WHITE PAPER

Supply chain disruption, resilience and recovery

Key issues for supply chain management practice

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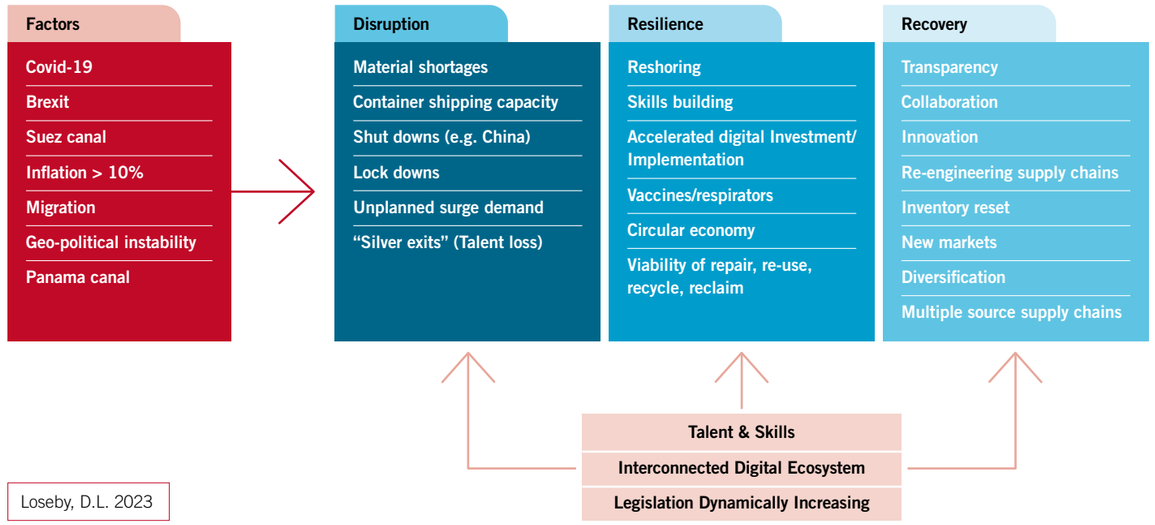
Setting the scene

1.1 A framework for supply chain disruption, resilience and recovery

Recent global events, starting with the pandemic in 2019, have created a dynamic environment that has not been witnessed for many decades. This has been catalysed by a series of impactful and ongoing instabilities (see Figure 1).

Fig 1 Functional activity affected by new digital technologies

VUCA and BANI



Loseby, D.L. 2023

The framework in Figure 1 is explained as follows:

Disruption
A series of notable and well-documented events, including Brexit, Covid-19, Suez and Panama Canal issues, Russia-Ukraine conflict, and numerous trade wars, have shown the fragility and complexity of global supply chains, which continue to be disrupted. Furthermore, there is a recognition in management and academic circles is that this will continue for some years to come and effectively endure as a feature of supply chain management.

Resilience
There has been a series of short-term and reactive responses to the disruption, some of which have been tactical, while others have been more strategic and structural, such as long-term investments and legislation. We can expect to see a greater emphasis on areas that will endure and grow in importance, such as more legislation to drive circular supply chains, sustainable practices (avoiding the use of finite, virgin materials, and creating digital ecosystems that support open collaboration and information sharing up and down supply chains. To ensure survivability and move into creating competitive advantage, the consensus from both business and policy is that we need to build resilience in order to ensure effective and efficient supply chains.

Recovery
Recovery will require an approach to global supply chains that will by necessity shift from tactical responses and short-term actions to strategic investments, innovation and a redefinition of how supply chains operate. There is no doubt that supply chains both upstream and downstream will need to operate more transparently and collaboratively in order to create competitive advantage. This should be incentivised, rather than taking a contractual "penalty" approach, and will require a significant reset to current behaviours and cultures.

Environmental factors (VUCA, BANI, etc.)
There are many environmental factors which are encompassed by the definitions of both VUCA and BANI:

VUCA – Volatility, Uncertainty, Complexity and Ambiguity, characterised by (in order); **V** – the environment you are operating in has unexpected or unstable characteristics of unknown duration. Further, it may not be hard to recognise or seek knowledge/solutions. **U** – the basic impacts may even well be known, however, change is not a given in the circumstances and therefore change may endure. **C** – a global supply chain is by definition complex with many interconnected materials, resources and transfers, most of which are not fully known or mapped. Generally, the quantum of information needed to map an entire enterprise's supply chain is very large, may take years to define, and will by nature be dynamic too. **A** – the interconnects within the supply chain are not fully mapped or clear. Casual relationships and indirect activities prevent comprehensive understanding of the supply network of an operation. This is in the territory of the unknown unknowns.

BANI – Brittle, Anxious, Non-linear and Incomprehensible, characterised by (in order); **B** – the strength and certainty you may believe you have in your supply chain is simply unfounded, and it is more vulnerable to external events than you believe. **A** – the recognition that our supply chains are more fragile than we first thought makes us anxious. Therefore, decisions are made quickly, which can lead to mistakes, with potentially disastrous results. Anxiety may also lead us to a state of passivity, since we fear making the wrong choice and worsening the situation. Therefore, we tend to delay decisions and actions. **N** – in short this is the disconnection between cause and effect, relative to actions in the supply chain either in terms of time, proportion or expected outcomes. Complexity in supply chains becomes nonlinear, i.e., without a single meaning or connection through the normal linkages that have been applied thus far. **I** - extremely difficult, if not impossible, to understand what is happening within a supply network or operation. Any attempt to find answers no longer makes sense. Further, analysis of any data or insights may cloud the ability to understand it, as well as make it hard to distinguish *signal* from *noise*.

Supporting factors:

Talent and skills
Emphasising the importance of talent management and developing a broader talent base (see Key Findings 5.1, page 12).

Interconnected digital ecosystem
Digital adaptability and digital agility are key components of developing a resilient supply chain (see Key Findings 5.2, page 14).

Legislation dynamically increasing
The past decade has seen a significant amount of legislation across Europe, the USA and Canada that aims to combat the brutal effects of modern slavery across the world. Zhang and Wong discuss the implications of 19 acts introduced in Europe and North America between 2012 and 2023 (Blog April 2023[i]). The provisions of these acts are applicable to organisations of different sizes, scopes of the supply chain, the level of scrutiny and transparency required, and impose different types of penalties for non-compliance. The analysis showed that:

- Most regulations are targeted at large multinationals.
- There are new regulations that also impact SMEs (but no clear mechanisms as to how these can be addressed by the SME business sector).
- New regulations cover both direct and indirect suppliers.
- There is an increased demand for a higher level of transparency.
- There is an increased emphasis on integrating supply chain due diligence policy.
- There are a variety of penalties for non-compliance.

In April 2023, the EU adopted The Critical Raw Material Act that aims to ensure that the EU can rely on strong, resilient, and sustainable value chains for critical raw materials. The Act was presented alongside the EU Commission's proposal for a Net Zero Industry Act, which aims to scale up the EU manufacture of key carbon neutral technologies for clean energy supply chains. This is just one example of the many pieces of legislation we are seeing across the globe.

1.2 Background resources

Research and management papers have reported, researched and commented upon the events of the past few years with vigour, and have created a great deal of insight relevant to supply chain resilience. The literature cites no less than 23 different definitions of supply chain resilience between 2010 and 2021[ii], cross-referencing the following key words: failure modes, ability, capability, adaptability, preparation, response, recovery, time, original state, better state, control, connectedness, robustness, competitive advantage, and cost effectiveness. The most holistic definition that captures these key elements on supply chain resilience is as follows:

> ***Supply Chain Resilience*** *is "The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than prior to the disruption".*[ii]

Research into supply chain resilience up to 2021, draws on ten different theoretical lenses: resource-based view, dynamic capabilities, systems theory, complex systems, complex adaptive systems, contingency theory, resource dependence, strategic choice, relational view, social capital and rational choice theory (see Resource Bibliography QR code at the end of this paper). Collectively, these lenses emphasise and capture a wide range of critical issues for developing supply chain resilience. Many of these are examined in this white paper.

What do we know about supply chain resilience? A review

2.1 The ADDAPT framework

An article, *Get Ready for the Next Supply Disruption*, that appeared in MIT Sloan Management Review (Winter 2022)[iii] provides guidance for supply chain companies to build capabilities to anticipate, detect, diagnose, activate resources, protect and track risks (presented as the ADDAPT framework), as shown in Figure 2.

Fig 2 The ADDAPT framework: extract from Rungtusanatham and Johnston. 2022. *Get Ready for the Next Supply Disruption*, MIT Sloan Management Review

Anticipate	Detect	Diagnose
Incentivise employees to share concerns about known and unknown-but-knowable supply disruption triggers.	Encourage organisational stakeholders to report occurrences of known supply disruption triggers and/or deviations in physical flows of products.	Provide the time, money, and expertise needed to support employees and relevant stakeholders as they engage in problem-solving activities.
Formalise procedures and assign personnel to hear concerns about those triggers.	Inform organisational stakeholders, strategic suppliers, and key customers of the trip wires for known supply disruption triggers.	Proactively engage external stakeholders, including strategic suppliers and key customers, in the development of a complete description of supply disruptions, immediate recovery interventions, and longer-term mechanisms, to prevent future supply disruptions.
Establish a learning lab to plan what-if scenarios for supply disruption triggers.	Connect trip wires to communication protocols for organisational stakeholders, strategic suppliers, and key customers.	
Regularly conduct drills and mock exercises to simulate supply disruptions.	Formalise rules, processes, and systems to easily, quickly, and widely communicate data that tracks known supply disruption triggers and the flow of products.	
Hold regular retreats with organisational stakeholders, think tanks, and experts to imagine future scenarios for the business, both positive and negative.	Create accessible dashboards to facilitate interpretation of deviations in planned activities (such as patterns of supply and demand), and to inform and shorten decision-making cycles.	

Activate	Protect	Track
Document the location of materials, personnel, and information within or beyond organisational boundaries, in real time.	Systematically review and evaluate the solutions activated as a rapid response to supply disruptions as desired practices for the long run.	Make ongoing investments in the personnel and systems needed to monitor known supply disruption triggers in real time.
Provide formal and emergency access and authorisation to deploy relevant resources.	Regularly update the rules, processes, and systems that support the other ADDAPT capabilities.	Provide dashboards to supply chain decision makers to ensure that they can easily see whether supply chains are operating normally.
Establish and deploy standby teams of experts from within and beyond the organisation to expeditiously respond to supply disruptions.	Share updated contingency and emergency response plans broadly within organisational boundaries and with critical suppliers and key customers.	Identify and define the leading indicators of supply disruptions and their associated risks.
Formalise relationships with preferred alternative suppliers for strategic items, including rules for tapping their capacity.	Conduct actual or virtual war games with relevant internal and external stakeholders to test the effectiveness of protection mechanisms against known supply disruption triggers on an ongoing basis.	Map and communicate the baseline indicators for physical flows of goods under normal conditions.
Codify contingency and emergency response plans and share them within organisational boundaries and with critical suppliers and key customers.		

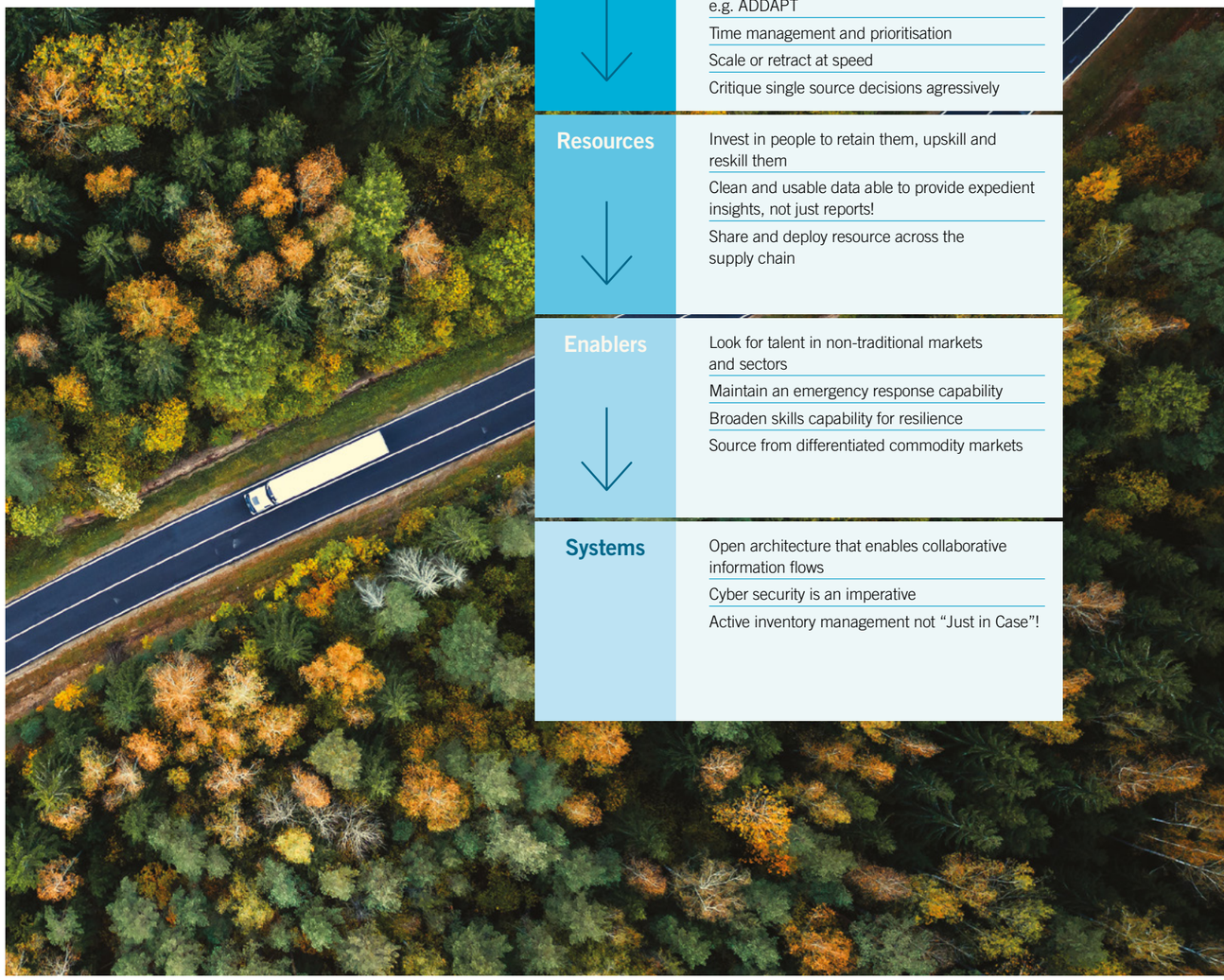
2.2 The thought leadership enablers: TARES

The following section is a curation of the common themes and key insights from a broad range of authoritative sources, which have been broadly categorised into a series of enablers; thought leadership, Action imperatives, Resources, Enablers & Systems (TARES).

Unpacking the concept of TARES into its primary elements we can break this down into the following attributes, shown in Figure 3.

Fig 3 Thought leadership, Action imperatives, Resources, Enablers & Systems (TARES), Loseby D.L. 2023

Thought Leadership	Adaptable leaders with an open and growth mindset Dynamic decision making void of bureaucracy Create a supportive and psychologically safe culture An organisational model designed for resilience (to seize new value opportunities)
Action imperatives	Embrace ESG & sustainability as a growth not compliance approach Embrace and cascade the right framework, e.g. ADDAPT Time management and prioritisation Scale or retract at speed Critique single source decisions agressively
Resources	Invest in people to retain them, upskill and reskill them Clean and usable data able to provide expedient insights, not just reports! Share and deploy resource across the supply chain
Enablers	Look for talent in non-traditional markets and sectors Maintain an emergency response capability Broaden skills capability for resilience Source from differentiated commodity markets
Systems	Open architecture that enables collaborative information flows Cyber security is an imperative Active inventory management not “Just in Case”!



2.3 Linkages to the WEF global risks research

A further take on this picture was summarised by the World Economic Forum (WEF) in The Global Risks Report (2023)[iv] that ranked the cost-of-living crisis as an immediate, number one concern and still a mid-ranking concern in the long-term. Further, when considered in the short term, environmental issues (natural disasters, extreme weather events, climate change, environmental incidents, etc.) all ranked in the top half of all the risks indicated in the survey results (out of 32 risks), but in the long-term, they are all clustered in the top 10 issues.

These technological, environmental, societal and geopolitical risks are interconnected and will not be mitigated unless positive action is taken to address them, including rebalancing the pursuit of short-term profit over long-term sustainability and societal cohesion. Therefore, the reality is that none of these attributes can be looked at in isolation. They will require a broad and coordinated approach if organisations are to become resilient and move beyond recovery into a new regenerative business model that responds and reacts to dynamic and ever changing external and internal environment more rapidly than ever before. The risk for some organisations is that "*technological delusion that leads to more data but less coordination*"[v] still remains a spectre in the supply chain challenges that lie ahead.

Addressing the five areas identified in the ADDAPT model in Figure 2, we can see that they map onto the key themes that the World Economic Forum (WEF) believes will be prominent over the next two

years and 10 years as respective horizons These short to medium-term horizons, or outlooks, break down in terms of risks to supply chains as global risks, as shown in Figure 4. This indicates no likelihood of stability for some time to come, hence the need for resilience and recovery amid ongoing disruption as a business imperative for supply chains to adapt to as a new paradigm of working. For instance, Technological maps onto the Detect, Diagnose, Activate and Track pillars from the ADDAPT framework.

Fig 4 Global risks perception survey results (WEF) – Top 10 risks. (Source: World Economic Forum Global Risks Report, 2023)

Technological	Environmental	Societal	Geopolitical
Widespread cyber crime and cyber insecurity	Natural disasters and extreme weather	Cost-of-living crisis	Geoeconomic confrontation
	Failure to mitigate climate change	Erosion of social cohesion and societal polarisation	
	Large scale environmental damage events	Large-scale involuntary migration	
	Failure of climate change adaptation		
	Biodiversity loss and ecosystem collapse		
	Natural resource crisis		

The importance of an agile and responsive strategy

As part of any strategy, we must consider the critical success factors and/or key enablers in advance of any investment, recognising that the wrong approach, choice of digital partners, providers, or the rationale for making such an investment could be disastrous.

The ability, , to make expedient decisions based on quality data and insights, in a well-delegated, non-bureaucratic, empowered, and transparent manner, is essential.

In addition to the considerations above, factors such as cyber security, economic stability and the regulatory landscape are likely to become more challenging and require greater consideration in the coming years.

On critical examination, we can see that the WEF has emphasised that skills will have a half-life of five years, and that procurement and supply chain functions have pivoted significantly to deal with supply risk, resilience, hyperinflation, disruptions, and a complete shift in their way of working. This can be termed as getting to "GRIPPS" with a new procurement paradigm, fit for a world where BANI is the norm, with increasing investment in digitalisation, re-shoring and increasing legislation in the space of ESG, sustainability and social equity. This is conceptualised in Figure 5.

Research and management reports have unanimously cited the above factors, and have emphasised in particular: agility and strength of leadership; investment and development of digital capabilities to derive insights and effect scenario planning at speed; ability to change course at speed and radically collaborate with the entire supply chain as the "eyes and ears" of the business in every corner of the globe.

Fig 5 Conceptualising Procurement 4.0 (DT) – Loseby D.L. 2022

Enablers for Procurement 4.0 (DT)

- **G overnance and Sponsorship**
- **R esources: Human, Fiscal, Insights, etc**
- **I nformation (clean and usable data)**
- **P rocess: Category Management, PMO, Company**
- **P eople: Talent, Skills, Capabilities, Opportunities and Motivations > Behaviours**
- **S ystems: Integrated, Secure, Open Architecture, APIs**

Getting to "GRIPPS" with Procurement 4.0 (DT) Digital Transformation (loseby 2022)

Recent surveys and interviews with the procurement community

Detailed below is a snapshot of some key statistics drawn from a broad base of published sources:

Disruption – are organisations prepared?	**a.** Procurement functions spend 60% of their time on administration and minor operational tasks[vi].
	b. 46% of automotive, manufacturing and engineering employees say they are somewhat likely to leave their current job in the next 3-6 months[vii].
	c. At the onset of the pandemic only 16% of organisations had an emergency response centre[viii].
Resilience and recovery	**d.** The payoff of organisational resilience is even higher in times of economic uncertainty. During the economic downturn following the 2007–08 financial crisis, about 10 percent of publicly traded companies outperformed the rest. By the time the downturn had reached its lowest point in 2009, their financial performance measured by EBITDA had jumped 10 percent; their industry peers had lost nearly 15 percent. This trend has also held true in recent years (Ref: as b above).
	e. 83% of supply chain leaders (113 surveyed) said that the footprint resilience measures they have taken over the past two years have helped them to minimise the impact of supply chain disruptions in 2022[ix].
	f. 38% of survey respondents have entered into new supply markets to reduce their risk to continuity of supply[x].
	g. Case studies of automotive manufacturers suggests that on average it takes one month to recover from 4-6 days of disruption[xi].
Digitalisation to achieve resilience, but talents are scarce	**h.** 99% of respondents to a survey said they need more in-house digital supply chain talent to support their current and planned digitalisation efforts - a tenfold increase on the previous year. (March 2022)[xii].
	i. 67% of respondents have implemented digital dashboards for end-to-end supply chain visibility. These companies were twice as likely as others to avoid supply chain problems caused by the disruptions of early 2022. (Ref. as e above)
	j. Only 8% of respondents felt they had sufficient in-house talent to support their digital ambitions. (Ref. as e above)
	k. In a typical organisation, suppliers log-on to an average of 8.4 systems[xiii].
Risk culture	**l.** Federation of European Risk Management Associations (FERMA): 75% of risk managers believe that improving risk culture and strengthening the integration of resilience into the strategy process are the most important actions[xiv].
More Just-in-Case inventory	**m.** Inventories increased by an average of 11% between 2018-2021. (Ref. as e above)
	n. 71% of companies intend to revise their inventory policies in 2022-23. (Ref. as e above)
Increasing use of dual sourcing	**o.** 81% of companies have implemented dual sourcing strategies up from 55% in 2020. (Ref. as e above)
	p. 70% of private and 63% of public sector respondents have increased their level of dual or multi sourcing within their strategic spend categories. (Ref. as f above)
Low visibility beyond tier 1 hides risks	**q.** 45% of survey respondents say that they either have no visibility into their upstream supply chain or that they can see only as far as their first-tier suppliers. (Ref. as e above)
	r. Only 14% have a good view of third-tier suppliers. Deep supply chain transparency remains especially problematic for the automotive, aerospace, and defence sectors, with only 9% of respondents confident in their third-tier supplier visibility and none expressing satisfaction with their supplier visibility at all levels. (Ref. as e above)
	s. There is low supply chain visibility across sectors: only 13% of respondents have a fully mapped supply chain network. (Ref. as f above)
	t. 71% of respondents have limited or no visibility beyond tier 2. In short, this highlights the need (as seen in Figure 6) to see down into the lower tiers of supply chains as an imperative. (Ref. as e above)

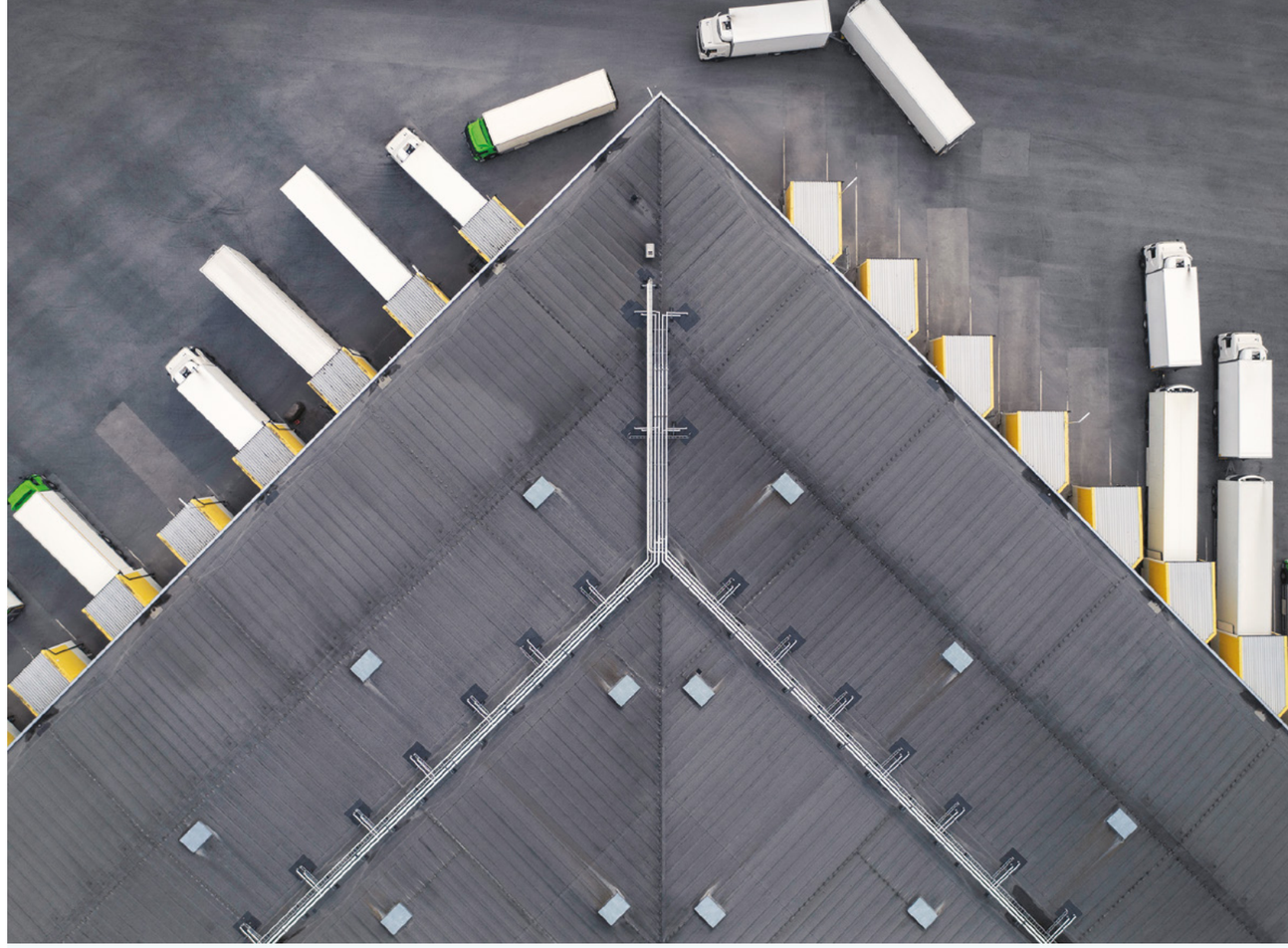
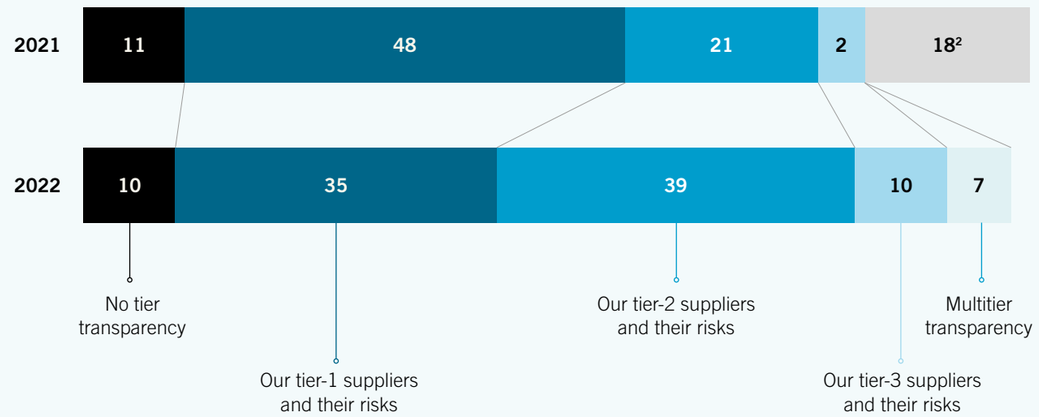


Fig 6 Limited visibility into supply chain lower tiers (Source: Taking the pulse of shifting supply chains – McKinsey, August 2022[xi])

Global supply chain leaders' visibilty into supply chain tiers,[1] % of respondents (n=113)



[1] Question: In 2021, "To what extent are you pushing for multitier transparency as a consequence of the COVID-19 crisis?"
In 2022, "To what extent are pushing the multitier as consequence of the crises of the past two years?"

[2] The remaining 18% did not answer this question.

Source: McKinsey survey of global supply chain leaders (28 March – 19 April, 2022)

Key findings

In reviewing the literature used for this white paper, as illustrated earlier, we would summarise the key findings under four themes: talent, digital ecosystem, collaboration and ESG.

5.1 Talent

An article by Fuller and Sigelman (2021), "Manage Your Talent Pipeline Like a Supply Chain"[xv], resonated well, and suggested the following actions for employers:

i. Employers must work actively to draw from a broader talent base.
ii. Employers must invest in "growing their own."
iii. Employers need to implement fundamental principles of supply-chain management.

In short, it declared that, "*A complex modern economy requires sophisticated, expertly managed supply chains. It's time to start building a good one for talent.*"[xv]

The Hackett report also recognised this, as it called for organisations to start "*Developing new capabilities to deliver on broader value expectations amid changing conditions.*"[xvi]

An MIT Sloan review stated that CPOs believe that their organisations need to develop employees with broad ranging skills[xvii]. However, under half the organisations surveyed were thought to have enough specialist skills (e.g. data, soft, ESG, etc.). It also recommended:

- The rotation of assignments and roles.
- The use of AI and machine learning to uncover and develop new skills.
- Caution regarding self-reporting of skills as they show an under-estimation of true capability.
- Embracing talent from all areas, not just STEM.
- Proactively looking at, and preparing for future needs.

A recent McKinsey report (2021)[xviii] identified the top 10 skills that survey respondents (over 700 senior personnel) identified as being the most critical to build. To avoid talent loss, organisations should reskill employees in critical thinking (44%); leadership and management (41%); advanced data analysis (36%); project management (33%) and complex information processing (30%). Advanced IT skills, statistical skills and digital skills all ranked above 25%.

Going forward, both broader and/or more complementary skills connected by more robust and integrative collaboration skills, will connect the four areas (of skills) listed below:

1. COGNITIVE: Critical thinking, planning and ways of working, communication and mental flexibility.

2. INTERPERSONAL: Mobilising systems, developing relationships, teamwork effectiveness and collaboration.

3. SELF-LEADERSHIP: Self-awareness and self-management, entrepreneurship and goal achievement.

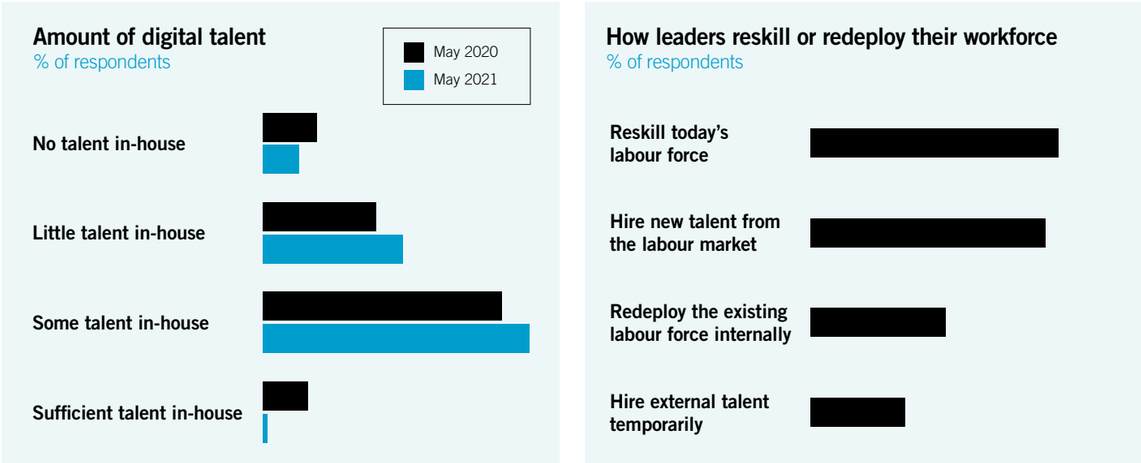
4. DIGITAL: Digital fluency and citizenship, software use and development and understanding digital systems.

Clearly, this does not mean that all the classical skills (problem solving, creativity, self-initiation, adaptability and grit) developed are no longer salient, but instead are at the core of a total skill set.

All the findings in many of the reports have been restated over and over again, as can be seen in this more recent McKinsey (2022) survey[xix], which amplified the call for reskilling and upskilling, along with the need to look for new sources and areas of talent. Further, as we have identified the research in talent, training and development, all feature in our calls for further research.

Fig 7 Talent and reskilling (Source: Transforming supply chains: Do you have the skills to accelerate your capabilities? pp2. March 2022[x])

Talent mismatches increase companies' focus on internal reskilling and redeployment



Source: McKinsey survey of global supply chain leaders (4 May – 16 June, 2021; n=71)

Fig 8 Key definitions – Dynamic digital capabilities and supply chain resilience: The role of government effectiveness[xxi]

	Source	Definition
1	Digital technologies (Warner and Wager, 2019, c.f. Bharadwaj et al., 2013, p. 471, p. 471)	"Digital technologies are defined as a "*combination of information, computing, communication, and connectivity technologies that can transform business strategies, business processes, firm capabilities, products and services, and key interfirm relationships in an extended business network*".
2	Digital capability (Sousa-Zomer et al., 2020)	Digital capability is defined "*as the ability of the organisation to use digital technologies to gain a competitive advantage in the digital environment*".
3	Digital agility (DAGL) (Grover, 2022, p. 709, p. 709)	Digital agility is defined by: "*…four tenets that characterise agile organisations: modular design and packaged capabilities, use of platforms over pipelines, ability to foster concurrency and agency through data, and a digital culture that promotes ambidexterity*".
4	Digital adaptability (DADAP) (Lee, 2021; Puckett, 2022)	The capability of an organisation to adjust its approach towards the dynamic situation, powered by digital technologies, is termed digital adaptability. The tenets of digital adaptability are "*the learning abilities of the organisation to adapt to new technologies to improve their supplier relationships, customer relationships, and new product development capabilities in the wake of dynamic changes in the market due to various reasons, including trade restrictions, natural disasters, geopolitical crises, or pandemics*".
5	Digital culture (Grover, 2022, p. 712, p. 712)	"*Digital culture has been described as a distinct type of culture that reflects a digital mindset*".
6	Supply chain resilience (SCR) (Ponomarov and Holcomb, 2009, p. 131, p. 131)	"*Supply chain resilience is defined as the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function*".
7	Government effectiveness (GOVE) (Garcia-Sanchez et al., 2013, p. 567, p. 567)	"*The notion of government policy effectiveness is oriented to more closely matching services with citizen preferences and moving governments closer to the people they are intended to serve, thus ensuring greater accountability of the public sector*".

5.2 Digital ecosystem

Research by Graham, Sharoff and Winn (2022)[xx] recognised the wider benefits gained from organisations positively embracing digitalisation, such as social inclusion and government accountability, as well as resilience. The research undertook to explore and understand how digital adaptability and agility can improve supply chain resilience, along with offering multiple future research directions. The research helped to summarise the various digital definitions into a succinct table shown in Figure 8:

The key findings from the study are:

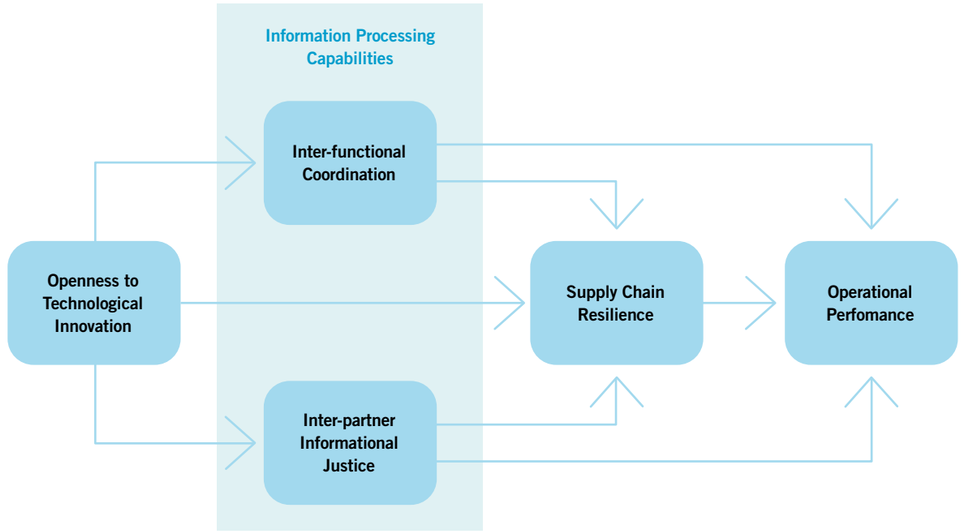
- Adaptability has a higher order capability than agility.
- Participation of consumers and producers improves collaboration, giving the ability to capture, analyse and exchange huge amounts of data, improving the (digital) platform's value for every stakeholder.
- Digital transformation is an ongoing process (not an end point).
- Digital adaptability has an indirect impact on digital agility, which in turn has a positive and significant effect on supply chain resilience.
- The moderating role of government policy effectiveness was proven through the study results.

5.3 Collaboration v protectionism

Chen, Sohal and Prajogo (2013)[xxii], identified supply chain collaboration as an area of specific focus, even before the Covid-19 pandemic occurred. They cited a strategic orientation towards collaborative efforts to align different supply chain entities into a unified whole, recognising that competition is no longer between individual companies but between different supply chains, and that collaborative advantage is about leveraging resources and knowledge as a whole network. In certain cases, collaboration has led to the development of risk mitigation frameworks aimed at two types of risk: operational risk and disruption risk, with information lying at the heart of reducing demand risk, which forms part of operational risk.

The results of the research identified a very strong relationship between supply risk and process risk, giving the known example of MRP systems that are using accurate and timely information regarding material supply delays to allow production activity to be rescheduled and amended, in order to mitigate disruption to production flows and activity, and negate cost impacts.

Fig 9 Model of Organisation Information Processing Theory (Source: Yu et al[xxv])



5.4 ESG, circular economy principles and sustainability

In recent papers[xxiii xxiv] on the role of Organisation Information Processing Theory (OIPT), consideration is given to how this can be an enabler in an area such as ESG, and how the activity of communication and collaboration among functional departments within organisations can be conceptualised for benefit. Figure 9 is the conceptual model relating to organisational information processing theory.

In essence, a resilient supply chain can continue to positively contribute to the ESG and sustainability needs of an organisation. This is in addition to its ability to contribute positively to cost efficiency, flexibility, and delivery performance.

According to an MIT Sloan Review article on commodity markets, global supply chains are opaque, turbulent and lack the provenance of their inputs[xxvi]. Supply chain traceability should focus on generating value, not just mitigating loss. However, the status quo fails to trigger demand signals that could drive transformative change. This is because the paradigm of "due diligence" primarily assuages concerns, instead of producing certainty. There are abundant examples from other differentiated commodities, where traceability underpins value creation. Diamonds, coffee, chocolate, and wine all have differentiated markets in which responsible producers are rewarded with a green premium for going beyond due diligence.

The solution proffered is differentiated commodity markets with product level, and even batch level, identification, followed by a chain of custody model leading to certification-enabling tracking and tokenisation, via a method known as *book and claim*.

Over the next several years, it is expected that we will see high performance standards emerging from many of the incumbent platforms, such as the Aluminium Stewardship Initiative, Responsible Steel, and the Copper Mark. Further to this, sustainability accounting will improve through projects like the Coalition on Materials Emissions Transparency (COMET) Framework, and Horizon Zero for the digitisation of supply chain accounting.

A recent paper looking at collaboration as an enabler for circular economy (CE)[xxvii] found the following: "*multi-stakeholder collaboration to be an important antecedent to CE implementation in a developing country context. Furthermore, multinational companies who implement CE business models generate a beneficial symbiotic relationship with local businesses. These benefits mainly revolve around technology transfer and organisational learning which is necessary for resource efficiency and clean technology - the basis for CE. Therefore, to advance*

knowledge and practice in this area, we propose a model for collaboration as an enabler for CE".

CE is defined as an economy that is "*restorative and regenerative by design*" (Ellen MacArthur Foundation, 2013). Additionally, it relies on the basic principle that someone's waste is a resource to someone else.[xxviii] Thus, CE involves a high degree of complexity, as it encompasses all activities from extraction to production and beyond. Moreover, CE is an economy that aims to keep the value and utility of components, materials and products at their highest, through regenerative and restorative design[xxix]. It also requires the development of new capabilities, networks and business models, such as "reduce-reuse-recycle", to help circulate and retain the value of natural resources for the long-term.

Mishra's research[xxx] (2021) has examined the implementation of CE business models and recommends that focus should be given to:

- Value proposition (e.g., long-lasting products, products as service).
- Value creation and delivery (e.g., implementation of R-processes, waste elimination, use of renewables).
- Value capture (e.g., reduced economic, environmental, and social costs).

Diversification

Identify alternative sources of supply to create flexibility in the supply chain.

To ensure resilience in circular supply chains, businesses need to rethink their use of products and materials. This needs to start from the product design level. For example, if you are in the apparel industry, you know that cotton is one of the thirstiest crops, so you would look for alternative materials and/or more diverse sources. Examples could be to use hemp or bamboo which is readily found and more sustainable than cotton.

International partnerships

Work with international partners to identify common challenges and strengthen the resilience of international supply chains and systems.

When Kingfisher[xxxi] decided to close the loop for some of their products, they organised a supplier summit to identify sources of sustainable materials. They identified a supplier in Sri Lanka to help them redesign their products. This illustrates the importance of international partnership. However, research has also highlighted that, in the long run, local partnerships could be more sustainable. Hence, priority should be given to local partnerships.

Onshoring

Identify whether increasing or expanding domestic capacity might be helpful in reducing risks.

For resource efficiency and meeting net zero goals, businesses need to move away from product stewardship to stakeholder engagement. Working with local suppliers could co-create opportunities for small businesses to grow. Moreover, these companies could initiate circularity and help to minimise waste. This was highlighted in the research by Pinheiro et al (2019)[xxvii], which identified that companies could have a stronger circularity if they had multiple stakeholders involved in the strategy of circular economy. With local companies, this process would be more efficient as companies could guide them and collaborate to have a circular mindset.

Data and visibility

Increased information and visibility of supply chains needs to underpin all efforts to increase resilience by providing the information needed to inform action.

Digital technologies can enhance the process of circularity in businesses, and can be particularly helpful in locating sources of products and materials, optimising routes, automating processes, and reducing waste. The Internet of things (IoT) and artificial intelligence (AI) could be used to develop smarter decision-making support for businesses to enable circularity[xxxii].

Policy levers

Government will identify whether there are policies, regulations or other levers which can be used to aid resilience.

The role of government is one of the key factors in making the circular supply chain resilient. Governments should promote the use of renewable energy and provide incentives to businesses. When looking at sustainability in the supply chain, Pinheiro et al found that certain incentives had been put in place by previous governments. Therefore, any subsequent changes in government would lead to uncertainty regarding the investment made by businesses toward sustainability.

Again, in another project[xxxiii] it was found that once products/materials are considered as waste, they cannot be brought back into the system as a raw material. Policies need to make the system more circular, so that the waste from one system can be used as raw material for another system.

Summary: Key insights on supply chain disruption, resilience and recovery

This white paper demonstrates the value of bringing academic research to the business domain, to inform future strategic direction, taking into account the lessons learnt during the Covid-19 pandemic and more recent geopolitical instability.

The relative stability enjoyed for many decades is no longer possible and therefore we must recognise, accept and adapt to a different work paradigm. The need for greater adaptability, flexibility and a constant dynamic in which the terms VUCA and BANI are the norm, is not merely a new experience that will soon disappear.

Unless we have radical collaboration, both socially and in a business context, then the inter-connected world will experience not only a loss of economic value but also social degradation. However, it's clear that supply chain disciplines have a pivotal role in mitigating and potentially turning these challenges into opportunities.

Summary recommendations from this white paper (the DEER model) are:

1. D igitalisation

a. Understanding our supply chains in a dynamic way is an imperative which can only be achieved through a digital ecosystem.
b. We must be able to track and develop new and nuanced scenarios to make decisions.
c. Digitalisation must take an open architecture approach.
d. An enabler for more productive and transparent collaboration.
e. Digital fluency and citizenship.
f. Contingency and continuity planning are an ongoing activity, not just for "pandemics"!

2. E nablers:

a. A strategy that is designed to live and breathe.
b. Design in "agility and flexibility".
c. Ensure greater levels of empowerment and remove bureaucracy.
d. Transparency as a competitive advantage in a supply network.
e. Entrepreneurial supply chains see threats as opportunities.
f. Psychological safety and a culture for progressive thinking and curiosity.
g. Collaboration throughout the supply network.
h. Communication at speed through the supply network is an enabler and mitigator of supply chain risk management.

3. E xternal environment:

a. Ongoing instability.
b. More legislation and at a greater pace.
c. VUCA and BANI will continue to prevail as concepts and must be planned for.
d. Climate change is real, and actions are needed now for the long term.
e. Understand the implications of forced migration on supply chains.

4. R esources:

a. Material resources are finite so we must shift to a more sustainable and circular approach to our supply chains.
b. People are a key factor to everything in the supply chain, therefore training, development, upskilling and retention must be a priority.
c. Clean data is a value commodity and must be treated as such.
d. Contracts and agreements with incentives rather than penalties will drive the right behaviours.

Future research considerations

Some consistent themes and knowledge gaps have emerged from this review. These suggest the following directions for future research:

- The benefits and value attributed to open, transparent and collaborative supply chains.
- The behavioural aspects of actors (people) within supply chains and the extent to which they can be value adding and value destructive to an entire supply chain network.
- Creating a culture of openness, not only to digital transformation, but also openness to information sharing at a level that is beneficial and that does not impede the integrity of an organisation's competitive position in the marketplace.
- Explore more closely how behavioural aspects of procurement management are embedded in procurement practice and training.
- Explore how inventory management strategies will evolve over the next few years, along with defining new proxies for how inventories are managed on a sectoral basis.

Research at the Centre for Operations and Supply Chain Research (COSCR) at Leeds University Business School

The Centre for Operations and Supply Chain Research (COSCR) is a multi-disciplinary research centre that focuses on developing and disseminating knowledge in operations and supply chain management, as well as advancing managerial practices.

Fig 10 Supply Chain Resilience research by Centre for Operations & Supply Chain Research

Digitalisation for resilience	Collaboration for sustainability
• Dynamic digital capability (Graham)[xxxiv] • AI-driven big data culture (Graham)[xxxv] • Internet-based DSS for circular economy (Mishra)[xxxvi] • Openness to technology innovation and data driven culture (Wong)[xxxvii]	• Collaboration for circular economy (Mishra)[xxxviii] • Environmental transparency and accountability (Wong)[xxxix] • Internal and external environmental collaboration (Wong)[xl]
Collaborative risk management and resilience	**Risk management and resilience**
• Risk management thinking (Loseby)[xli] • Collaborative risk management (Chen)[xlii] • Supply risk mitigation (Chen)[xliii] • Supply chain resilience (Manners-Bell)[xliv]	• Supply chain evolutionary design (Graham)[xlv] • Institutional forces (Wong)[xlvi] • Federal supply chain (Bhandal)[xlvii]

8.1 Recent research by COSCR

Researchers from the Centre for Operations & Supply Chain Research at Leeds University Business School have studied supply chain resilience and sustainability from four perspectives and distilled a greater sense of the state-of-the-art as well as the future research agenda. The four perspectives are set out in Figure 10 with cross references to published research.

Wong (2023), reflects on the need for a new paradigm of "competitive advantage for supply chains from resilience and recovery". He contends that the wider macro view beyond the current situation warrants further exploration and consideration both in academia and industry, through some form of radical collaboration that will enable effective policies, plans and proactive steps.

Key challenges facing us in the next decade include:

- Collapse of systematically important supply chains.
- Oil and gas scarcity (e.g. due to the Ukraine war being potentially escalated or expanded).
- Medical (COVID-19 pandemic, and the next one).
- Large-scale "migration" of industries away from conflict zones and state collapse.
- US debt default/ceiling, banking crisis.
- China's economic downturn and mass unemployment.
- Climate crisis becomes triple planetary crisis (planetary emergency). Triple planetary crisis refers to three interlinked issues: climate change, pollution and biodiversity loss that could lead to mass migration and extinction.
- The above collapses could further increase the cost-of-living crisis, leading to another scale of loss in social cohesion unseen in recent decades.

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About this white paper

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