' expectations.

The true value of digitisation of the supply chain lies in the possibilities that transparency provides to handle supply chain processes. The technology is now available to digitally trace material flows throughout the entire supply chain. The technologies involve knowledge graphs, provenance determination and real-time data collection. Careful planning and implementation is required for the latter real-time step to efficiently deal with the data and to enable staff to still connect data flows and catch up with the technology steps.

With the real-time data and the correct interconnection of the datasets, supply chain transparency allows the identification of bottlenecks and delayed deliveries. By identifying a transparent and reliable delivery date, the transparency eases communication processes, thus providing a true value gain for supply chain coordination if implemented correctly.

As transparency in the supply chain involves data sharing, companies need to be able to trust in providing data and envision the value gained by sharing data. Several players in the supply chain are still extremely uncertain about the added value of sharing their data.

While companies evaluated the risk of negative consequences of a lack of data or so-called lock-in effects as very high, the trend shows an opening up towards data sharing due to the experiences during COVID-19. This is now the right time to start projects towards supply chain transparency and to identify appropriate technologies.

The main features for data sharing involve an open system architecture and the principles of data sovereignty and interoperability. Decentralised operator models will prevent lock-in effects and the use of federated services will provide access to necessary platforms and ecosystems within the network of supply chains. First steps have been taken by a major project from the automotive industry, Catena-X, which implements a contractually secured and highly efficient peer-to-peer communication with end-to-end semantics to ensure data sovereignty, realised via an Eclipse Dataspace Connector (EDC)<sup>156</sup>.

One of the major challenges for companies remains the identification of secure and fraud-resistant mapping of transactions in a digital, information-based supply

chain. Different Distributed Ledger Technologies (DLTs), amongst them blockchain, have the potential to provide tamper-proof data exchange<sup>157</sup>. This enables further automation and autonomisation of intercompany processes in a supply chain. Accordingly, several blockchain projects deal with secure data transactions to enable reliable transparency in a supply chain; Everledger, for example, uses blockchain-based solutions for effective tracking and tracing of products while ensuring the provenance of the information<sup>158</sup>. As an example, the BORDER project facilitates customs clearance processes via national and cross-border digital credentials using blockchain technology<sup>159</sup>.

The digitisation of processes generates several new digital business models. Some of them directly impact the supply chain design, while others are generated out of necessity. Foremost of all, supply chain transparency provides a data ecosystem that increases the resilience and flexibility of supply chains. It is also an enabler for adaptive supply chain solutions. With the support of end-to-end digital documentation, it is furthermore possible to implement an integral carbon footprint and social traceability as requested by the Supply Chain Act.

There is still plenty of room for additional ideas for appropriate business models that apply supply chain transparency and technologies that incentivise supply chain transparency.

### **Embrace current and new technology.**

Next to digitisation, several other technologies support supply chain transformations. The concept of platform technologies and their collaborative use with suppliers can enable or simplify different AI applications in logistics. One of the examples already applied by some manufacturers or in planning is an AI-based delivery note identification combined with an automated goods receipt in the inbound. This enables deliveries to be received throughout the day independent of shifts. Especially for smaller delivery volumes for SMEs this can provide a major advantage to adapt delivery frequencies and order policies. Once the generated data from the inbound deliveries is connected to the platform, it provides direct access to the received parts for production processes or value-added services.

Future developments towards implementing digital twins and the metaverse further enhance the possibilities of supply chain transparency. Implementing metaverse options provides the opportunity of creating a digital continuum by integrating different planning levels into digitised processes. This facilitates collaborative planning between departments and with different supply chain entities, including the consumer of the products. It furthermore allows the coordination of quick amendments

of the supply chain as planning and operative processes get interconnected. In this regard, the digital continuum acts as an enabler for adaptive supply chains.

Other technological developments can influence future supply chains due to changes in the production. One of these is the integration of Automated Guided Vehicles in production and their connection to the overall planning and execution system. A connection of IoT devices to real-time data exchange can enable automatically controlled adaptations of the production. This flexibility for the production processes has its effects on logistics and parts supply. Another technology affecting supply chains is 3D-printing options. Manufacturing companies often integrate a 3D-printer to produce toolkits and auxiliary materials. This enables companies to deal with a high number of variants in the production and integrate additional production steps that would otherwise be outsourced. Furthermore, 3D printing's flexibility adds an option for short-term supply fluctuations and shortages of critical components as long as they are 3D printable.

In addition, future developments of drones envisage deliveries to the production using the vertical space<sup>160</sup>. The drones can facilitate logistics between close locations of a company and enable further stock pooling concepts via transfer between nearby locations. This again changes delivery and supply chain strategies and can provide flexibility to the supply chain.

### **Need for adaptive supply chains for rapid reconfigurations.**

Supply chains have typically been configured for running on a long-term basis. Resilient strategies of these supply chains therefore included different strategies to prepare for known risk events. The disruptive black swan events of recent years, however, allowed companies to rethink their approach to resilient strategies. Companies realised that not all risk events can be prepared for. Especially unexpected risk events like COVID-19, but also rare events with high impact like the blockage of the Suez Canal, require different methods and approaches for the management of supply chains.

In line with the experiences of the last few years, there is a shift of paradigm from resilience to adaptiveness. Adaptive supply chains have the ability to execute response options in a rapid manner in the event of a major disruption or an unexpected event, or an event that has not been considered by the company during the setup of a resilient design. While adaptiveness considers general response options, especially in cases of long-term disruptive events, adaptiveness can include strategic redesign decisions. The major capability of adaptiveness includes agility and agile organisation settings that enable a rapid reorganisation of

supply chain operations and structures. The capability of having adaptive supply chains enables a rapid identification and execution of response options.

In many manufacturing areas, the concept of adaptive supply chains requires the support of certification and quality processes, which currently makes it difficult to agilely integrate changes. Hence, by establishing adaptiveness for supply chains, it is necessary for companies to include agility in their organisational settings. Thereby, companies need to think of their organisational structure in terms of complex systems in a network structure<sup>161</sup>. Especially very volatile manufacturing environments require clear organisational structures that enable the staff to transform the supply chain according to the given disruptive situation in the form of an agile organisation.

The implementation of adaptive supply chains means at the same time that advanced and future supply chains will be more dynamic with temporary settings, sometimes created on-demand in order to better cope with supply risks, market demands and volatility in volumes. In some cases, this will reflect in a more complex and wider network of supply chains as frequent changes broaden the number of suppliers and customers.

To provide this agile setting, more flexible intermodal systems that support adaptive supply chains are required. Once suppliers and customers change or, even more importantly, if a disruptive event causes damage to a particular chain in the intermodal system, intermodal transport needs to provide alternatives to balance the overall supply chains, leading via this intermodal route. To support these agile settings, supply chains have to embrace current and new digital technology by integrating digital and technological means as mentioned in the previous intercept. Technology and digitisation support the early detection of risks and the identification of suitable responses to disruption, but also data transparency by enabling close collaboration with supply chain partners necessary to find suitable and actionable agreements on responses to disruption. Especially virtual environments, as envisaged by the approaching metaverse, support rapid transformation, as required for adaptive supply chains. A further technological support for adaptiveness are plug & play integration models, rapid supply chain contracting, e.g. with DLTs.

### **Address skills shortages across supply chain transformation.**

Re-skilling, upskilling, and talent retention are some of the most commonly used practices by manufacturers to address the labour shortages that have become apparent across several domains. In this sense, we are

talking not only of the long-discussed shortage of staff to complete logistics, such as drivers, but also in relation to many other required activities. Often, staff shortages which have recently been generated by resignations caused by mismatches between employees' values and a company's vision, resulting in a lack of joint purpose, have had a great impact on the planning of work. Today, most manufacturing companies address these challenging shortages through leases or subcontractors. This has triggered manufacturing managers to rethink the way processes could be automatised, for instance, through AGVs and other changes to inbound processes.

However, a strategy that is gaining traction is to address the disconnect between (future) employees and companies by rethinking the company's purpose so that it is aligned with that of its employees. Clearly defining and formulating the purpose and objectives of the company beyond revenue can make a difference in terms of retaining and attracting talent.

To overcome workforce shortages, companies have increasingly looked at the investment that would be required to adopt increased autonomisation. At the moment, autonomous systems are mostly integrated in the production area and for quality checks. It is further envisaged that autonomous processes be employed in the inbound area to facilitate the unloading and storage of incoming products. Once autonomous trucks are in place<sup>162</sup>, the complete inbound logistics process can work independently. A connection of the autonomous trucks with unloading by autonomous vehicles can result in complete driverless inbound deliveries. There is still a way to go, but once it is in place, it will have a strong effect on supply chains and new settings will have to be integrated into the supply chain transformation.

In order to employ such autonomous inbound processes, it is necessary to couple the information relating to the different autonomous entities in a system, e.g. via cyber-physical systems. This requires reliable real-time data and the respective transparency in the system. Certainly, before such a process can be realised, the structure and processes have to be optimised. Moreover, planning and operating systems have to be integrated into a common platform to enable decision-making throughout the different planning and execution steps.

### **Creating value beyond the material flow.**

The supply chains of the future will require the value they deliver to their customers to be reinforced and expanded, necessitating investments in capabilities to create a safety net and remain competitive. Some managers have referred to the fact that beyond the need to develop competitive advantage, today's market is about competitive necessity – staying afloat is becoming increasingly demanding.

This approach, applying digital solutions across supply chains, is a powerful way for businesses to deliver results among several dimensions, meaning that in every step of the value chain, manufacturing faces an opportunity to react to new needs and challenges in such a way that they can capture value if they notice it. Although each firm has different capabilities and needs when it comes to their development, the digitisation of supply chains requires starting with the customer and roadmapping backwards to find any source of missed value that a manufacturer can capture through a new business opportunity. In this sense, digital services can cover many of the needs that only those partners closely collaborating can spot and react to in a structured manner.

To achieve this, some companies have proposed that when dealing with business-to-business (B2B) relationships, key opportunities might arise if relationships mimic the smooth and efficient business-to-consumer (B2C) customer experience that retailers like Amazon have implemented. This way, new services and opportunities for delivering value appear, and trust-based relationships are developed, which can potentially make it easier to align values and expectations across companies and define a common path for future transformations.

## Redesigning Towards a Greener Future – a Mission and a Duty. The Case of Sandvik Coromant

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Climate change, natural disasters and the COVID pandemic remind us that the linear production paradigms must be redesigned into more sustainable patterns. They have also highlighted the role of manufacturing as a global engine, which delivers much more than products.

Manufacturing can no longer endure a product-centred approach. As a market leader in the manufacturing sector, Sandvik Coromant has adopted services, transforming products into solutions, and becoming an interconnected mix of tangible tooling systems supported by digitally enabled services and platforms that maximise value captured from data.

An early enthusiast of the twin transition, Sandvik Coromant envisions digital technologies and sustainability transitions as means to enable circularity. The firm has responded to the latest volatile years by becoming more responsive and creating strategies to be reactive and agile.

### **Business model and sustainability as a competitive advantage**

Sandvik Coromant's business model is based on the co-creation of value with customers to enhance their functionality, productivity, and sustainability. The main competitive advantage is maximised value capture, selecting circularity as an advantageous strategy to enable both tangible (i.e. materials and resources) and intangible (i.e. information and data) feedback loops.

Tangible loops enable the retention of materials and resources, allowing competitiveness in an era of shortages of semiconductors and critical materials. Sandvik Coromant believes in the value of integrating and working with suppliers at different levels of maturity in both digital and sustainability, considering it a learning experience. Also, global presence highlights the value of local adaptation, which has a great impact on the varying regulations for suppliers and clients which have

geographical-specific needs and requirements. Then, intangible feedback loops allow the transformation of data into knowledge, develop organisational learning, and improve critical decision-making. After the operational disruptions recently experienced, Sandvik Coromant has worked hard to establish tighter collaboration to enable flexibility. The development of trust-based relationships with customers has been key to being considered a reliable and dependable partner.

### **Prioritising sustainability**

Circularity and sustainability, two main pillars for Sandvik Coromant's operations and decision-making processes, have guided projects such as the installation of solar cells in different plants<sup>1</sup>, energy-saving initiatives and other innovations that are being used to reduce carbon emissions and achieve established targets. Some of the environmental objectives have been achieved ahead of schedule, partly because efficiency and waste avoidance align with the lean-working philosophy implemented early in Sandvik's operations.

Today, science-based targets<sup>2</sup> support the quantification of supply chain goals and actions. From a supply chain perspective, the selection of key suppliers undergoes an extensive prioritisation process. Further, suppliers also become teachers, some have developed high levels of maturity, and Sandvik learns from them whenever possible. Additionally, Sandvik Coromant considers it compulsory to educate the workforce, making it their responsibility to allow them to be well-versed in sustainability concepts by offering relevant education.

### **The role of digitalisation**

Sandvik Coromant has been a very early adopter of digitalisation in cooperation with IBM, Microsoft, and other digital pioneers. Their digital journey builds on their core lean philosophy – the firm strives for coherence and to develop systems where there is a seamless connection

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through the supply chain. For this matter, business intelligence applications are increasingly used to analyse KPIs and measure sustainability. Further, strategies such as IT roadmap development pave the way for the inclusion of increased automation, such as robot applications for the scanning of outliers in planning processes, particularly useful in this era of volatility and high volumes of data which require synthesis.

In conclusion, Sandvik Coromant is a believer in the power of digitalisation along with strong leadership and well-established working methods to achieve sustainability objectives and enable a more circular economy. Accountability, both as a company and as individuals, has guided and will continue to give direction to the growth of this company.

Statements from managers at Sandvik Coromant such as *“Nobody is questioning, why are you striving for sustainability? We just know we all must do it”*, bring strength and hope for a more sustainable future in the manufacturing industry.

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## The Demcon Response to the Sudden Increase in Medical Equipment Supplies

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### General background

Medical equipment was in high demand during the COVID-19 pandemic. As a result, manufacturers of medical equipment experienced unanticipated high order peaks, with an up to tenfold increase in demand compared to the standard order intake. As a consequence, manufacturers had to adapt and ramp up their production, change the planning of their production lines and manage the increased deployment of staff. After having addressed these internal issues adequately, the supply of ample critical parts to the production lines turned out to be an additional, external challenge. With a supply chain laid out for the expected production quantities according to a 'normal' annual growth rate, manufacturers faced issues in receiving the necessary components.

Due to the global COVID-19 pandemic and the associated sudden increase in demand, several medical equipment manufacturers and their suppliers faced major supply chain challenges. These challenges were twofold:

- **Production ramp-up:** the pre-pandemic production resources were limited, which delayed production capacity expansion.
- **Supply chain streamlining:** supply chains were disturbed by border closures and transportation issues resulting in extended lead times, plant shutdowns of suppliers or sub-suppliers leading to reduced material availability, and a surge in demand from several customers culminating in a fierce competition for materials.

### Production ramp-up at Demcon and effects on the supply chain

Demcon, a developer and supplier of technology and innovative products, located in the Netherlands, faced an exceptional increase in demand for its ventilator modules and respiratory systems. Demcon's supply chain was unable to respond immediately to this sudden and extreme increase. At the peak, demand numbers reached a thirtyfold

increase with respect to the regular production quantities. This increase had implications for the whole supply chain, as suppliers were asked to ramp up their production output for Demcon by up to thirty times. The challenges were even greater at suppliers that manufactured unique parts that were used by different ventilator manufacturers. In addition, tools to quickly identify supply chain bottlenecks were not available at Demcon.

Demcon had to respond and take immediate action to ramp up its production and secure the supply of parts that were sourced globally. At the same time, Demcon had to deal with the uncertain development of global production shutdowns and transportation availability. Bottlenecks in the supply chain were, however, initially undiscovered, disguised by a lack of information from suppliers and/or by a lack of the appropriate tools to evaluate the incoming supply stream and cross-check the material availability with the intended production schedule. It was only when Demcon and other medical equipment manufacturers started to increase their orders with their largely overlapping supplier bases that these major bottlenecks became apparent. The gravity of the bottlenecks further increased when suppliers were restricted by local lockdowns. Demcon had to monitor the dynamic settings in the supply chain to trace the most significant upcoming bottlenecks.

Several factors influenced the most critical suppliers for Demcon. Partly the critical suppliers supplied to other manufacturers of respiratory devices, with the effect that they allocated an insufficient part of their capacity to Demcon. In addition, capacity levels at the suppliers were instable, as suppliers made efforts to ramp up their own production and experienced hiccups in their schedule. As these factors, in combination with transportation availability and local lockdowns, had significant impact on the lead times of suppliers, Demcon had to reschedule production daily. In addition, Demcon had to deal with



material dependencies between the supply chain partners at second- and first-tier network level.

## **Overcoming bottlenecks in the supply chain**

Supply chains faced turbulent times during the pandemic, with high uncertainty. It became difficult to trace transportation delays, harbour closures and lead time amendments per supplier. One of the most critical suppliers for a part of a ventilator module came from China. The Chinese supplier produced unique die-casting moulds and was limited in their total production output. To keep up with the scheduled production quantities at Demcon, weekly transportation from China to the Netherlands was necessary. But sea freight was blocked, and operating flights were rare due to the extreme scarcity of cargo/freight aircraft during the early days of COVID-19.

To overcome the major bottleneck for the die-casting moulds, Demcon approached the Dutch government for support. The Dutch government initiated an air bridge between China and the Netherlands that operated for several Dutch companies. This helped Demcon to transport items from China and reduce the lead time from several weeks to several days. As soon as the air bridge became operational, Demcon set up a weekly transport frequency to ensure sufficient supply for its production.

## **Supporting tools for bottleneck analysis**

Supply chain simulation tools enable the identification of bottlenecks at an early stage and evaluate the impact of a reconfiguration of supplier relations. A simulation can serve to enhance the analysis of the reconfigured supply chain and help to define the steps by specifying the ramp-up phases that all the supply chain partners have to take.

## Enhancing Connectivity of Small-Medium Manufacturers

### Steve Carroll

COO, Sustainment

Founded in 1987 and based in Leander, Texas, a suburban city just north of Austin, Cypress Technologies specialises in electronics manufacturing services (EMS). Some of the company's specific focuses include manufacturing, engineering and design, quality control, and service and repair. Family-owned and operated, Cypress Technologies uses a specialised approach to high-value assemblies that are frequently difficult to create and typically involve thorough testing and inspection processes.

Serving primarily the alternative energy, diversified industrial, heavy equipment, military, mining, and oil and gas industries, Cypress Technologies, as Vice President of Sales Susan Child has put it, "can build anything that doesn't leave the ground." Particular examples of projects Cypress has worked on include software, circuits, prototyping, box and panel builds, and PCB, electromechanical, and cable and harness assemblies. Through project management and support, design for manufacturing, component sourcing, and more, Cypress helps make it possible for startups and entrepreneurs to take their ideas from the back of napkins to the market.

In addition to focusing on service, relationships, efficiency, and building quality products, Cypress Technologies also has a firm commitment to integrity and ethics in both the company as an entity and in the people who represent it and with whom it develops partnerships and other relationships. For instance, the company does not merely abide by all applicable laws and regulations but also stands against human rights abuses and the use of conflict minerals (e.g. tin from the Democratic Republic of the Congo) and advocates for strong ethics and environmental responsibility.

The supply-chain issues affecting businesses and economies worldwide over the past couple of years did not spare Cypress Technologies. In some cases, the company has faced lead times of 30 to 50 weeks on some needed

### Katie Sihler

VP Marketing, Sustainment

parts, but in early 2022, Cypress faced a particularly acute challenge. The company handles nearly everything in-house, but two exceptions are coatings and sheet metal, and the latter was what led to the 2022 challenge.

For several years, Cypress Technologies had outsourced a portion of their sheet metal requirements to a company in Mexico. The arrangement worked well because Cypress was receiving a product of good quality at a reasonable price. Early in 2022, though, the company in Mexico let Cypress know that they would not be accepting small-batch orders any longer. Because most Cypress clients are small companies, the orders for sheet metal were typically low in volume. Suddenly, Cypress no longer had a source to provide key components required in their electromechanical assemblies.

With the United States having a fragmented manufacturing base it makes it difficult to engage with new suppliers outside of personal relationships.

This is where another Texas-based company, Sustainment, came in. Sustainment is not a manufacturing company; instead, it is a firm founded and run by manufacturing experts who use their experience, knowledge, and connections to connect companies with manufacturers who meet their needs. Rather than creating another step in the process, Sustainment actually economises processes by saving its clients the time, trouble, and expense of finding manufacturing solutions on their own. Sustainment builds cutting-edge software and AI applications to transform how commercial, government, and regional teams discover, engage, and interact with the US manufacturing economy.

Cypress Technologies asked Sustainment to help with their challenge. Specifically, they were seeking a local or regional business who could fulfil their small-batch orders. The solution didn't take long and wasn't complicated.

In reality, that solution was rather straightforward. For several months prior to receiving the request from Cypress Technologies, Sustainment had already been recruiting manufacturing firms in Texas and creating searchable profiles for them, expanding the dynamic network of companies. The platform is organised around the capabilities and processes in which a company specialises and has expertise. Because of this, Sustainment was able to execute a search using their advanced AI-based algorithm to identify several sheet metal manufacturing firms.

Based on swiftness of response and a willingness to take on small-batch orders, Cypress settled on Amtex Precision Fabrication, operating out of the Houston-area community of Manvel, as the best potential solution for their needs. Wanting to make sure Amtex was in compliance with its standards, Cypress asked Sustainment to share its (Cypress's) vendor requirements with Amtex. After Sustainment had done so, and Amtex had provided confirmation of meeting those requirements, Sustainment introduced representatives of the companies to one another, and the companies took it from there. With secure messaging and file transfers on the Sustainment platform, the two companies were able to move quickly in forging their collaborative partnership.

The Sustainment manufacturers' platform is an example of using technology to better link the entire manufacturing ecosystem on a single platform that delivers value driven by intrinsic incentives, resulting in consistent engagement and comprehensive manufacturer (and workforce) data, furthering economic growth. As we can see in the example of Cypress Technologies, growing a national digital manufacturing community reduces the lack of diversity and inclusion that results from manual processes for supplier discovery, qualification, and engagement, thus strengthening our supply chains and expanding connectivity.

Small-medium manufacturers are essential to the US manufacturing economy. They often have an underutilised production capacity and are undiscoverable and unnecessarily siloed into one or two industries. Sustainment's use of technology moves the manufacturing base into a hyperconnected, secure, and resilient ecosystem of local and regional suppliers who can more easily connect and interact with the government and industry organisations that support or rely on them.

## Preventing Disruptions with External Data – How Martinrea Got Predictive

### **Bryan Smith**

CEO, ThinkData Works

Martinrea International Inc., one of Canada's largest auto parts manufacturers, is a global leader in the design, development, and production of lightweight structures and propulsion systems for the automotive industry. When recent global issues threatened to disrupt their supply chain operations, they needed a technology solution that would provide increased visibility into all layers of their supply chain and enable them to make quick decisions in order to mitigate risk and maintain production and delivery.

### **The Situation**

The Russia-Ukraine war has had a significant impact on supply chain operations across the world, causing slowdowns and shortages in nearly every industry. The cost of downtime is highest in the automotive industry, with every lost hour costing manufacturers US\$1.3 million.<sup>1</sup>

With many manufacturers and suppliers starting to appear on sanctions lists, preventing them from importing goods from certain countries, Martinrea knew the risks posed by a supply chain disruption were too significant for a 'wait-and-see' approach; they would need a data-enabled approach to proactively identify possible disruptions and put mitigation measures in place. The alternatives they faced were materials shortages, missed SLAs, business interruptions, and even a possible shutdown.

To fortify operations and ensure consistent delivery, Martinrea recognised an urgent need for N-tier visibility: going beyond their immediate network and offering insight into all layers of their supply chain. This next-level transparency would help prevent unplanned downtime, thereby protecting the company's profitability and providing them with up-to-the-minute insight into their supply chain that they could communicate to their customers, building trust and transparency at every interaction.

### **Megan Hunter**

Executive VP Procurement and Supply Chain Operations, Martinrea

### **The Solution**

Leading the charge, EVP of Procurement and Supply Chain Operations at Martinrea, Megan Hunter, enlisted the help of experts in data: data catalogue provider, ThinkData Works, to manage external data, and data analysis leader, Palantir Technologies. Together, they designed and implemented a Supply Chain Resiliency Platform that would allow Martinrea to collect, analyse, and act on data about their suppliers, and suppliers' suppliers, powering informed decisions about how to effectively manage their entire supply chain. "Without external data, we were stuck in a holding pattern, only being able to react to problems instead of heading them off. That didn't sit well with us," said Hunter. "ThinkData Works and Palantir gave us the full picture of our supply chain network. Armed with this insight, we can make proactive data-driven decisions to prevent any major disruptions." Martinrea formed its partnership with ThinkData Works and Palantir through Canada's Advanced Manufacturing supercluster programme, NGen, Canada's Global Innovation Cluster for Advanced Manufacturing, allowing them to quickly adopt the same data and analysis solutions deployed at multinational banks, federal governments, and other highly complex and sophisticated environments. They knew their business would be in good hands.

ThinkData Works and Palantir worked with Martinrea to create data products and an analysis platform that would solve for their specific needs. Here's how it worked: ThinkData Works used their data catalogue technology to connect to and standardise external data from multiple sources, comprising dozens of metrics and intelligence vectors (including shipping manifests, weather data, and geopolitical events). This flowed into Palantir's Foundry platform to manage analysis, alerts, and overall visibility, as well as AI-enabled prediction layers. The Supply Chain Resiliency Platform provides Martinrea with a competitive edge that would help them determine how to proceed with each supplier and every link in their supply chain.

data to create a digital twin of their ecosystem. They simulate supply chain disruptions, create back-up plans, and analyse and optimise their processes, giving the company access to insights they wouldn't get by operating in a reactionary mode with a closed system of intelligence.

## The Results

Together, Martinrea, ThinkData Works, and Palantir use external data and machine learning to address a real-world problem that could have had a catastrophic impact. At the outset of the engagement, Martinrea estimated that the outcomes of this implementation would result in more than US\$40 million in annual value from avoided disruptions and optimisations.

“Even within the first few months of deployment, we’ve seen a massive return on investment,” says Hunter. “We’re tracking million in savings and efficiencies already, and we’re confident that it will only get more effective.”

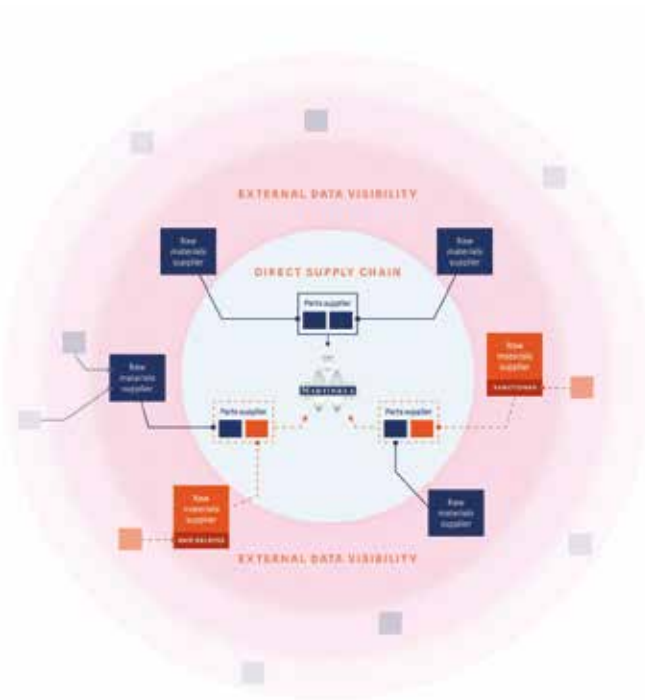
Beyond that, by having increased visibility into their supplier network, they could adopt a proactive vs reactive business model, leveraging data to predict potential issues and pivot early to prevent business-impacting delays. This would give them an advantage against their competitors who struggled to meet their KPIs while managing risk on the fly.

Enhanced predictability also put Martinrea in good standing with its customers. At the sign of any slowdowns, the company could proactively communicate with its customers and give them assurance that the issue was being monitored and resolved, something that wouldn't be possible without on-demand access to real-time insights.

Perhaps the best return on investment for the company, however, was having a repeatable model that can be employed anytime there is a significant global event. “It’s a game-changer for the business,” said Hunter. “Data is at the centre of our new business continuity strategy. We can now rely on the Supply Chain Resiliency Platform to help us mitigate risk and identify process improvements, and that will serve us for many years to come.”

## References

1 Senseye (2021). *The True Cost of Downtime*



Using this technology, Martinrea successfully identified 50 suppliers that had sanctions imposed on them, effectively extending their analytical scope beyond direct suppliers and into second- and third-degree relationships. The new data and insight at their disposal also allowed them to find alternative sources to ensure business continuity and instil confidence in their strategy going forward.

Most businesses were in crisis mode already; a speedy implementation was key to the effectiveness of the solution. Martinrea needed quick, reliable, and real-time insights to make critical decisions that could affect the livelihood of the business. From start to finish, the ThinkData Works and Palantir teams moved swiftly, yet strategically, to implement the best solution to the given challenge based on their industry-leading technology and expertise.

The Supply Chain Resiliency Platform also enables Martinrea to plan for the future by mixing in their internal

# **Vision for the Future of Manufacturing and Relevance to Supply Chains**

# Trends for the Future of Manufacturing

Future-Oriented Manufacturing, a new industrial vision formed by multidirectional focus to reinforce sustainable growth and increase global societal wealth, was developed and presented in the 2018 WMF Report<sup>163</sup>. Information was gathered, combined with input from a panel of worldwide experts, to create the vision for the future of manufacturing. Leading representatives from manufacturing firms, prestigious institutions, and both governmental and non-governmental organisations participated in expert interviews. Experts were chosen for their in-depth knowledge, as shown by their published research and articles, as well as their status as an internationally renowned leader in the manufacturing industry. Selected scenarios for the manufacturing industry in the future were given to experts to assess for validity. The future-focused scenarios and vision presented in that first global report by the World Manufacturing Forum has served as a jumping-off point for considering a variety of options possible for the development of the manufacturing sector. In this regard, the following six disruptive trends for the future of manufacturing were presented as sources of great opportunity to deliver solutions of excellence: cognitive manufacturing, circular manufacturing, global risks-resilient manufacturing, hyper-personalised manufacturing, rapidly responsive manufacturing, and inclusive manufacturing. These trends are likely to play out simultaneously and not alternatively.

## Cognitive Manufacturing

**To prepare for the large influx of data and the complexity of analytics, the new era of Cognitive Manufacturing at the intersection of hyperconnectivity and advanced artificial intelligence will revolutionise the factories of the future in four core dimensions: hyperconnected intelligent machines; AI-driven cognitive operations; smart optimisation of resources; and collaborative manufacturing as a service in the Cloud.**

The promise of cognitive manufacturing is to transform industry by giving production systems perceptive and decisive capabilities, enabling autonomous operations based on embedded cognitive reasoning, in which intelligence and reasoning are retained by humans and supported by the core technologies of the Industrial Internet of Things, big data analytics, and mobile computing. The emerging field of cognitive manufacturing is defined by the vision and capacity to perceive changes in the production process and know how to respond to these dynamic variations with little human intervention by proposing improvements in processes and operations while suggesting alternatives

to reduce cost and environmental impacts. Cognitive manufacturing is built on the foundations of the Industrial Internet of Things and uses data analytics combined with cognitive technology. Universal connectivity, cloud computing delivery models, smart digital manufacturing machines, and plant automation are just a few of the long-standing manufacturing and information technology trends that have come together to define the new face of manufacturing. These trends collectively bring about a digital revolution in manufacturing.

## Circular Manufacturing

**By controlling the whole lifecycle of a manufactured good, Circular Manufacturing would sustain the reuse of resources in the form of materials and energy through smart sociotechnical system design and efficient information use to address issues like resource scarcity, waste generation, and pollution.**

To address issues like resource scarcity, waste generation, and pollution, circular manufacturing, an emerging paradigm in the context of zero waste in the factories of the future, perpetuates the reuse of resources in the form of materials and energy through the inventive design of sociotechnical systems and an effective use of information. This is done by managing the entire lifecycle of a manufactured product from conception, through engineering design and manufacturing, to service and disposal. As more businesses see the true worth and benefits of this innovative, environmentally friendly method of conducting business, the circular economy is quickly emerging as a vibrant and quickly spreading mainstream trend. This tremendous innovation – the circular economy for manufacturers – is being driven forward by a regenerative model in which manufacturers find methods to utilise resources and products for much longer, establishing multiple product lifecycles, supported by new digital technologies and new finance structures. This type of creativity is fundamental to what it means to be human: generating wealth and success while maintaining respect for the environment and ensuring future generations' access to it. Manufacturers are at the centre of this new revolution, and their attempts to switch to circular business models – which some are already beginning to do – represent one of the greatest challenges to innovation in modern times.

## Global Risks-Resilient Manufacturing

Through strategic decision-making and the

**upgrade of business models taking into account the hyperconnectedness of value creation chains, Global Risks-Resilient Manufacturing systems will be able to resume their roles in the reality of global risks.**

Global risks-resilient manufacturing systems will be able to resume their functions in the realities of global risks through strategic decision-making and business model updates considering the hyperconnectedness of value creation chains to reinforce cybersecurity, utilise Social IoT systems, integrate blockchain technologies, involve all stakeholders in the digital value chain, and respond to offshore threats while adapting to changing market needs as a result of their capacity.

It is crucial to move towards future-oriented resilient manufacturing systems that can recover their functions in the realities of global risks through strategic decision-making and business model upgrades taking into consideration the hyper-connectedness of value creation chains. This is because we face the challenge of overcoming data and cybersecurity concerns in a world where high volumes of sensitive data move over the internet.

## Hyper-Personalised Manufacturing

**By analysing information in the public domain, Hyper-Personalised Manufacturing will advance personalisation by developing distinctive, accurate, and personalised product and service offerings that are closely matched to customers' wants and needs.**

Hyper-Personalised Manufacturing, which is powered by data through access to vast amounts of information along the value chain, advances personalisation by analysing information in the public domain to create distinctive, accurate, and individualised offerings of products and services that are highly tailored to the requirements and needs of consumers. This type of business environment can create specialised products for both domestic and international markets.

While Industry 4.0 develops smart factories with a lot of assets, inclusive development will be fuelled by local, asset-light, hyper-personalised production and assembly. Future-proof businesses will be able to develop closer relationships with their clients and react quickly to their needs. In that vein, hyper-personalisation enables Industry 4.0 to listen to customers by analysing publicly available data and then creating products that are highly tailored to customers' requirements and needs, as in the case of a clothing manufacturer who analyses the likes and dislikes of a specific group on social media to determine what sort of designs will work for a particular group in the future. Due to discerning customers' expectations for hyper-

personalised experiences, producers need to recognise via Industry 4.0 that operational excellence goes well beyond product manufacturing. There is a noticeable trend away from standardisation via mass manufacturing towards personalisation through automation and smart manufacturing now that the internet and digital services are present in every aspect of life. The customer becomes the main point of how manufacturing operations are built as companies grow more and more customer centric.

## Rapidly Responsive Manufacturing

**Rapidly Responsive Manufacturing will respond swiftly to and seize opportunities from changes in market situations, customer preferences, manufacturing conditions, and social demands as a predictive, agile, flexible, and lean type of production.**

Rapidly Responsive Manufacturing is a predictive, agile, flexible, and lean model of production that responds quickly to and takes advantage of changes in market conditions, customer preferences, manufacturing conditions, and social demands. It also enables rapid innovation, a quick response to market demand signals, and consistent, high-quality, socially responsible operations. All of these factors help manufacturers run in a smarter, faster, and simpler way.

Manufacturing's plant floor will become much more efficient thanks to the emergence of several game-changing technologies, including collaborative robotics, big data analytics, additive manufacturing, and 3D printing. The next challenge will be to achieve higher levels of agility, rapid responsiveness, and innovation with the help of technology and people's skills. As a result, manufacturers of the future will shift from today's sole emphasis on efficiency to a tighter focus on meeting customer needs. In the future, addressing consumer requirements with greater degrees of flexibility will be considerably more crucial than efficiency. In this context, making factories agile and responsive will be the quintessential capability, and such a shift will require the adoption of principles such as proximity to demand, postponement of variability and centres of excellence, along with a massive change in mindset.

Rapidly Responsive Production will, in this regard, adapt swiftly to and benefit from modifications in market circumstances, consumer preferences, manufacturing circumstances, rapid innovation, and societal needs. Rapidly responsive manufacturing calls for adaptive and responsive production facilities that can react to volume changes of more than 70%, quickly and flexibly adopt supply chain decisions, including moving production to locations where economies of scale can be realised, and significantly shorten the concept-to-market time.



## Inclusive Manufacturing

**With the help of people-, environment-, and technology-focused innovations, Inclusive Manufacturing will empower people of all genders, ages, and social, economic, and cultural backgrounds to ensure equity and the wellbeing of every societal unit.**

Inclusive manufacturing empowers people from all social, economic, and cultural backgrounds by involving them in a variety of manufacturing-related activities. This is done by developing the necessary skill sets for the future workforce, fostering innovation in rural areas, promoting open-source designs for products that benefit a very large and diverse customer base, promoting innovative business models for easier access to markets, and providing all other necessary resources. The creation of sustainable product service systems that can be accessed and used by a very broad and diverse customer base is one of the most significant modern manufacturing difficulties in today's technology-

intensive world. The essential components of a diverse workforce, environmentally friendly manufacturing processes, and human-centered automation can all help with this. In response to this challenge, the current manufacturing paradigm places a strong emphasis on the inclusion of manufacturing drivers throughout the entire value chain.

The modern manufacturing ecosystem must take into account socially inclusive development, equal opportunity and benefit distribution, community involvement, value-based engineering, responsible innovation, product lifecycle management, and planning for end-of-life recycling or reuse. Manufacturing micro-shops, computer-aided product lifecycle management and engineering, smart supply chain management, cloud-based access to open designs, digital distribution platforms, and other cutting-edge mechanisms are just a few of the existing and emerging technologies that play a significant role in developing and managing such an inclusive manufacturing paradigm of sustainability.

# Relevance of Six Key Trends to Supply Chains and Key Takeaways for the Manufacturing Community

**As the sector transforms itself for the digital era, factories of the future and their supply networks will be significantly different from those they are now.**

Manufacturing will be very different in the next decades from how it is today<sup>164</sup>, and successful businesses will be able to quickly adapt their physical and intellectual infrastructures to take advantage of technological advancements as manufacturing becomes closer to customers and more responsive to shifting global markets. Future factories will use highly sustainable materials and production techniques, with built-in reuse, remanufacturing, and recycling for products that have reached the end of their useful lives<sup>165</sup>. Numerous cutting-edge enabling technologies are being used to transform the manufacturing sector, including 3D printing, the Internet of Things, artificial intelligence, cloud computing, data analytics, visual technologies like augmented reality and virtual reality for factory workers, cognitive computing, digitalisation from design to production, advanced robotics, and blockchain, among many others. All of these technologies will have an overall influence on manufacturing in two ways: how businesses operate internally and how they engage with external ecosystems and value chains.

In the following subsections of the report, we will discuss the six trends in the context of supply chain redesign and provide guidance for the future of manufacturing in that regard.

## Key Takeaways Concerning Cognitive Manufacturing with Respect to Supply Networks

AI has proven useful in demand forecasting and the accompanying synchronised planning, automated warehouse management, automated design and development, and connected services at the broadest Supply Network level. According to a Deloitte survey on AI adoption in manufacturing conducted in 2019<sup>166</sup>, the most popular applications of AI in industries will shift from smart production to products/services and supply chain management.

**Promote AI to support resilient supply networks<sup>167</sup>.**

The use of artificial intelligence will be crucial in business alliances and networks. Even though some businesses could be reluctant to share data, there will likely be

alliances and organisations that frequently collaborate or operate in supply networks that attempt to organise and align in terms of AI. In order to become more robust and prepared for the future as a new economic order emerges, supply chains must be reinvented<sup>168</sup>.

### Utilise AI to track and respond to supply network disturbances<sup>169</sup>.

AI may potentially assist supply networks in coping with major catastrophes. Though it should be mentioned that we should approach these circumstances cautiously and that using AI may not be the best course of action, it could assist supply chains that are experiencing disruptions like those brought on by the 2019 coronavirus pandemic. Businesses must reconsider how they engage, develop, and support their people in light of the current era of constant disruption, which has highlighted the fragility of supply chains. Despite the caution that should be exercised prior to adoption, AI has potential for developing robust supply networks for certain scenarios. Supply chains and the businesses that operate in the sector will become more robust to disruption thanks in large part to sustainability and technology. Responsible decision-making should be fuelled across the whole value chain by the potent combination of data, a people-first mindset, and new networks of collaboration.

### Exploit AI to improve daily operations<sup>170</sup>.

In addition to large-scale disruptions, AI can assist organisations in their day-to-day operations on a much smaller scale. Faster analysis of supply chains, demand-side chains, operations, processes, and procedures is possible with AI. For instance, AI systems may analyse data to provide process flow maps that show opportunities for automation and improvement, as well as the biggest bottlenecks in the process and suggestions for alternatives when breaks in processes occur.

## Key Takeaways Concerning Circular Manufacturing with Respect to Supply Networks

Recovering and managing end-of-life (EOL) items and reducing pollution are becoming more and more crucial for industry, and this presents new economic possibilities and difficulties for many industries of the industrial supply chain. Circular Manufacturing keeps valuable materials out of landfills and in manufacturing supply chains, leading to significant economic opportunities, and, therefore, considerable potential and benefits.

**The circular economy (CE) is acknowledged as a way to minimise effect and encourage firms to look into new circularity prospects.**

By rethinking goods and packaging, collaborating on resources, and fostering industrial symbiosis, businesses and their supply chains will experience improved operations.

Despite the apparent efficiency of manufacturing and freight distribution, industrialised economies have large amounts of waste due to the consumption and use of material commodities. More than half of the materials used will either be burned or discarded, depending on the supply chain, while just a small portion will be recycled or reused. Numerous factors contribute to this reality, but a common one is the cost difference between buying new and buying recycled materials. As a result, supply chain strategies may play a significant role in boosting sustainability because they open up new sourcing options. The circular economy is a feedback system that seeks to reduce both the production of waste that leaks into the environment and the input of resources. It is an extension of the ideas of reverse logistics into a more comprehensive framework that has two subsystems, one for biological commodities such as food and the other for technological goods such as products.

Although supply chains in a circular economy resemble traditional supply chains which follow a linear path from suppliers to manufacturers and distributors to the end user, there are two key distinctions, since the circular economy actively promotes supply chain collaboration<sup>171</sup>: the first is about the socioeconomic setting of consumption and product design. In a circular economy, products are made to survive longer and be reused in some way once their lifecycle is finished. Additionally, it is expected that most commodities are shared (especially capital goods), increasing their level of utilisation and resulting in the need for fewer goods to deliver the same level of service. The second involves gathering discarded or consumed technological and biological items for various forms of reprocessing, when the typical linear supply chain's structure turns into a feedback loop.

### Enable cooperation among relevant stakeholders in building circular value chains<sup>172</sup>.

Promoting trust and cooperation among the various necessary actors in the value chain is more critical than ever, since switching to circular manufacturing has become ever more challenging. Stakeholders in circular value chains must have access to trustworthy information regarding a product's sustainability. For instance, producers and recyclers should work closely together to make sure that the latter have access to knowledge about the product's components and manufacturing process to enable recycling. When creating a product, manufacturers should consider the ideal configuration to facilitate recovery and recycling after it has served its purpose.

### **Facilitate information sharing in the value chain<sup>173</sup>.**

Seamless connectivity and data interchange throughout the supply chain should be ensured to promote information sharing. It is crucial to build the required digital infrastructure and involve various players around these (digital) platforms in order to do this. Utilising widely accepted standards for data capture and storage can also make it easier to communicate information, reduce information asymmetries, and enhance supply chain traceability. Increased circularity requires enhanced interorganisational information sharing between business areas such as manufacturing and recycling, improved access to information for all circular economy players, and the creation of incentives for CE information sharing.

### **Track the flow of materials and/or products in different stages of the value chain<sup>174</sup>.**

Systems that make it simpler to trace the movement of goods at various points in the value chain will define circular supply chains. This will make it easier for manufacturers to reclaim goods when necessary. This is only achievable if all value chain participants collaborate and work towards the same goals.

## **Key Takeaways Concerning Global Risks-Resilient Manufacturing with Respect to Supply Networks**

**The goal of a globally competitive and resilient manufacturing system will be realised via the combined efforts of several players from different sectors and across various governance levels.**

Blockchain technology will be primarily used by manufacturing companies in the near future for smart contracts, process transformation, supply chain tracking, asset sharing, track and trace, warranty management (e.g. to track the vendor source of any defects and detect counterfeit goods). The rise of blockchain technology, however, will be incorporated into all aspects of manufacturing operations and the value chain, eventually causing supply chains to transform into demand chains and the manufacturing process itself to become distributed, in line with the future-oriented manufacturing vision.

The COVID-19 pandemic-related disruptions in global supply chains have sparked the discussion on the production vulnerabilities inherent in sophisticated global production networks. Due to their reliance on offshore supplies, many businesses at the company level were dramatically exposed to supply chain disruptions during the pandemic and the associated lockdowns. Given that the pandemic occurred as a shock in a context of emerging trade disputes, and increasing pressure for

more sustainable business models, it is now difficult to believe that managers could simply restart to focus only on efficiency and growth without paying the necessary attention to risk-related practices.

**Prior to redesigning global supply chains, it is important to understand the actual problems that businesses encountered during the crisis and the policies that can address such problems<sup>175</sup>.**

Given their many parallels, supply chains and blockchains are extremely significant to one another. In supply chains, which involve many different players and stakeholders in interaction, there are a lot of transactions going on, and each physical flow is connected to a supporting information flow. In order for supply chains to perform their job (provide the proper product, amount, condition, location, and time), they are organised as sequences where the integrity of the orders must be preserved.

The cyberthreats that target an interconnected system of suppliers and consumers are not addressed by the cybersecurity products and solutions now available for the security of information technology (IT) systems. Future manufacturing companies will use specialised safe data-sharing services by implementing methods to promote intra- and inter-industry collaboration in order to meet these information security challenges. The integrity of manufactured goods from design through the factory floor, securely connecting the factory to the supply chain, cyber intelligence, and machine-to-machine security, including legacy systems, are thus five priority areas where factories of the future will place a significant emphasis on manufacturing-specific cybersecurity needs.

**Build resilient global value chains through effective policies<sup>176</sup>.**

Global value chains have been severely disrupted by the COVID-19 outbreak in large part due to trade restrictions and the increased difficulty of procuring commodities and managing logistics. In order to keep these industries adaptable and successful, governments should work to preserve their respective supply chains for strategic industries. Additionally, this calls for reevaluating current regulations to decrease the burden placed on businesses and accelerating legislative and bureaucratic processes.

**Diverse sourcing and digitisation are key to building stronger and smarter supply chains<sup>177</sup>.**

Global trade and investment have been impacted by COVID-19 at a speed and scale never seen before. Multinational corporations experienced an initial supply shock, followed by a demand shock as more and more nations issued stay-at-home orders. Governments,

companies, and individual consumers all found themselves unexpectedly unable to obtain essential goods and materials, forcing them to acknowledge the weakness of the global supply chain. One of the most important lessons from this crisis is the urgent need to create supply chains that are smarter, stronger, and more versatile.

### **Utilise new demand management strategies to create robust supply chains.**

Demand has been highly inconsistent due to environmental uncertainty. This necessitates sustainable and adaptive demand management in businesses. Demand management would enable multiple actors along the whole supply chain to share and access real-time data to facilitate choices. It would be powered by a strong technological ecosystem and collaboration models.

## **Key Takeaways Concerning Hyper-Personalised Manufacturing with Respect to Supply Networks**

The demand-driven supply chain idea has been around for some time now. The approach calls for supply chain organisations in markets focused on consumers to be able to ramp production up and down based on short-cycle changes in demand. The capacity to serve customers as individuals through hyper-personalisation will allow companies to finally give customers what they want, when, where, and how they want it. However, getting this new normal right would need significant adjustments to the end-to-end procurement process<sup>178</sup>. Customers are expecting more and more to be able to select products that match their preferences, receive them within a day or sooner, and not pay a premium for these requests. Personalisation, or improving the customer experience by leveraging technology and data to fulfil and anticipate demand and facilitate interactions, is becoming ever more difficult, especially for supply chains that are heavily influenced by global competition. New data sources and technology are what drive personalisation, which produces more useful customer insights<sup>179</sup>.

### **Hyper-personalisation commands a certain closeness with, and to, the customer.**

Companies can now produce distinctive, accurate, and individualised services thanks to their access to vast volumes of information from across the value chain. The capacity of new disruptive technologies to bring manufacturing as close to the customer as possible, allowing value addition in the same region, territory, county, city, or community as the consumer, is a positive aspect supporting the hyper-personalisation trend. Hence, in hyper-personalised environments, consumption

facilitates production or part of the production in the same locality and allows for inclusive growth.

### **The post-COVID future of customer involvement in retail is hyper-personalisation<sup>180</sup>.**

Brands must push beyond basic personalisation to hyper-personalisation, using consumer data to produce nuanced, unique experiences, in order to continue to respond and adapt to changing customer demands and expectations. Every industry has been put to the test over the last few years, but retail has stood up well. Companies who are setting the bar for customer involvement will keep up the adapt-and-respond strategy that has served them well during the outbreak as they go past the just-survive triage phase and attempt to define their futures. They will be in the best possible position to react to continuous changes in customer preferences as the pandemic worsens and ideally, eventually ends.

### **Customise for Local and Global Markets.**

With the client at the centre, hyper-personalised manufacturing will enable local add-ons that create brand stickiness, while fostering inclusive growth for the consumer's country or region. This is especially relevant for emerging markets, as it will allow local companies to be part of a high-tech, global value chain, thereby boosting their competitiveness and the overall national economy.

## **Key Takeaways Concerning Rapidly Responsive Manufacturing with Respect to Supply Networks**

In order to retain a strong brand image in the era of instant communication, manufacturers must now cater to a variety of markets, exceed consumer expectations, ensure timely manufacturing, and manage complex supply networks that have replaced historically linear supply chains. In this regard, rapidly responsive manufacturing is the means by which manufacturers may handle these issues and maintain their position as market leaders. Companies use a predictive, agile, flexible, and lean form of production in rapidly responsive manufacturing. The whole product lifecycle, from creation to delivery, has been optimised to create rapidly and just the required number, fulfil quality expectations, and cut out unnecessary expenditure, all while having the potential to grow and adapt in response to changes in demand.

### **Speed has become more significant than scale on a number of fronts, including time to market, time to gather input and learn from it, and time to make and carry out decisions.**

Companies should react to the most recent market trends through a rapidly responsive supply chain, frontline feedback mechanisms, and smart decision-making. Businesses must address an underlying tension: the struggle between size and speed, to overcome the scale and intimacy trade-off. The nature of scale benefits is shifting due to digital disruption. Businesses can no longer afford to allow a slowdown in their metabolism. They must continue to grow quickly as they do so in order to surpass rivals and satisfy customer expectations.

**Flexible supplier bases enable businesses to better withstand unexpected events that disrupt the supply chain<sup>181</sup>.**

As the COVID-19 impact grew, it became evident how essential was the need for more varied and durable supply chains. Although terrible, this crisis has taught us that we must innovate more to withstand future global impact events because of our interdependence. The COVID-19 pandemic mostly revealed the weakness of the lean manufacturing approach when used in extended global supply systems. Despite being cost-effective, single-sourcing and keeping minimal inventories have turned out to be very detrimental. Individual supply chain management teams and industry executives are therefore evaluating the implications of continuing existing approaches. They understand that a solution to these problems is required. Supply networks must be made stronger, more intelligent, rapidly responsive, and diversified.

## **Key Takeaways Concerning Inclusive Manufacturing with Respect to Supply Networks**

With the aim of generating economic impact within different communities, supply chain diversity has changed over the past two decades from a compliance-driven exercise to a corporate strategy requirement for major organisations. In addition to being more innovative, accessible to new markets, and able to generate socioeconomic benefit in local operating areas, diverse and inclusive supply chains are also more competitive<sup>182</sup>.

**Inclusive supply networks are a key tool the manufacturing sector may use to make a lasting and beneficial impact<sup>183</sup>.**

By including underrepresented groups such as women-owned businesses or those who reside at the base of the economic pyramid as suppliers, distributors, and retailers, firms can promote innovation, boost brand value, and explore new markets. This is what we call inclusive supply networks. In addition to giving historically marginalised populations economic opportunities, inclusive supply chains help organisations develop stronger resilience

and ethical business practices that can withstand the complicated environment of supply interruptions and changing consumer demands that exists today. Besides, in order for SMEs to survive in the future, Original Equipment Manufacturers (OEMs) must assist the other actors in the supply chain in becoming digitally integrated.

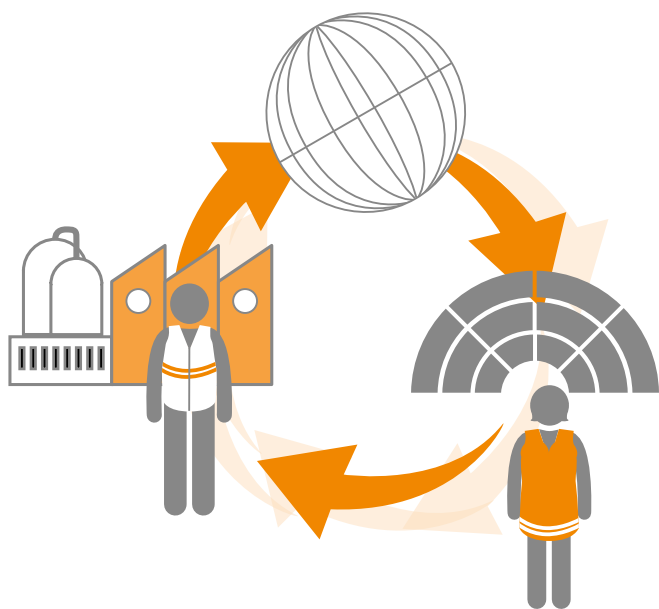
**An inclusive supply chain will lead to a resilient economy<sup>184</sup>.**

Initiatives to diversify and include suppliers can significantly impact communities and business profits. Along with broadening the tax base, benefits include boosting innovation and bringing new goods to market. It offers opportunities for innovation and competition among companies. Additionally, it gives firms that reflect shifting demographics more leverage. But for these programmes to be successful, everyone involved in the manufacturing sector must be aware of their responsibilities within the ecosystem of the supply chain.

# Key Recommendations

The World Manufacturing Foundation, in collaboration with experts globally, is pleased to present the Ten Key Recommendations of the 2022 World Manufacturing Report. We hope our readers can embrace these recommendations and work together towards more resilient supply chains and ecosystems.

## 1. AVOID OVERREACTIVE POLICIES THAT BRING BACK THE PENDULUM OF GLOBALISATION



- Do not overreact
- Consider the long-term impact of decisions
- Improve communication between companies and policymakers to design a regulatory environment that supports change

Historically, globalisation happened in waves. After the Second World War, autarky-based initiatives were followed by a greater integration of global supply systems. Predictive analytics has seen rapid technical advancements that have reduced production processes to the point that inventories are now nearly non-existent. The increased geopolitical risks that have resurfaced in the past years, however, have reminded us once again that specialisation goes hand in glove with increased dependence.

The COVID-19 lockdowns in China or the energy crisis brought about by the war in Ukraine, among other recent global shocks, have caused a cascade of impacts that have forced both the private sector and nation states to reconsider the trade-off between efficiency and self-sufficiency. While this is a great juncture to diversify production processes and create more sustainable, local supply chains, there is an actual risk that the “pendulum swings back too far”.

Ultimately, much of what is happening right now probably reflects short-term shocks. Historically, however, we have seen policymakers and firms “overreact” to such shocks. There is no new normal. There is a risk that we are going back to increased autarky and all the red tape and distortions that go with protectionism. In this regard, it is also important to remember that the move towards more localised supply chains might be primarily political.

Besides, there is a well-established theory and empirics that considers economic integration – such as via global supply chains – as a driver not just of prosperity but also of peace. There is a serious risk that the current trend in global manufacturing towards going local will contribute to the shift in the international order that we are seeing.

Although it is understandable that businesses are not interested in having governments intervene in how they run their supply chains, some disruptions are going to evolve into collective problems. This implies that governmental action is going to be needed to ensure supplies or mitigate the effects of shortages. To achieve these objectives, on the one hand, governments will need a better understanding of what will happen when parts of the supply chain are disrupted, as well as better communication from businesses about what they are trying to do. On the other hand, businesses should be persuaded that they should diversify their supply and engage in a dialogue with the government to design a regulatory environment that supports change.

All in all, although this is a frightening and unprecedented period in history, it is crucial that policymakers do not panic and overreact. The supply chain is frequently disrupted by pandemics, war, and other events. To handle these kinds of events, businesses should also stay flexible and have resilience plans in place.

## 2. ENSURE PRUDENT, CLEVER, ENTREPRENEURIAL, AND PROACTIVE REDESIGN OF SUPPLY CHAINS TO SECURE CRITICAL SUPPLY



- **Avoid counterproductive strategies by keeping continuity**
- **Take supply chain redesign for resilience as an opportunity to shorten the supply chain**
- **Exploit opportunities to combine reshoring with friendshoring**

Maintaining continuity is one of the key steps in avoiding counterproductive strategies and behaviours that have a detrimental impact on costs, pricing, and other factors when supply chains are being redesigned for resilience. Direct supplier collaboration is crucial for this, especially for OEMs that want to reduce the length of the supply chain. Redesigning the supply chain for resilience should therefore be viewed as an additional opportunity to shorten the supply chain. Additionally, in order to ensure crucial supplies, all parties involved should take care to restructure supply chains in a responsible, innovative, entrepreneurial, and proactive manner. On that note, research initiatives that enable less reliance on specific essential elements, such as cobalt, should be encouraged. In order to assure crucial supplies, vertical integration should also be taken into account.

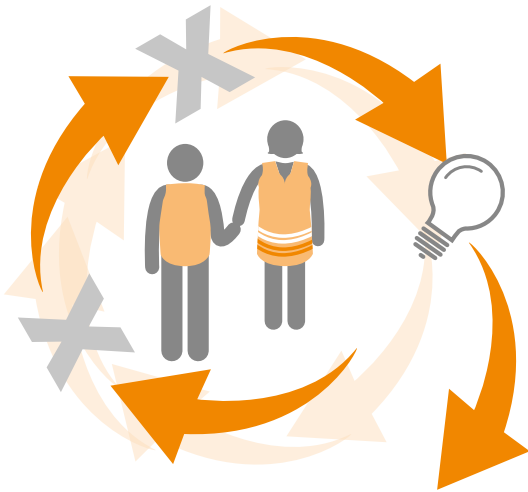
The strength of our future lies in raw materials. However, a small number of nations today manage processing and supplies. Governments should act on crucial raw materials

with strategic programmes on extraction, refinement, processing, and recycling in order to prevent the world from falling into the same old dependencies.

Critical supply networks should be reshored wherever possible to strengthen their economic resilience. In that approach, creating regional hubs and developing smaller-scale integrated manufacturing capabilities close to home would assist in lessening dependence. Reshoring has its limitations, too, and not all supply chains can be entirely reshored because some essential and critical materials might only be found in a few places on Earth. Other supply chains may be constrained by economics because it would be more expensive to replicate them domestically than the value of the entire industry. Therefore, policymakers should consider further opportunities to combine reshoring with friendshoring, which offers a clear way to enhancing the resilience of many crucial businesses while fostering global relationships.



### 3. ADOPT AN ITERATIVE AND CONTINUOUS IMPROVEMENT APPROACH TO SUPPLY CHAINS



- Use a continuous improvement approach to adjust to frequent changes
- Build and maintain relationships based on dependability, organisational compatibility, commitment, and trust
- Incorporate supplier considerations into product design as a way to reduce costs and the impact of disruptions

Supply chain disruptions do not appear to be slowing down. As a result, businesses must assess their supply chain design processes and put in place cutting-edge strategies that can adapt to the turbulent marketplaces in which they currently operate. Markets and the supply networks that sustain them are described by terms like unpredictability, volatility, complexity, and ambiguity. Thus, companies need to be extremely adaptable in order to consistently redesign their supply networks for resilience. They should also always keep in mind that redesigning supply chains is a dynamic process that is constantly evolving and never-ending. Supply chains and operations must use a continuous improvement approach to adjust to frequent changes, rapid technological innovation, increasing demands, rising customer standards, and ambiguous industry trends. In this regard, continual feedback plays a key role in continuous improvement by successfully analysing and prioritising the development of concepts and ideas in order to always seek out opportunities for improvement. The supply chain depends on its suppliers upstream and must constantly increase the level of customer

satisfaction at the downstream end. Static and company-level competencies are no longer adequate to generate and explain a firm's competitive position as relationships between organisations develop and form a more linked structure. Therefore, the ability to communicate with external partners, which necessitates a cultural orientation towards collaboration and openness, is the real competency that needs to be acquired today. Companies need to build and maintain relationships based on dependability, organisational compatibility, commitment, and trust, as well as support from the top management.

A development in the industrial sector that lowers design costs and delays is the co-design of a product and its supply chain. Hence, joint redesign of supply chains and products is getting more and more strategic to fulfil customers' requirements and address critical issues. The performance of supply chains is significantly influenced by the product's design and materials. Because of this, manufacturing companies should incorporate supplier considerations into product design as a way to reduce costs and the impact of disruptions across the product lifecycle.

## 4. DESIGN PRODUCTS FOR AN AGILE REDESIGN OF SUPPLY CHAINS



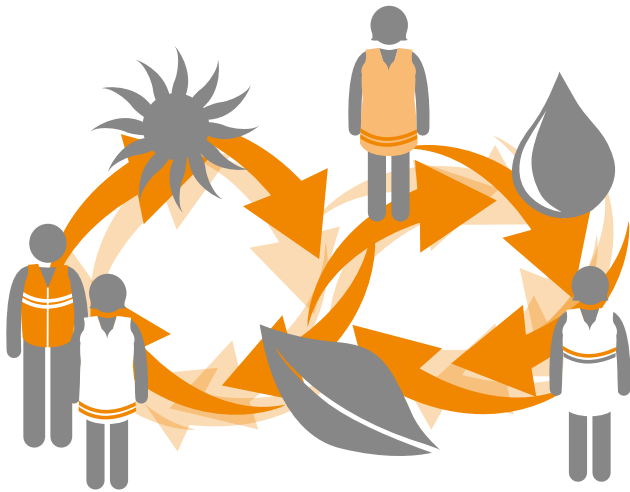
- **Optimise product design and management for supply, production, and sustainability**
- **Design products and services to match the agility of supply chains**
- **Shift from the traditional Design for X approaches to Design for Supply Chains**

Product development and supply chain planning are no longer managed by businesses as separate departments. The practice of handing product design over to supply chain planners, who decide how to get materials and construct the items, is no longer quick or effective enough to be competitive. To speed up profitable innovation, businesses should therefore optimise product design and management for supply, production, and sustainability.

To provide easier reconfigurability for dealing with unpredictable events and a rapidly shifting global environment, businesses should design their offerings in the form of products and services to match the agility of supply

chains and the ability of supply chain transformations. Products should therefore be created with agile supply chain redesign in mind. This requires shifting from the traditional and well-diffused Design for X approaches, such as design for assembly, towards embracing new concepts like design for resilience and design for supply chains. Businesses should create products with easily replaceable parts or materials in order to provide value. Therefore, companies should design their offerings to be adaptable, thus design for agility, taking into account every stage of a product's lifecycle. Additionally, their manufacturing facilities should be flexible enough to adapt to supply chains.

## 5. EXPLOIT THE OPPORTUNITY OF REDESIGNING SUPPLY CHAINS TO DRIVE CIRCULARITY AND SUSTAINABILITY



- Use the opportunity given by supply chain redesign to achieve a competitive edge by proactively incorporating sustainability issues into business models
- Include more multi-tier circular supply chains
- Establish more genuine circular supply chains to proactively reduce the adverse environmental effects

Manufacturing companies could make use of the opportunity presented by supply chain redesign to gain a competitive edge by proactively including sustainability issues into their business models and the way that they engage with their customers. Their approach to circularity should not just be reactive, based on regulations, but should also attempt to proactively reduce the adverse environmental effects that their business or products have. In contrast to the current traditional methods of achieving circularity by collaborating with a retailer or a certain customer to gain the reverse flow of the items, the manufacturing industry should see more genuine circular supply chains in the future. This environment should change to include more multi-tier circular supply chains where products are recycled and fed back into the system. However, given that the already complicated supply

networks will undoubtedly become even more complex as a result of this shift, the effects on the global supply chains should be minimised.

Promoting trust and cooperation among the various necessary actors in the value chain is more crucial than ever because switching to circular manufacturing is complex in nature. Stakeholders in circular value chains must have access to trustworthy information regarding a product's sustainability. For instance, producers and recyclers should work closely together to make sure that the latter have access to knowledge about the product's components and manufacturing process to enable recycling. The ideal configuration should be considered by manufacturers when creating a product to facilitate recovery and recycling after it has served its purpose.

## 6. ACCELERATE THE URGENT ADOPTION OF DIGITAL TOOLS AS ENABLERS FOR RESILIENT AND ADAPTIVE SUPPLY CHAINS



- Accelerate the adoption of digital technologies as enablers of resilient and adaptable supply chains
- Develop the skills necessary to analyse the data for utilising digital technologies
- Invest in effective data analytics to mine data for important insights for building flexible supply chains

Digital technologies are very useful in the realm of companies to visualise the supply chain and to collect data from its different parts and bring it together so as to look at their product performance or product on customer sites, or to interact with customers for facilitating self-service and so on. From a technical standpoint, blockchain technology could also help promote transparency by allowing a certain level of tracking while protecting companies' most sensitive information. Thus, the urgent adoption of digital technologies by companies as enablers of resilient and adaptable supply chains needs to be accelerated. The next step is to figure out what to do with the data, how to use it, analyse it, and get interesting insights out of it, possibly, and then creating further business opportunities. So, there are a lot of ways that digital technology can help facilitate interactions with customers, suppliers, and other parties in terms of collecting and capturing data; a lot of companies already implement these activities and are quite successful with them. To regain a competitive edge, however, we must develop the skills necessary to analyse that data utilising digital technology.

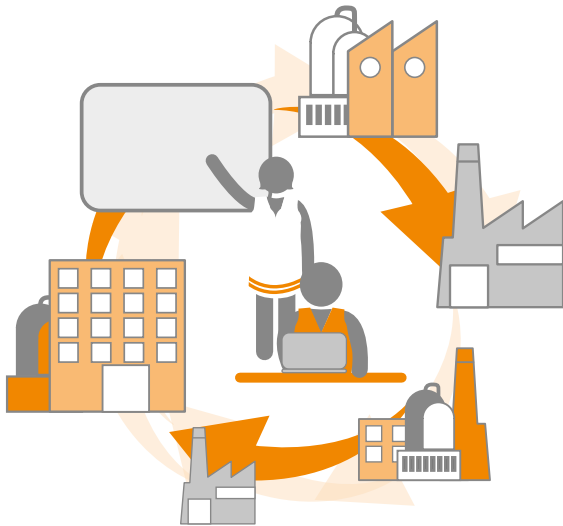
Data is a crucial element of digital transformation and is essential to making advancements in supply chain redesign.

The boundaries between the virtual and real worlds are becoming increasingly vague with the creation of the metaverse. Organisations must invest in effective data analytics to mine data for important, proactive insights and expedite intelligent decision-making to build a supply chain that is flexible enough and ready for such a future world. Besides, digital twins are helpful for evaluating what-if scenarios when redesigning supply chains because they eliminate the risk of making an expensive error. They also greatly aid in root cause analysis, risk management, demand forecasting, inventory management, and analysis of supplier data to determine the best course of action in any given situation.

Manufacturers should consider additive manufacturing when redesigning their supply chains as an option to adapt some of the process steps and become more flexible in managing the variance of the products.

The ability to change items or components after the creation of a prototype resolution also allows for flexibility. In some cases, localised 3D printing closer to the location of demand in the required — usually small — quantity can solve the problem if there is a worldwide supply chain breakdown, and the part is required overseas.

## 7. SUPPORT SMALL AND MEDIUM ENTERPRISES BY INCLUDING THEM IN THE REDESIGNING OF THE SUPPLY CHAINS LEVERAGING ON THEIR CAPABILITIES AND ADDRESSING THEIR NEEDS



- Equip SMEs with digitalisation to enhance the capabilities of value chains
- Establish and maintain relationships along the value chain to strengthen support for SMEs
- Include SMEs in the redesign of the supply chains to utilise their strengths and address their needs

Equipping SMEs with digitalisation is one of the elements crucial to enhancing value chain capabilities by using supply chain redesign as a chance to improve. Allowing and assisting SMEs in tracking information more effectively throughout their value chains will help them determine their environmental impact and take action to reduce it. In this context, SMEs should develop digital skills to enhance data collection and processing, capitalising on clever solutions that make use of the Internet of Things and Artificial Intelligence, as well as to encourage information sharing with other businesses.

Companies in the supply network should make judgments more quickly regarding supply chain redesign operations. Small and medium-sized businesses have the advantage of moving more quickly and carrying less weight, or less than that of a large organisation, which makes them more adaptable and flexible in terms of modifying their own operations as well as their own supply relationship. However, SMEs also face significant challenges in executing

the necessary adjustments for transformation due to their smaller resource pools, which has a negative impact on their resilience. In order to support SMEs, relationships must be established and maintained along the value chain. A viable strategy for solving this issue is to increase the coordination and integration of supply chain participants by forming relationships with SMEs.

Additionally, SMEs must be supported by the larger companies in the supply network in order for them to be included as much as possible in the redesign of the supply chains, utilising their strengths and addressing their needs. Therefore, the necessity to adapt to the various size requirements should be given top priority and consideration while redesigning supply chains for resilience. In particular, aligned with the purpose of inclusive manufacturing, OEMs must assist small and medium-sized enterprises (SMEs) and other organisations of all sizes with their various capabilities and needs.

### 8. **ADOPT A MULTI-DIMENSIONAL APPROACH TO CONSIDER GEOPOLITICAL RISKS AND OTHER NON-COST FACTORS IN REDESIGNING SUPPLY CHAINS**



- **Develop a better understanding at the collective level of how supply chains operate**
- **Think of long-term planning that emphasises localisation of supply and flexibility**
- **Modernise the cost calculus by adopting a multi-dimensional approach to consider geopolitical risks**

Over time, the world has developed a system in which supply chains are widely dispersed and organised for efficiency. These work pretty well as long as there are no disruptions. However, in the last couple of years, first with COVID-19 and more lately with political factors, we have seen that global supply chains can be highly subject to being disrupted, with unpredictable effects.

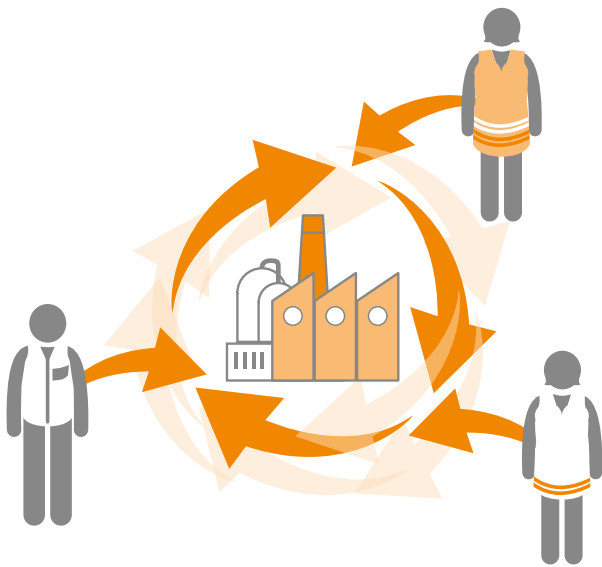
To ensure greater stability in the face of shocks, there needs to be a better understanding, at the collective rather than company level, of how supply chains operate and where things come from. One example of this is the pharmaceutical industry, where active pharmaceutical ingredients that go into generic drugs are not known that well, putting the industry at risk of being disrupted in unpredictable ways.

Within the last two years, computer chip shortages at first led to the temporary closure of operations by automakers, and the cost of lumber then increased rapidly. Furthermore, because global supply networks had been so overburdened, it is likely that at some point within the last year, everyone across the globe had to wait longer than they would have liked for a final product. Therefore, a lot of comments focused on the need to redesign supply chains. Thus, many are urging long-term planning that emphasises localisation of supply and flexibility in operations.

It is essential to encourage a new level of collaborative integration when rebuilding supply networks for resilience. At the corporate level, a vibrant understanding of systemic risk is critical. Once understood, it will be possible to identify dangers that are out of a company's control and call for cooperation amongst businesses, industries, and governments. Geopolitical risk, for example, cannot be understood or managed in isolation and must be considered as a collective good requiring some amount of collective action. We require a level of collaborative integration that is novel, distinct from what we may be experiencing at the moment, and that entails some degree of politicisation in order to manage these threats.

At least to some degree, globalisation is irreversible as it is just too efficient. Nonetheless, if left to market mechanisms, the shocks we are experiencing can result in shortening the chains. One way of ensuring an orderly movement towards efficient and more secure supply chains is to price in systemic risk – especially geopolitical. Today, if something is manufactured in a place known to be vulnerable, this vulnerability is not factored into the cost until something happens. Therefore, this cost calculus should be modernised by adopting a multi-dimensional approach to consider geopolitical risks, resilience aspects, and other non-cost factors in redesigning supply chains.

## 9. RECOGNISE SKILLS AS THE NEXT MISSING FACTOR IN PRODUCTION



- **Upskill the future workforce with the skills required for supply chains**
- **Adopt a culture that involves the entire workforce in strategic decisions for supply chain redesign**
- **Facilitate distinctive managerial abilities required for the redesigning and ongoing improvement of supply chains for resilience**

Year after year, supply chains get more intelligent and digitally enhanced, which inevitably results in a considerable evolution of the supply chain workforce, with new or developing job roles. Hence, supply chain competencies found in the majority of businesses today are not those that companies will increasingly require to compete and expand in the future. The need to equip the workforce for resilient supply chains is critical. Because of this, the future workforce needs to be adaptable and well-prepared for the new expectations that the transformation of supply chains will place on them. Hence, the future workforce should be upskilled with the skills required for supply chains, including leadership skills like strategic thinking, problem solving, team management, and effective communication, as well as technical and technological skills such as risk management, statistical modelling, data literacy, and machine learning. During this supply chain redesign and transformation it is crucial to adopt a culture that creates the vision while taking into account and involving the entire workforce, placing

them at the heart of strategic decisions. Success in this regard depends on the supply chain actors engaged being upskilled to match the demands of the future-oriented supply networks. Therefore, all the actors involved in determining the future of value chains through their actions and decisions, including businesses, governments, and educators, should be aware of the shortage of specific or skilled workers for a variety of roles throughout the supply chain, especially in the long term, and redesign supply chains taking these issues into account.

Besides, companies are in urgent need of elevated supply chain leaders who can orchestrate the chain and drive better collaboration. To achieve this, it is crucial to support the development of new and distinctive managerial abilities required for the redesign and ongoing improvement of supply chains for resilience. Additionally, managing trends may involve overseeing structural and political issues as well as technological advancements, which will call for a new set of managerial skills.

## 10. TAKE ACTION THROUGH POLICIES TO EMPOWER RESPONSIBLE CONSUMER BEHAVIOURS TO REACH A STABLE ECONOMIC DEVELOPMENT



- Take new customer requirements into account while modifying business models and supplier networks
- Put in place measures through regulations that support responsible consumer behaviour
- Educate consumers about their impact on supply chains to establish responsible behaviour

Due to recent global events like COVID-19 and the crisis in Ukraine, the world has seen significant disruptions in supply chains, and as a result, we have observed a change in consumer behaviour. Furthermore, most companies are having a very difficult time keeping up with the fast-evolving consumer trends and expectations, such as the Amazon effect, which, among other things, increases customer expectations as regards delivery times. Therefore, companies must, on the one hand, take new customer requirements into account while modifying their business models and supplier networks. On the other hand, in order to create stable economic growth, governments should put in place measures through regulations that support responsible consumer behaviour, and consumers themselves should take responsibility for changing their own behaviour. This responsible behaviour may also serve as a buffer against disruptive events in the future, bringing stability and balance to value chains on a global scale. In this regard, educating consumers about their impact on supply

chains and effectively communicating this information could assist in establishing responsible behaviour.

The arrival of the metaverse promises to alter how people live and operate in society.

The digital and the physical is combined in this next generation of the internet, enabling individuals to participate in a brand-new, shared experience from any location. For companies, this means finding new ways to make customers' lives easier, anticipating and predicting market changes and the risks they pose throughout the supply chain network, and managing business performance and decisions based on a balanced view of profits, sustainability, and inclusion. Additionally, as consumers and businesses become more intertwined through digital technologies, there is an exponential growth in customers' supply chain data that can be analysed. Utilising this wealth of data, businesses can build more customer-focused supply chains that support innovative products and services for consumers.



# Conclusion

The disruptive events characterising the recent scenarios in our society, especially in the last two years, have impacted among all the manufacturing sector and its supply chains. As elucidated throughout the Report, the disruptive events and the related implications have been many. To cite some examples, the COVID-19 pandemic disrupted supply chains globally from toilet paper to construction materials, the blockage of the Suez Canal obstructed a major global shipping route, the shifts in global politics, caused also by the Russia-Ukraine war, impacted the ability of supply chains to source internationally and the introduction of trade restrictions further amplifies these impacts.

Moreover, these events, in addition to their direct implications, have generated several side effects, impacting for instance on people operating and working for different organisations worldwide in terms of new skills needed and changed working environments. At the same time, consumer behaviours and habits have emerged to evolve over time, requiring fast adaptation on part of the organisations as well.

Indeed, countermeasures should now be put in place to reinforce the resilience of our organisations and countries by enabling them to react quickly or anticipate similar scenarios in the future. Among these, it is suggested that a prudent, clever, entrepreneurial, and proactive redesign of supply chains be ensured in order to secure critical supply, including workforce, that an iterative and continuous improvement approach to supply chains be adopted, and that the opportunity be exploited to redesign supply chains to drive circularity and sustainability — which, we must not forget, has become the new normal — and that Small and Medium Enterprises be included in the redesigning of supply chains, leveraging on their capabilities and addressing their needs.

**:YML**

# **Young Manufacturing Leaders**

**Winning Case Studies  
on Redesigning Supply Chains in the  
new Manufacturing Scenario**

**YML Contest for the  
2022 World Manufacturing Report**

Young Manufacturing Leaders is a global initiative for students, young workers and professionals interested in a career in the manufacturing sector.

The YML network is strongly committed to raising awareness of the opportunities in manufacturing, and to spreading knowledge of the skills needed in this sector. It supports members with different activities such as peer-to-peer seminars, mentorships with professionals and entrepreneurs, and participation in the activities of the World Manufacturing Foundation.

From May to September 2022, the YML Contest for the 2022 World Manufacturing Report was held, inviting young leaders from all over the world to submit a case study relevant to the topic of Redesigning Supply Chains in the new Manufacturing Scenario. The submissions were evaluated by the World Manufacturing Foundation and the winning case studies are included in this section.

The Young Manufacturing Leaders network initiative, launched in 2020, now has nine partners: Politecnico di Milano, Chalmers University of Technology, Czech Technical University in Prague, the Federation of Estonian Engineering Industry, IMH Campus, Technische Universität Braunschweig, University College Dublin, University of Porto, and the World Manufacturing Foundation.

The initiative is co-funded by the European Union, within the framework of the EIT Manufacturing programme.

For more information, visit [youngmanufacturingleaders.org](https://youngmanufacturingleaders.org)

## SMART WAREHOUSE: a Place where all Data is Connected

**Elena Fernández Calvo**

R&D Engineer, Schneider Electric – YML Basque City Hub

Schneider Electric (SE) is one of the leading companies in the electric power sector. Like other companies, it has a strong commitment to sustainability in supply chain because the use of natural resources and CO2 emissions must be lowered in order to reduce the greenhouse effect. All companies must be aware of the need to be sustainable, take advantage of the digital era, and promote equality between women and men.

There is no exact definition of the supply chain because it depends on the type of product or service being marketed. In general terms, it encompasses all the processes involved in the manufacturing of a product or service from the raw material to what is delivered to the customer.

Among other products, Schneider manufactures Medium Voltage Switchgears. These devices require a well-designed supply chain as they are made up of numerous materials – around five thousand of them. Having an adequate supply chain for these products will add value to them and reduce the waste of materials, which will make the company's processes more sustainable and more efficient.

The MV switchgears supply chain involves the components supplier, warehouse, and shipping. Schneider already presents a highly sustainable supply chain. However, work continues by reducing waste by using recycled materials (mainly for the packaging) and improving shipping methods.

One of the improvements to be carried out is to reduce the stock of materials, which will be reflected in a lower use of natural resources (only those needed for manufacturing the MV Switchgears) and reduce company expenses, which will lead to greater benefits.

Among the factors to take into account when reducing stocks are: knowing the components that make up the MV switchgears, having a good sales forecast and having a controlled process in place to identify any faults or improvements to be made.

In one of Schneider's factories that produces MV Switchgears there are four different types of products, some of which have materials in common. The first step in redesigning this company's supply chain is to have identified all the materials needed to manufacture each product and to have them entered into adequate inventory software. Within that, they are managed automatically, always knowing the needs of the workshops and the warehouse in order to keep stocks as optimised as possible.

The stock must be defined by the delivery time given by the supplier and by the estimated annual sales.

On the supplier side, one of the best options is to have a Vendor Managed Inventory to keep track of the materials in real time and to know when the factory will need more materials. This allows the company to have an accurate forecast, enabling them always to deliver orders on time. Also, as was mentioned before, it is very important to reduce stock storage so as to have an adequate sales forecast work team. This team will predict the scope of the sales for a year and within that, the company will be able to have only the storage needed to satisfy demand and will eliminate the waste of materials.

The second step is to have a well-designed warehouse. In the case of having many different materials and those of different sizes, corresponding to different products, one way of organising the warehouse is as follows:

- incoming orders: where the material orders enter and are registered;
- materials for each product: where the different parts of a product are stored;
- common materials: where the shared parts for the products are stored;
- outgoing final product: where the final product is prepared to be sent to the customer.

Once the warehouse has been organised in this way, each of the sections into which it is divided must have the required access, by means of aisles, to pick up the materials with the necessary machinery.

With the advance of new technologies, the digitalisation of warehouses is getting closer and closer. Most companies will end up by having at least part of their warehouses digitalised to improve their productivity.

This is directly related to the improvement of the supply chain by having received all the information on material orders, with current stock and material needs always connected and their status known.

For example, in the case of Schneider, by having the warehouse as perfectly defined as possible in terms of order entry, material storage and product output, the warehouse can be automatized and optimised by digitalising each of these sections.

In the incoming orders section, all the necessary information can be recorded by leaving the packages on a conveyor belt and scanning them with an automatic scanner that sends the data to a software tool suitable for storing all supply chain data. Once a package has been scanned, the system automatically gives you the updated stock and sends the location of that material to the person in charge of putting it in place. In this case, the data will be sent to a tablet, but in the case of a robot it will be sent directly to its own software.

One way of knowing the real number of materials that are stored in the warehouse is to have a digital counter that receives the information from a weight sensor, which is configured according to the weight of each material and of the wooden crate where materials are stored. The information that the sensor sends to the counter will update the number of materials when weight variations occur.

With these technologies, every company is able to reduce the waste of materials by having a digitalised and well-designed supply chain. All this will be reflected in the reduction of pollution generated in the environment by industry.

## Data-Driven Modelling of Digital Twins to Ensure Resilience, Sustainability and Technological Continuity

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Why has the redesign of supply chains/manufacturing systems in more resilient ways become such an important research field in the past few years? This question may have different answers depending upon all the effects of pandemics, wars, and weather events. Even if it is true, we must understand that there will always be new events that force management teams to rethink the topological structures of their systems. In fact, Artificial Intelligence/Machine Learning techniques can be considered as a partial answer to this problem as they are highly flexible and sometimes easy to train. But even this approach is unable to handle disruptive behaviour in historical data, as they need to be trained to do so<sup>1</sup>.

This perspective leads us to the conclusion that there is no model capable of delivering an immutable system appropriate to all existing scenarios. So, how is it possible to deal with this transient characteristic of supply, demand, and resource availability? There are three closely connected words capable of providing a robust approach to this problem: resilience, sustainability, and digitalisation. Digitalisation supports the development of resilient models that can be used to simulate disruptive changes in virtual environments. In this way, the virtual environments allow the study of what-if scenarios to understand the real-world consequences, enabling more sustainable decision-making. This is a summary of the field of research into Digital Twins, first introduced by Dr. Michael Grieves<sup>2</sup> and regulated by ISO 23247:2021.

Currently, Digital Twins are true virtual monuments, that is, their analytical models require such a huge amount of time and intellectual effort as to make their implementation unviable in some contexts. In turn, we present the automated simulation model discovery as a trend alternative to the development of analytical models<sup>3</sup>. However, as mentioned above, changes (which are often disruptive) in production and supply chains are constantly occurring – and furthermore, this situation ends up constraining the synchronisation between the digital twin simulation models and system behaviour.

I will also present some examples from an ongoing real-world research project which aims to show the trends in digital technologies and the rethinking of processes. This case began at the contact with an industrial data analytics company that wanted to perform some what-if analysis of several systems. Their challenge was that the systems were not standardised, there were no simulation models, nor was it viable to develop any. Even so, they wanted to find a solution to this, because it was necessary to understand where they could create more value from a data analysis perspective. However, a major part of the datasets could be stored in an event log format<sup>4</sup> with some standard characteristics such as the timestamp, event, resource, and process entity identification.

When the delimitation of the project scope began, it was necessary to define a standard format that could represent the common characteristics between the monitored systems. Besides these, what type of data is needed to develop this approach? From the beginning, it is necessary to understand the availability of the status, events, and sensor data, as the simulation models must be aligned to the real-world data. We tried to get in touch with companies that could set up databases, but the privacy terms ended up limiting the scope of this work at that stage.

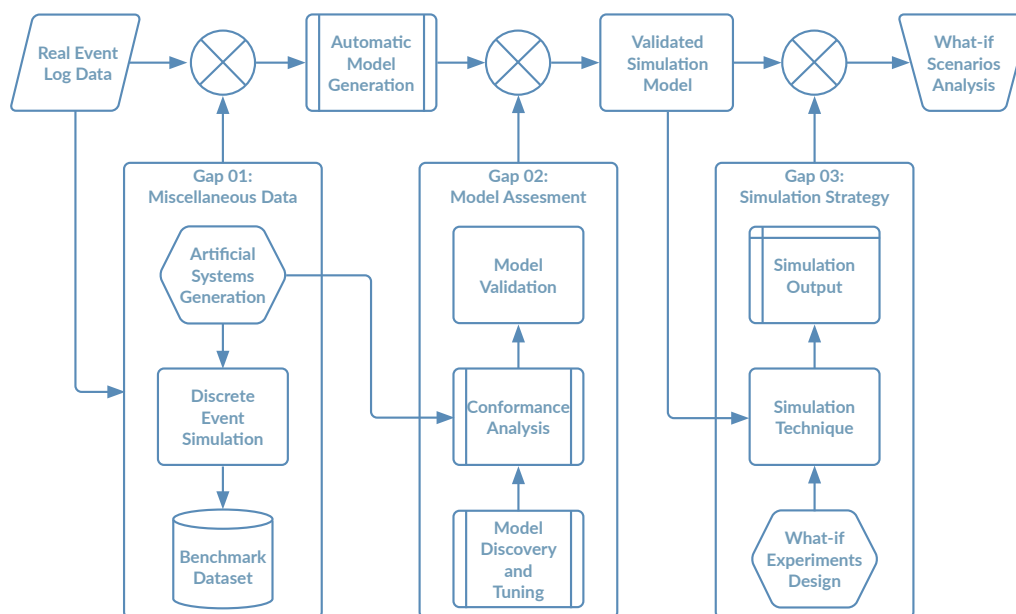
We then came up with the question: how can we develop comprehensive what-if approaches if the datasets of real-world applications do not permit us to explore the boundaries of the models? This issue claims the importance of developing a clear methodology to model evaluation and validation. Without it, it becomes increasingly difficult to ensure the accuracy of the simulation of different scenarios. I therefore realised that a fundamental piece was missing in this puzzle, one which had already been presented in the Process Mining Manifesto<sup>5</sup> as one of the ten biggest challenges for the advancement of this area of knowledge: it was necessary to create representative benchmarks. So, the solution to this problem was the design of a complex network simulation model for artificial data generation with defined probability distributions for the elements.

With this work done, it was finally possible to move forward with generation strategies for the design of automatic simulation models. Here, the concept of technological continuity was responsible for choosing the field of process mining<sup>6</sup> as the main area of knowledge to fill this gap. This was because process mining is a field of research with consistent scientific production in recent years and in constant growth, so I believe that integrating these technologies is an option to keep this solution within the global innovation loop. For that, the discovery and tuning techniques of the process models can be used to build the simulation model, while conformance analysis techniques can be used to evaluate the models discovered in the validation phase, and for updating previous models in the operating phase.

After these techniques have been defined, the last big challenge is the simulation of the discovered models. As for the implementation of these models, the challenge

is the integration between the output of the discovery techniques and the input of the simulation techniques. This is because commercial simulation techniques are generally user-friendly software, while the discovered models are presented in matrixial or graph format. So how can we overcome this main challenge? I propose that it can be done by organising the process mining algorithms outputs, carrying out a survey on the inputs of simulation techniques, understanding the experiment design and then assessing the requirements for this integration.

At this stage, it was possible to address the three major gaps for the implementation of the data-driven modelling of Digital Twins: i) an open-access dataset benchmark to represent the miscellaneous real data, ii) validation experiment design for assessing the boundaries of the model generator, and iii) a flexible simulation strategy integrated with the discovery techniques to perform the what-if scenarios analysis. The proposed framework for filling these gaps is presented in the following flowchart.



The application of the process analysis research field covers supply chains, workflows, production lines, and so on. We further expect that this improvement in autonomy can be observed in several areas of application. But why is this autonomy important? First, it avoids rework when it is not necessary. Second, the autonomous discovery of models and their integration with simulation techniques converge towards the development of an adaptive Digital Twin paradigm. In conclusion, automated simulation model generation approaches, which are essential for the wide application of digital twins, can preserve a series of algorithms, techniques and analyses that had been developed previously, providing technological continuity by recycling these systems even under disruptions.

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## Partnerships Centred on a Combined Supply Chain Strategy to Foster Sustainable Manufacturing: the Case Study of an On-demand “Micro-factory”

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Humanity is faced with many critical challenges, especially with the lowering rates of nature’s resources and altering life-sustaining tendencies. Recent times are a testament to many of the revolutionising technologies, strategies, and partnerships in order to iron out these problems in production/manufacturing and also, to be more environmentally sustainable. This case study centres on highlighting the likes of fast fashion in the fashion industry, how technologies are increasingly important for industry and opening up new business challenges and opportunities for many industries in the manufacturing supply chain.

Three technologically powered companies, *Kornit*, *Zund* and *Fashion Enter*, have come together through a technically driven alliance. This partnership centres on sustainable manufacturing in the fashion industry.

**Kornit** – the organisation is focused on sustainable fashion production. The company is committed to responsible production, especially in cutting down overproduction by strictly following an on-demand manufacturing policy, eliminating as much as 1.1 billion items of apparel each year. In addition to dispensing with overstocks, Kornit’s on-demand generation will bolster saving an assessed 4.3 trillion litres of water yearly. These operations also essentially prevent up to 17.2 billion kilograms of greenhouse gas emissions annually<sup>1</sup>.

**Zund** – a Swiss company that leads in the manufacturing and distribution of fine cutting systems, well known for offering digital cutting. The organisation is keen on adapting the ‘leanness’ from the modular design of the various cutters as the machines are built to absorb upgradations rather than there being a necessity to change the system or the machine as a whole<sup>2</sup>.

**Fashion Enter** – a social enterprise involving the business in building an interactive industry practice; it comprises a combination of a production facility, an institute for mentorship and a publication portal<sup>3</sup>. The amalgamation of the technology from the partnership of these companies is key to next-generation manufacturing practices. The

methodology is to foster a pull system – an on-demand production strategy – by tackling lead times through the combined capabilities.

This case study sheds light on two important transition factors in the face of supply chain as well as sustainable manufacturing practices, introducing the concepts of the **Micro-Factory (MF)** and **Partnership in Supply Chain**. The Micro-Factory model ideates bringing together the entire process, from product design to finishing, with all operations under one roof. However, this process could be recognised as ambitious, considering the peculiarities of fast fashion. Fast fashion production chains share crucial perspectives such as delocalisation and contracting to third parties; nevertheless, the recent priorities in the fast fashion industry seem, in fact, to be increasingly attentive to sustainability or social commitment or being in favour of a cause. Factoring in these sustainable goals, the micro-factory concept converges consecutive phases in the upstream for the make-to-order business model, characterising highly flexible production facilities that provide ‘push-button readiness for a fast, efficient print-cut-sew process’<sup>4</sup>, which allows the retailer or brand the opportunity to seamlessly facilitate on-demand production. This manufacturing approach allows local small-scale suppliers to partake in the process, adding content appreciated by regional markets. Also, combining modular supply strategies with ‘off-the-shelf’ purchasing aids in reducing cost and helps achieve better economies of scale as well. Thus, this inherent flexibility of MF manufacturing provides better customer care, as well as shorter lead times, and much later configuration of the product. One of MF’s primary recognisable features in connection with the current mass production system is that it would break through the ‘monoculture’ of expansive centralised factories making a standardised, relatively undifferentiated product in exceptionally large numbers. Low cost and manufacturing-push make this clothing/apparel (in this case study) successfully expandable. These facilities draw on worldwide supply networks and global supply markets.



One of the significant variables in overseeing a supply chain is having collaborative partners. Setting up a sound relationship comes from a solid establishment of communication, common objectives, increased transparency, and mutual collaboration. Observing the supply chain operations, the partnership establishes a system that perfectly balances efficiency and effectiveness. It is effective in handling all pre-order operations digitally, 'a far better fit for today's hyper-connected, web-driven economy whereby consumers expect instant gratification, customisation, variety and, in many cases, personalization'<sup>5</sup>. Furthermore, it is efficient in operations such as adopting direct-to-garment printing or direct-to-fabric printing according to the scale of the order. It uses less energy and less water and generates fewer greenhouse gas emissions than any comparable production mechanism, thereby generating a smaller carbon footprint.

This system alters the notion of supply chain as it centrally evolves around establishing working models and business decisions based on the reduction and elimination of waste.

In an extract from the Drapers interview with Robert Zoch, Global Content Manager at Kornit Digital, Gaj Jeevanandan, Marketing Manager at Zund UK, and Jenny Holloway, CEO of Fashion Enter, London, UK, Robert Zoch defines the partnership as follows: *"The micro-factory model and proximity production approaches eliminate logistical and transport waste. We're giving creators and brands the opportunity to improve their sustainability practices without sacrificing on quality or creativity. As far as the role we play, Kornit systems provide the sustainable base from which Fashion Enter and Zund then benefit – if you're only printing the materials that are needed, you're only cutting those materials to spec, and you're only processing and shipping orders for those materials. It's a cost-effective, efficient fulfilment model that is inherently eco-friendly"*<sup>6</sup>.

Such partnerships are what the world looks forward to, on one hand to be on top of our game and on the other hand, making better choices in order to reach this point. The study is likely to conclude that the companies as well as

individuals are at the beginning of a long journey in terms of attempting to make better choices. These are just a few examples of what the industries are up to and are capable of; their applications in the world of manufacturing are very diversified and still under development. Technology is bound to play a key role in the sustainability of manufacturing processes and in transforming supply chains.

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# Biorefinery Supply Chain and Biomass/Biowaste Development: the Case of Polyhydroxyalkanoates

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Biorefineries are industrial facilities that transform biomass into biofuels and high value-added biomaterials. Within the framework of the energy transition and the bioeconomy, biorefineries are presented as an alternative to traditional refineries. Behind the concept of the biorefinery there are many different industrial structures. Several classifications of these structures are proposed, which are mainly distinguished by their raw materials (type and number) and their final product(s). Biorefineries are supposed to make the best use of local resources, sometimes considered as bulky waste, and derive energy, fuel, or biomaterials like polyhydroxyalkanoates. While in the past, the efficiency of a biorefinery was mainly established according to economic criteria, sustainability and a human-centric approach are now typically taken into account within the framework of Industry 5.0<sup>1</sup>. Technological and political aspects must also be considered.

Research on the biorefinery concept has focused primarily on the design and optimisation of biomass conversion processes. In comparison, supply chain aspects have long been considered secondary. However, a biorefinery cannot function efficiently without a reliable supply chain<sup>2</sup>.

The design and optimisation of a biorefinery's supply chain are now facilitated by digitalisation. Digitalisation facilitates better traceability of raw materials, semi-finished products and finished products thanks to real-time tracking throughout the supply chain. Some challenges remain to optimise biorefineries' supply chains. First of all, the logistical aspects of biomass are still the subject of intense reflection. In recent biomass logistics models, the dispersed availability of biomass in supply areas, uncertainties in biomass supply, integration with geographical information systems, emissions from logistics operations and traffic congestion due to biomass transport are often considered, but not without some difficulty. The traceability of raw materials and finished products can be managed using digital technologies. A secure exchange of data in real time is needed between the different actors in the supply chain, be they suppliers, producers and/or consumers. The supply chain can even be integrated into

a digital twin of a biorefinery, making real-time monitoring, control and even predictive scenarios or better lifecycle assessment studies possible.

Lifecycle assessment studies have become commonplace in industries of all kinds, including biorefineries. They are based on data that needs to be assessed for quality. They should enable decisions to be made about a company's activities, particularly from an environmental point of view — this, even if, here again, economic and social, or even political and technological aspects can also be integrated into this type of analysis. The digitalisation of biorefineries makes it possible to collect these datasets, analyse them and derive useful information for decision-making, whether in real time or not. The digitalisation of a biorefinery supply chain can extend beyond a company and also link its branches, suppliers, transporters and customers. A much broader lifecycle assessment is then possible through data exchange between these different partners<sup>3</sup>.

Supported by more flexible conversion technologies and the improvement and digitalisation of the supply chain, a current trend in biorefineries is to diversify feedstocks to produce different types of end products. In particular, supply chain optimisation must be able to adapt to variations in feedstock prices or availability, changes in suppliers and changes in markets for the final products. This should take into account not only the economic but also the environmental and social aspects of such a strategy. These three aspects are the pillars of the sustainability of a biorefinery and of many other industrial structures<sup>4</sup>.

Through the example of polyhydroxyalkanoates, the importance of defining an efficient biorefinery supply chain can be highlighted. Polyhydroxyalkanoates are linear polyesters whose thermal and mechanical properties can compete with those of traditional petroleum-based plastics. Polyhydroxyalkanoates have a wide range of applications: biomedical applications, nutritional supplements, printing and photographic materials, drugs and fine chemicals, biofuels, etc. More and more studies show the interest

in producing these biopolymers in biorefineries from renewable raw materials. Many scenarios are envisaged: for example, they can be produced simultaneously with some biofuels or biohydrogen. Although the bioproduction of polyhydroxyalkanoates is still a complex and costly multi-stage process, it meets a social and political demand and makes it possible to envisage the sustainable production of biodegradable plastics in reasonable quantities to meet some of the needs currently met by petroleum-based plastics<sup>5</sup>. Companies producing polyhydroxyalkanoates are committed to digitalising their supply chain and improving the lifecycle analysis of their products. One example is 'Newlight Technologies, Inc.', which enables its partners to know the carbon footprint of its products thanks to blockchain technology.

The production of polyhydroxyalkanoates as a co-product within a biorefinery allows the promotion of compounds that were previously considered to be worthless waste. This change in status of these compounds, from waste to raw materials for recovery, implies technological changes and a profound reorganisation of the supply chain. For example, consider a sugarcane biorefinery. The environmental impact of sugarcane burning can be reduced, while the brown leaves can be exploited, together with bagasse, for the production of biofuels, ethanol, lactic acid, furfural, itaconic acid, succinic acid, and polyhydroxyalkanoates in a biorefinery<sup>6,7</sup>.

Finally, the current improvement in the supply chain of biorefineries, as appreciable as it may be, does not make it possible to drastically reduce the costs of polyhydroxyalkanoates, especially those generated in the downstream stages of their production. The aim is not to completely replace petroleum-based plastics; the quantities of polyhydroxyalkanoates currently produced are too small in relation to people's needs. However, in a growing biopolymer market, polyhydroxyalkanoates have, and will have, their place. The efforts to make them more competitive from an economic, environmental, social, political and technological point of view with regard to petroleum-based plastics are numerous and rely in part on

improving the supply chain of biorefineries in cooperation with their internal and external partners.

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## Redesign an Integrated, Sustainable and Digital Supply Chain to Enhance Competitiveness: EssilorLuxottica Case Study

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EssilorLuxottica is a global leader in the design, manufacture, and distribution of ophthalmic lenses, frames, and sunglasses. Formed in 2018, it presents a vertically integrated business model covering every single step of the value creation process, with a strong focus on manufacturing excellence. EssilorLuxottica's mission is to help people around the world "to see more and be more" by addressing their evolving vision needs and personal style aspirations. The company brings together the complementary expertise of two industry pioneers, one in advanced lens technology, Essilor, and the other in the craftsmanship of iconic eyewear, Luxottica, to set new industry standards for vision care and the consumer experience around it<sup>1</sup>.

Before, Essilor and Luxottica were companies using their strengths to explore the potential of eyecare and eyewear around the world; today, EssilorLuxottica combines those strengths as one group. The creation of a fully integrated champion in the eyewear industry, combining lenses and

frames under the same roof, required a redesign of the supply chain from a single product manufacturer to an integrated network company.

The company generated consolidated revenue of €21.5bn (2021); it is present in both direct and indirect distribution channels in more than 150 countries covering all segments, serving 18,000 stores worldwide. Each year, EssilorLuxottica produces around 700 million between glasses frames and lenses<sup>2</sup>.

EssilorLuxottica currently has a complex supply chain covering the production of both frames and lenses. Actually, after the merger, the network was integrated and composed of:

- 14 frames mass manufacturing facilities;
- 39 lens production plants;
- 18 distribution centres;
- 564 prescription laboratories;

### EssilorLuxottica Supply Chain

- ◆ 14 Frame/Sunglass manufacturing facilities
- 29 Prescription lens production plants
- 3 Sun lens production plants
- 8 Integrated prescription laboratories
- ▲ 18 Distribution centres
- 480 Local prescription laboratories



The foremost vital drivers enabling companies to succeed at redesigning supply chains include digitalisation, automation, and supply chain integration<sup>3</sup>. Indeed, the company, exploiting digital technologies, has gathered and analysed a significant amount of data that provides useful insights for a holistic rethink and transformation of individual Luxottica and Essilor SC into a single integrated supply chain<sup>4</sup>.

The recent redesign of the supply chain has allowed the company to consolidate its position as a world leader, and to build more flexible operations and sustainable supply chains. In addition, it has enabled the speeding up of synergy capture, consequentially maximising efficiency, agility, and competitiveness. Estimations provided by the company demonstrated that supply chain integration, optimisation, and digitalisation lead to a reduction in logistics costs and operating expenses of €150-200m per year on EBIT.

EssilorLuxottica has invested hugely in Big Data Analytics, IoT, AI, and ML. They are crucial to creating integrated and dynamic supply chains. They are highly beneficial in terms of productivity, predictability, and efficiency, also by improving firms' capabilities to target customers effectively and satisfy the dynamic environment.

By adopting a digital supply chain management approach it has been possible to enhance internal processes and improve SC performance, which is needed to manage the considerable amount of data coming from the integrated supply chain. EL leveraged digital technologies to combine the respective supply chains and unify their operations to integrate frames and lens production leading to:

- **Operational efficiency and optimisation.** Implementing standardised and automated processes and technologies, permitting the reduction of production costs and supporting an improved business continuity plan.
- **Improved utilisation of assets to enhance quality and productivity.** Implementing a common equipment platform to support the transfer of knowhow and

best practice, sharing a fully integrated IT platform. This replaced the existing STARS (Superior Turn Automatic Replenishment System) used in Luxottica and ARTEMIS in Essilor, allowing optimised production schedules, inventory management, and automating the replenishment system. In addition, exploiting big data insights from the market, the management system tracks the level of inventories at wholesale as well as at retail level, so that its implementation would reduce operating expenses.

- **Consolidation of planning, distribution, and delivery of frames and lenses to reduce back order and delivery time.** EL redesigned the distribution network to improve replenishment, prevent an out of stock, and reduce the obsolescence of products.

The rationalisation of distribution centres brings the frames and lenses together under one distribution network to generate logistics cost reductions – it is estimated that €30m of distribution cost savings have been achieved – thus reducing delays to orders, which resulted in: **encouraged innovation and product development to prevent technological disruptions; new enabled commercial offers, elevated joint product proposals, which led to better cost management; reduced working capital and addressable spend**, i.e. synergies coming from the combined spending of overlapping categories. Estimates of the impact of cost synergies on P&L, with the largest reduction in COGS, indicate a reduction in purchasing costs of €70m per year<sup>5</sup>.

In addition, sustainability has always been deeply rooted at the core of EssilorLuxottica. “Eyes on the Planet” is the company’s programme that outlines its strategy and commitment towards environmental sustainability (e.g. carbon neutrality, circularity), social sustainability (e.g. ensuring equal opportunities to developing innovative inclusive business models, eliminating uncorrected poor vision, and improving occupational health and safety), reaffirming how mission, sustainability and business strategy are strongly intertwined at EssilorLuxottica.

The company, as an industry leader, is adapting its manufacturing activities to climate change and is reducing the carbon footprint of its direct and indirect activities to build a low-carbon supply chain. Specifically, EssilorLuxottica aims to achieve carbon neutrality for its direct operations (scopes 1 and 2) by 2025 and is completing a carbon footprint assessment (through LCA methodology) to prepare for a more comprehensive carbon reduction roadmap.

It continuously makes efforts across its supply chain to limit and reduce its impact on the climate, adopting the best practices relating to emissions in the new integrated supply chain. These include investing in energy efficiency programmes, maximising the use and production of renewable energy where possible, optimising production organisation and logistics flows and innovating in the field of sustainable and low-impact raw materials and low-carbon products and services. Thanks to these measures, EL has reached carbon neutrality in direct operations in both France and Italy<sup>6</sup>.

The company has focused particularly on manufacturing and transportation, which account for one of the most important indirect carbon emissions sources that works to reduce GHG emissions by optimised flows, combining the Essilor and Luxottica supply chains. The supply chain integration process has allowed for a significant reduction in CO<sub>2</sub> emissions by optimising the flows within the same network.

Climate-related actions represent drivers of operational efficiency, innovation, and enhancing competitiveness. Furthermore, digitalisation could support the transition to sustainable production, promoting the introduction of new business models through which to produce value to establish a competitive advantage in the market.

The implementation of the Industry 4.0 paradigm underpinned the company in the building of an integrated supply chain: driving optimisation measures, resource efficiency to achieve the targets of sustainability and circular economy, and the overall welfare of the staff and society.

To conclude in this way, EssilorLuxottica, thanks to digitalisation and sustainability, integration, and competitiveness have also been able to maximise value creation, not just to minimise costs.

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# The World Manufacturing Foundation

## Vision

“We strive to enhance manufacturing’s role as a dynamic and positive driver for economic, social, and environmental growth and sustainability”.

## Mission

The World Manufacturing Foundation is an open platform spreading industrial culture worldwide. We promote innovation and development in the manufacturing sector, with the fundamental goal of improving societal wellbeing and inclusive growth in all nations through dialogue and cooperation among the manufacturing sector’s key players.

We will pursue our goals by:

- supporting and shaping local and international industrial agendas
- providing a framework through which companies, governments, academic institutions and social organisations can interact or collaborate, acting as a catalyst for finding innovative solutions to major global challenges
- creating and disseminating knowledge in both policy and technology through local and international meetings and publications.

## Spreading Industrial Culture Worldwide

The World Manufacturing Foundation was formally established in May 2018 in Milan, Italy, as a platform to promote industrial culture and sustainable manufacturing practices worldwide. This undertaking was spearheaded by three founding partners: Confindustria Lombardia, IMS International, and Politecnico di Milano. The Foundation aims to spread industrial culture by expanding knowledge, promoting innovation, and fostering cooperation in the manufacturing sector.

The Foundation capitalises on its wealth of experience in hosting annual manufacturing events to discuss the most pressing challenges confronting the sector. In fact, long before the Foundation was formally established, the annual World Manufacturing Forum has been staged since 2011. The very first edition was held in Cernobbio in Lombardy and started as an important platform for global industry leaders and other stakeholders to exchange opinions on different issues related to manufacturing. The Forum started as a project funded by the European Commission, which has also supported its succeeding editions.

The World Manufacturing Foundation also has the support of important organisations. The Foundation was kick-started with the support of Regione Lombardia, which has also provided financial support in the last few years. In 2018, the World Manufacturing Foundation also signed a joint declaration with the United Nations Industrial Development Organization (UNIDO) to promote a common global agenda on technological innovation and inclusive and sustainable industrialisation, and to advance the 2030 Agenda for Sustainable Development.

The business model which defines the Foundation is that of the Triple Helix. Its competitiveness is empowered through an intersectoral collaboration engaging industry, academia, and government. This is evident in the nature of its founding and key partners and a large community of institutional partners from all over the world, which support the Foundation's initiatives.

### Founding Partners



### Thanks to







## **2022 KEY RECOMMENDATIONS BY THE WORLD MANUFACTURING FOUNDATION**

- 1 AVOID OVERREACTIVE POLICIES THAT BRING BACK THE PENDULUM OF GLOBALISATION**
- 2 ENSURE THE PRUDENT, CLEVER, ENTREPRENEURIAL, AND PROACTIVE REDESIGN OF SUPPLY CHAINS TO SECURE CRITICAL SUPPLY**
- 3 ADOPT AN ITERATIVE AND CONTINUOUS IMPROVEMENT APPROACH TO SUPPLY CHAINS**
- 4 DESIGN PRODUCTS FOR AN AGILE REDESIGNING OF SUPPLY CHAINS**
- 5 EXPLOIT THE OPPORTUNITY OF REDESIGNING SUPPLY CHAINS TO DRIVE CIRCULARITY AND SUSTAINABILITY**
- 6 ACCELERATE THE URGENT ADOPTION OF DIGITAL TOOLS AS ENABLERS FOR RESILIENT AND ADAPTIVE SUPPLY CHAINS**
- 7 SUPPORT SMALL AND MEDIUM ENTERPRISES BY INCLUDING THEM IN THE REDESIGNING OF SUPPLY CHAINS, LEVERAGING ON THEIR CAPABILITIES AND ADDRESSING THEIR NEEDS**
- 8 ADOPT A MULTI-DIMENSIONAL APPROACH TO CONSIDER GEOPOLITICAL RISKS AND OTHER NON-COST FACTORS IN REDESIGNING SUPPLY CHAINS**
- 9 RECOGNISE SKILLS AS THE NEXT MISSING FACTOR IN PRODUCTION**
- 10 TAKE ACTION THROUGH POLICIES TO EMPOWER RESPONSIBLE CONSUMER BEHAVIOURS TO REACH A STABLE ECONOMIC DEVELOPMENT**



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