
**¹Causes of Paints and Coatings Raw Materials Supply Chain Crisis and its
Impact on Businesses**

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Received: Dec 21, 2022; Revised: April 3, 2023; Accepted: June 25, 2023

Abstract:

Abstract: The paints, coatings, and surface technologies industry's global supply chains have grappled with severe shortages and significant disruptions. This research investigates the underlying causes behind this failure, which results from a complex interplay of interconnected events with a cascading impact. Logistical challenges, plant accidents, environmental regulations, Brexit, the COVID-19 pandemic, and a surge in demand, have led to undesirable outcomes and highlighted management challenges. Adopting a pragmatic approach, the study identified practical solutions managers and procurement teams could adopt. Utilizing an inductive methodology, the research focused on the root causes of the crisis, emphasizing that understanding the origin is essential for effective management. To validate the proposed strategies, a survey among industry practitioners was conducted. Relevant case studies of market leaders were examined focusing on the inbound logistics and procurement perspective, highlighting the critical role of strategic procurement and supply chain risk management for company competitiveness and survival in challenging circumstances. At the organizational level, the research identifies a gap in understanding the compatibility of lean principles in supply chain management with the realities of globalised supply chains.

Keywords: *supply chain, globalisation, lean, just in time, resilience, mitigation strategy.*

Introduction

During and immediately after the COVID-19 pandemic, the chemicals market has been under huge pressure due to shortages and unavailability of many raw materials. As a result, for around two years, manufacturers of paints and coatings faced supply chain issues as the flow of the materials has been disrupted many times. Supply Chain (SC) managers and purchasers struggled to provide their production operations with sufficient components (Francis, 2021) and supply volatility was one of the top worries of the businesses concerned (Fitzgerald, 2022).

According to (Fitzgerald, 2022), in 2021, up to 85% of critical components, such as epoxy resins, monomers, specific additives, silicones, and surface-active agents, were in limited supply along with acrylics and solvents (Cox, 2021), while (De Castro, 2021) specifically mentions scarce

¹ DOI: <https://doi.org/10.51659/josi.22.172>

solvents, binders, and pigments of specific colours such as white, yellow, and red. At the same time, other authors (Fitzgerald, 2022; Cox, 2021; O'Shaughnessy, 2021), state that demand for paints and coatings was increasing significantly. As a result, the combination of supply challenges for crucial raw materials and customers' increased interest in coatings has created an unprecedented supply and demand mismatch in the sector (Fitzgerald, 2022; De Castro, 2021). Ingredient scarcity produced a “*domino effect*” further down the SC, leaving businesses with out-of-stock commodities and end users with empty stores (Fitzgerald, 2022; Rezai, 2022).

The significance of the issue for the paint industry can be better understood when considering that, in most cases, raw materials account for roughly 80% of the selling cost, while production overheads, sales, marketing, and other costs account for only 20% (Rezai, 2022). Because paints are made from so many different chemicals, the business is strongly reliant on raw material availability (De Castro, 2021). Additionally, (De Castro, 2021) argues that the large diversity of components is at the heart of the complexity of paint and coatings SCs, which were impacted by a combination of geopolitical, logistical, and capacity challenges due to their global character. As a result, SC resilience has remained the chemical industry's top focus over the last few years (Fitzgerald, 2022), while paint and coatings manufacturers have been dealing with disruptions, inventory volatility, demand shocks, and increasing operating costs since early 2020 (Rezai, 2022; HPS, 2022).

Because paints and coatings are often considered merely a décor supplement to other products, this may appear insignificant, however, paints and coatings provide a variety of other functions, such as scuff and scratch-protection, anti-corrosion, antibacterial, chemical resistance, water resistance, and so on. They improve the functionality of other items (Rezai, 2022). Moreover, chemical shortages impacted not only paint makers but also the automotive industry, which was unable to obtain semiconductors. Though there were other causes for chip shortages, one of the most significant was a lack of solvents, which are essential in the semiconductor manufacturing process (Braun, 2021).

Literature Review

Paint and Coatings Industry Overview

The paints and coating market ecosystem is highly structured although substantially divided into the Decorative (~40%) and the Industrial Paints and Coatings (~60%) (Markets and Markets, 2023) and one of the most strictly regulated in the world (S&P Global, 2023). As a result, companies have been compelled, to embrace low-solvent and solventless technologies over the last 40 years (S&P Global, 2023). The number of coatings producers is significant, but the majority are regional, with only a few large multinationals. Consolidation has been the most notable trend, particularly among the major manufacturers (S&P Global, 2023).

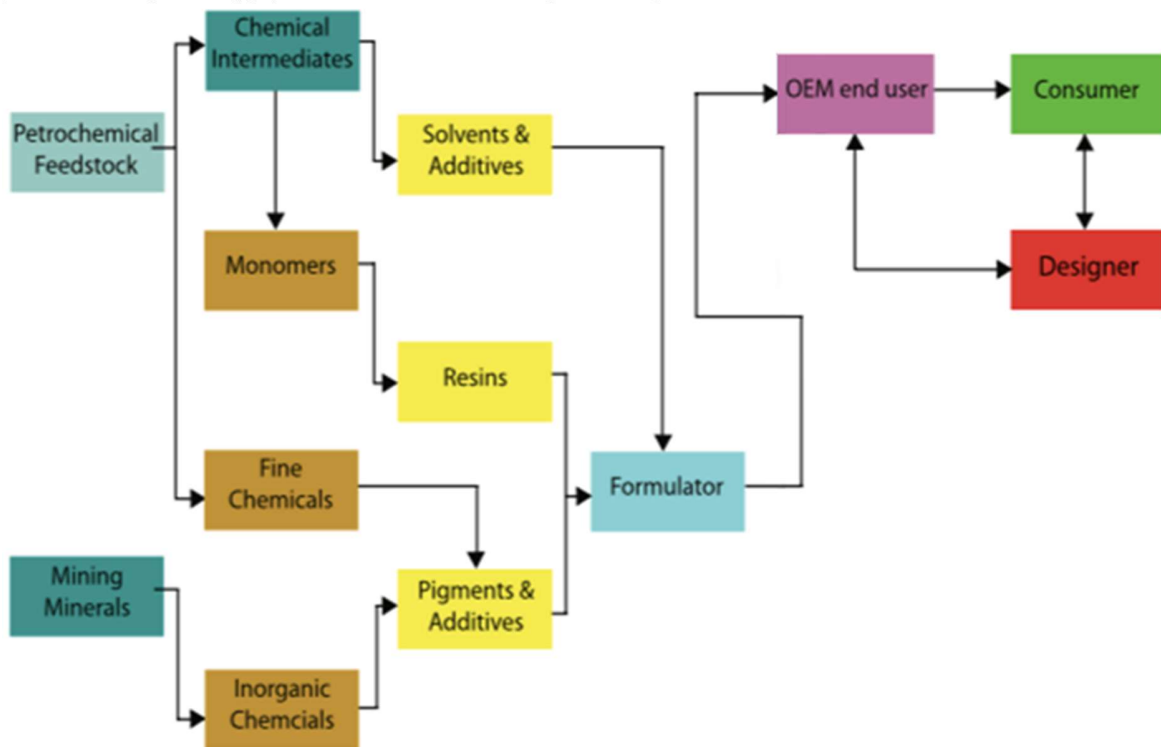
Environmental laws in all regions are getting increasingly stringent to limit emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Energy conservation and growing solvent and raw material costs are additional considerations. Raw material costs account for 40-60% of overall coatings production costs (S&P Global, 2023). The coating sector is a major consumer of solvents, which are mostly produced from petrochemical feedstocks and refinery operations. It also consumes a significant amount of nonpetrochemical feedstocks, such as pigments and additives, which are not as sensitive to crude oil and petrol prices. Nonpetrochemical feedstocks account for roughly one-third of total feedstock volume (S&P Global, 2023).

Supply Chain of Paints and Coatings business known and recent issues

One of the major problems of the paints and coating SC was already addressed back in 2005 pointing out the tendency to hold as little stock as possible while having a global and extended SC

(Challener, 2005). Interestingly, the (S&P Global, 2023) analysis of the Paint and Coatings industry shows that this has not substantially changed. The peculiarities of the Paint and Coatings SC emerge also in (Shvets, et al. 2022) study on the challenges encountered in establishing global value chains in the paint and coatings sector, and (Pilcher, 2023) analysis of coatings raw materials following the SC crisis, while the point of view of the industry is best reflected in Coatings World publications, from a description of the true complexity of its SC (Lowry, 2007) – see Figure 1 – to the clash between its value and SCs (Phillips, 2015), or the value of the brand for coating formulators and additive supplies (Shawhan and Phillips, 2019).

Figure 1 - The full Supply Chain in the Coating Industry



(Source: Adapted from Lowry, 2007)

According to (Pilcher, et al, 2021), demand for paint and coatings surpassed supply. The industry's exceptional demand was due in part to the reopening of enterprises following lockdowns, which raised consumption (Bowtell, 2021). In addition, the rise of the market in general, and increased consumption in numerous industries, exacerbated the problem. According to (Statista, 2021a; b), the market is growing steadily in both monetary terms and quantity sold. Business recovery following COVID-19 lockdowns, particularly in China, resulted in dramatically increased demand for paints and coatings as well as raw materials, resulting in significant shortages (Zimmerman, 2021), which led to price increases, imposing even more challenges on paint manufacturers (CME, 2020). China's role was twofold: first, as a global hub of raw material production (Pilcher, et al, 2021), and second, due to its recent policy to reallocate materials and energy resources to more profitable sectors (CME, 2020), (Francis, 2021). According to (Prieto, 2022), the V-shaped economic rebound in China is linked to material shortages in Europe, because of China's export restrictions on a number of products, certain components were simply unavailable.

Based on the aftermath of the COVID-19 pandemic, what Challenger wrote back in 2005 was still true in 2022, the only difference being that, due to raw materials shortages and low availability, the task of managing SCs effectively was even more challenging and crucial than ever, if then we consider the increasing volatility, uncertainty, and complexity characterising modern SCs (Robertson, 2021), it makes it extremely challenging to manage them successfully. Therefore, future events such as a pandemic or other disruptions (e.g. the 2021 Suez Canal obstruction, etc.) pose a significant threat. Those coatings' producers and raw material suppliers who have taken stock and learned a lesson from the 2021-2022 supply chain debacle, will no longer order, purchase, price, source, transport, and inventory raw materials like before the 2020 events (Pilcher, 2023). This crisis made clear the threat inherent in "*just in time*" when operating global sourcing and procurement (Pilcher, 2023).

The impact of globalisation on Supply Chain Management

Globalisation, as described by (Homann, et al. 2016), is the integration of the world's marketplaces which implies stretching supply networks to unprecedented levels (Pope, 2012; Rushton et al, 2017). Market competition has been driving enterprises to go "*global*" in search of cheaper and/or higher quality products, while the international side of trade has grown considerably for three decades (Christopher, 2012). While the (UN, 2022) report on key trade statistics and trends, predicted international trade to reach over US\$ 32 trillion by the end of 2022, representing a 26% rise over pre-pandemic levels in 2019, geopolitical events and the connected rising energy prices worldwide have heavily influenced global trade trends. Now, after falling for two straight quarters, global commerce in goods and services increased between January and March 2023, but the outlook for the year is still grim (UNCTAD, 2023).

Both in terms of supply and demand, globalisation has caused the networks to become extremely complex, resulting in a high level of difficulty in management, and a lack of sight and transparency (Medina-Serrano, et al. 2022) and, as a matter of fact, global chains are more likely to be disrupted due to their heavy reliance on external factors (Laradi, 2017; Rushton et al, 2017; Medina-Serrano, et al. 2022), while (Kliem, 2022) points out that globalisation invariably creates insecurity in the commercial environment.

Global chains are more vulnerable not only because of the distance between participants but also because of political dangers. Kliem (2022) the power of international institutions such as the EU and differences in jurisdictions in the buyer and seller countries as examples of such concerns. Governments can limit the level of globalisation through a variety of mechanisms, including embargoes, tariffs and quotas, border closures, free trade zones, trade subsidies, and so on. As a result, when sourcing abroad, SC professionals should thoroughly assess the scenario, the status of the market, and the political climate, weighing the benefits and drawbacks (Kliem, 2022), although, he recognises the benefits of globalisation for an SC, such as the potential to increase the number of alternative suppliers while improving quality and purchasing prices. However, firms who have chosen this approach should be aware of the risks they face and work to strengthen the resilience of their SC.

Several experts concur that a SC spanning multiple international locations is more vulnerable compared to domestic sourcing (Nishimura, 2021). While this is possibly an effective way to reduce costs, companies that source globally, expose themselves to additional risks. Nishimura (2021) sees the problem of global chains not only as complexity and a lack of expertise in local markets but also as a much higher interdependence of the chain's parts, where failure of one unit, results in failure of the entire system. This remark is true for any SC, domestic or international;

nonetheless, (Nishimura, 2021) emphasises that a global chain is more vulnerable because of its exposure to more hazards.

Lean chains vs Global chains, what the Pandemic has revealed

Back in 1996, Richard Lamming was arguing the benefits of lean SCs though making it clear that the *“theory of lean supply does not lend itself to straightforward implementation ... However, lean supply, as lean production, derives from market competition: its exploitation may not be a matter of choice for very long”* (Lamming, 1996).

In (Saeed, 2012) analysis of lean thinking in SC operations, integration is viewed as a requirement for superior performance in a globalised SC context, which seems to suggest the compatibility between lean and global approaches to SC. A similar concept is present in (Novais et al. 2020) findings that using cloud-supported logistics plays a significant role in producing improved business results in lean production environments. They argue that through cloud-supported logistics and SC integration, lean production has both a direct and an even stronger indirect effect on performance. They also argue that SC Integration has a mediating influence on the relationship between Cloud-Supported Logistics and performance.

According to (Ugochukwu et al, 2012), a lean mindset is a source of competitive advantage. Similar opinion may be observed when it comes to SC globalisation. The premise is that globalisation, and particularly global business competitiveness, compelled firms to seek cost reductions and implement lean procedures (Ugochukwu et al, 2012). They cited low inventory levels, optimisation, and cost reduction as advantages of lean SCs. Furthermore, global sourcing is prevalent, and as managers are looking for ways to gain a competitive advantage, *“lean”* is one tool to use in this regard (Myerson, 2012). Arif-Uz-Zaman and Ahsan (2014) also support this idea of globalisation being at the root of the birth of lean philosophy, as organisations must stay competitive in the global market. Raji et al. (2021) agree, that in an era of globalisation, the sustainability of SCs necessitates the implementation of lean tactics. As a result, we can conclude that many authors believe that the adoption of *“lean”* in the SC was influenced by globalisation. However, the COVID-19 epidemic has undoubtedly impacted globalisation creating additional risks (Marinov & Marinova, 2021), it introduced interruptions, with raw materials SCs bearing the brunt of the damage, mostly because numerous raw materials are imported from China, where manufacturing was shut down (Arunmozhi et al, 2021; Ivanov & Dolgui, 2020; Milmo, 2020). Some companies were directly impacted, while others were indirectly affected through their Tier-*n* suppliers (Arunmozhi et al, 2021).

The pandemic led to workforce shortages (Arunmozhi et al, 2021), and governmental limitations on people movements caused further strain on SCs (Nagarajan, et al., 2021), worsened by transportation issues with product-forwarding businesses unable to deliver goods owing to lockdowns (Queiroz, et al., 2020). Since China has a huge number of manufacturing facilities, its lockdown cut off other countries from vital resources with foreign businesses severely impacted (Arunmozhi et al, 2021).

Overall, the multi-national subcontracting trend complicates things even more by adding levels to a chain and diminishing transparency, which is critical in managing a chain during times of uncertainty (Arunmozhi et al, 2021); they also argue that from the logistics standpoint, while completing or executing a supply contract, it is difficult to assess the risk because the structure of the entire SC may not be fully visible and the number of tiers increases the likelihood of a partner within the chain having issues that can affect the entire flow, thus, the more levels there are in a chain, the more the risk increases. Corporations have been ignoring the risks associated with globalisation for years, leading to a situation in which SCs were not prepared to cope (Arunmozhi

et al, 2021). For a long time, much effort has been made in numerous areas to obtain just-in-time supplies; yet the pandemic has revealed the world its downsides (Nagarajan, et al., 2021). They also argue that purchasing shall be adaptable, though lean principles have made supplies “fixed”. COVID-19 has been a global-scale challenge and a test of resilience in SC management and the Chemical industry was among the hardest hit by the pandemic (Accenture, 2020), additionally, COVID-19 has also resulted in an unexpected event as many chemical component manufacturers shifted their production capacities into the manufacture of sanitisers and antiseptics (Zainzinger, 2020), considerably worsening the scarcity of raw materials for paints.

The SC crisis has demonstrated that the most robust SCs are flexible SCs that can be swiftly altered and adapted (Bhakat & Arif, 2021). Making supply networks more resilient has emerged as a top concern for corporations. From the standpoint of SC management, “resilience” is defined as a SC's ability to adjust and normalise swiftly in the face of disruptive occurrences (Dadsena, et al., 2021).

Methodology

Pragmatism, according to (Saunders et al. 2019), does not limit itself to a single philosophy in particular; rather, it employs a variety of methods to identify the best feasible techniques to answer the research questions. Additionally, the value of theory is when it is linked to practice; thus, this philosophy is appropriate for business research (Pouryousefi & Freeman, 2021) and was chosen due to the need to examine the issue from both theoretical and practical perspectives. In accordance with (Saunders et al. 2019), the Research Strategy of choice is Action Research as a direct result of the adopted philosophical stance. The context is examined in the literature, as are the findings of professional and industry associations. Both qualitative and quantitative data were collected in accordance with (Bryman, 2012, p.397). As a result, the research was based on a mixed strategy, in which secondary and primary data were acquired and linked. Numerical data was taken from pertinent statistics, while case studies of top paint and coatings manufacturers were analysed in industry-specific publications. The evaluation of market leaders' behaviour sheds light on decision-making and methods that other firms could emulate, adding a qualitative component to the research.

Results and Discussion

Causes of the Raw Materials Crisis in the Paints & Coatings Industry

Paint and coatings professionals have been invited to take part in the survey. Twenty companies from around the world participated. Most respondents are either managers (65%) or buyers (25%). The survey responses confirmed the existence and severity of the problem, as 100% of practitioners admitted to experiencing raw material supply shortages over the last 2-3 years, with 80% citing raw material availability issues as one of their companies' major concerns. For 60% of respondents, the problem was so serious that their companies had to remove some of their final products from sale due to a component becoming completely unavailable because certain formula constituents were missing. At the same time, half of the respondents indicated only specific components as having limited availability, while the rest rate overall availability as low or very low (40% and 10%, respectively).

The findings are consistent with what has been reported in the literature; price and lead time increases have been confirmed by 100% of respondents with resins, specialised additives, and pigments being among the most affected. However, the literature argues the most extreme increase in solvent prices, with some of them, such as N-Butyl Acetate and MIBK, rising 200%-300% in 2022 compared to 78% in 2021 (BCF, 2022), reflecting the short supply, making solvents one of the most problematic items to source, while only 15.8% of responders found it difficult to obtain

them. Such a discrepancy could be due to these specific companies having dependable solvent sources but could be also the result of effective sustainability rules regarding VOC content, which could mean that manufacturers are using fewer organic solvents in favour of more eco-friendly options like water. In any case, solvent shortages and price rises are likely to push firms to transition to more sustainable alternatives sooner. This is also consistent with the findings of (Pilcher and The ChemQuest Group, 2018), who discovered a decrease in solvent use.

The COVID-19 epidemic compelled several manufacturers of raw materials for the paints and coatings industry to shift to the manufacturing of disinfectants. The Powder Coatings Institute conducted an interview with coatings company managers in April 2020, which highlighted alcohol shortages as a result of such redirection in favour of sanitisers (Johansson, 2020). BASF utilised hundreds of litres of isopropanol to make hand antiseptic treatments. Dow Chemical also shifted its five manufacturing locations to a weekly output of 200 tonnes of sanitisers. DSM N.V., a Dutch firm, switched to producing disinfection at its Waalwijk factory, which previously produced resins (Zainzinger, 2020). Resins account for most of the raw material value in paint formulas, acting as a binder accounting for 44% of the formulation on average, as a result, the change from resins to antiseptics has had a significant impact on the SC of coatings components. According to (CME, 2021), epoxy resins and polyester resins were the most in-demand and consequently difficult to find.

It is arguable that manufacturers diverted their capacities towards antiseptics in a profit-driven decision that can be explained by the economic concept of opportunity cost (Cowie, 2010). This is also related to the supply theory, because the higher the prices, the more players will want to enter the market (Cowie, 2010). Prices for antiseptics skyrocketed due to scarcity from the outset of the epidemic and consumers were willing to pay practically any amount offered. This caused enterprises to substantially raise their prices, resulting in massive price inflation and big profits for sellers. In the United Kingdom, the price of a 3 oz. liquid hand sanitiser rose from £3.49 to £109.99 in March 2020 (Taylor, 2020), what the OECD defined as “*exploitative pricing*” as many manufacturers took advantage of extremely high demand (OECD, 2020).

Johansson (2020), on behalf of the Powder Coatings Institute and in partnership with ChemQuest Group, investigated the impact of COVID-19 throughout the paints and coatings industry SCs at the start of the pandemic. During a series of interviews, it was discovered that several raw materials required for coatings manufacture, including alcohols, became scarce because of the shift to antiseptics, while photo-initiators were scarce due to global sourcing from China and India and their lockdown. Prieto (2022) recognises China's significant impact on the chemicals sector, being the world's biggest chemical maker since 2019 and (Francis, 2021), adds that sodium hypophosphite became nearly unavailable because of China's energy conservation strategy, implemented by the Chinese government in September 2021 following power shortages, prompting energy-intensive industrial sectors to reduce output capacity, among these, phosphorous mines were forced to function at only 10% of their real capacity. Given the dramatic decline in output, as well as China's 70% share of the global phosphorus market, the world has experienced acute phosphate shortages (Francis, 2021). Additionally, a severe incident occurred at a Chinese chemicals factory facility in Jiangsu, in 2019 interrupted the supply of key chemicals, resulting in supply disruptions of water-based coatings preservatives, UV ink photo-initiators, and red and yellow pigments (European Coatings, 2019), which had a long-term impact on the coating sector (BCF, 2019a). Finally, the 2021 ice storms in Texas where the largest USA petrochemical sites are concentrated and ship globally, paralyzed chemical plants affecting Chevron Phillips

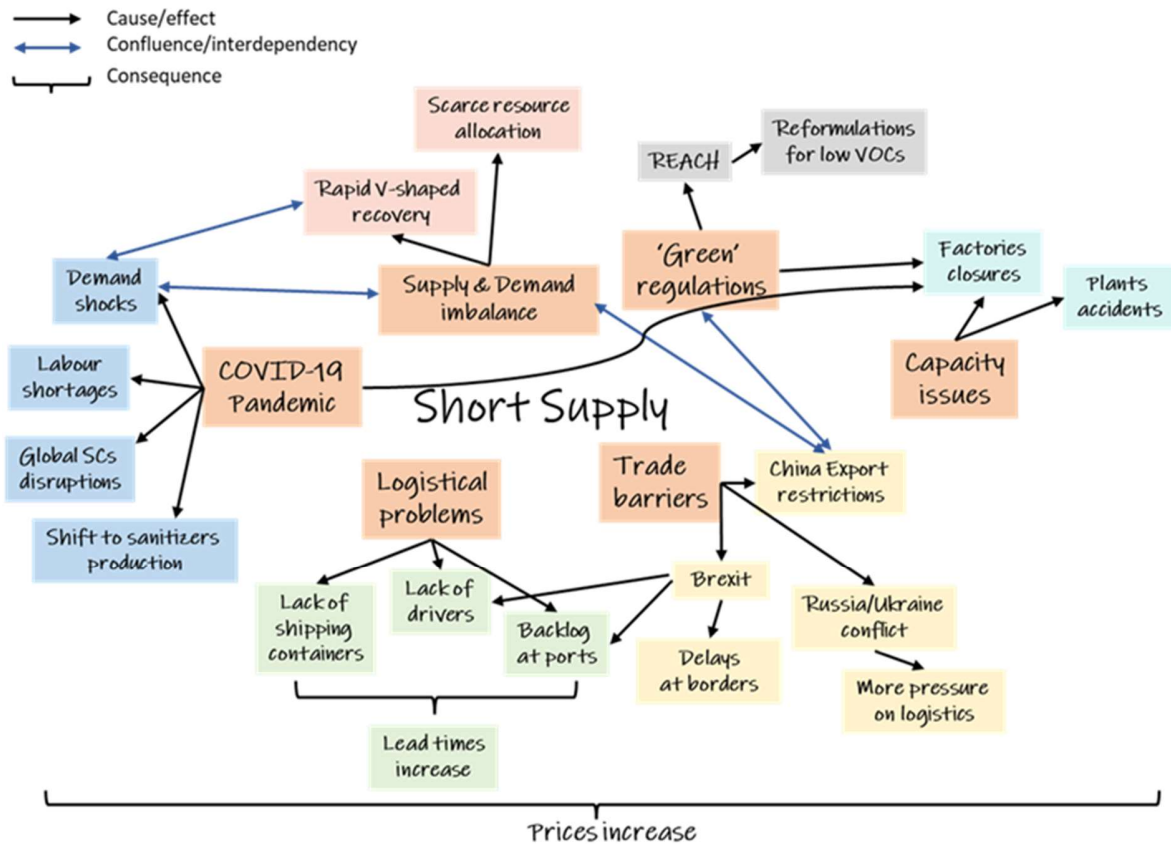
Chemical, Dow Chemical, ExxonMobil Chemical, Formosa Plastics, Lyondell Basell, and Sasol Chemicals (Trager, 2021).

Though the problem of shortages was global, producers in the United Kingdom faced additional restraint in raw material procurement: Brexit. The UK coatings industry is strongly reliant on European chemical raw materials. According to British Coating Federation (BCF, 2019b) research, the UK manufacturers of paints and coatings buy over 60% of their raw ingredients from EU member states. Additionally, 80% of UK-based manufacturers have been negatively affected by the EU Trade and Cooperation Agreement in the post-Brexit period, with 60% experiencing difficulties in raw material supplies (BCF, 2021) and the severe scarcity of lorry drivers further contributed to slowing the process for logistics services nearly trifold (Pilcher, et al. 2021; Francis, 2021). Construction market specialists (CME, 2021) reported availability challenges for both land and sea modes of transport, resulting in a 400% price increase for container shipping in just over a year between 2020 and 2021. Such a quick development has impacted access to raw resources by limiting the territory into which a corporation can look for sourcing.

The importance of risk management in procurement, is paramount (Chopra & Sodhi, 2004; Van Wyk & Baerwaldt, 2005; Pope, 2012; Christopher, 2012; Nishimura, 2021; Laradi, 2017; Rushton et al, 2017; Medina-Serrano, et al. 2022). The survey results support this in practice: 90% of respondents import raw materials from other countries, and 100% have experienced disruptions. Furthermore, 55% of respondents believe that importing raw materials is more difficult than procuring locally. As a result, concerns with material supply can be linked to global chain characteristics.

Overall, globalisation has increased the sources of supply (Pope, 2012), which is especially beneficial during times of scarcity, but it has also introduced issues and challenges such as longer lead times, higher transportation costs, unnecessary handling, and faulty items being more difficult to deal (Pope, 2012) and a higher fragility (Medina-Serrano, et al. 2022).

Figure 2 – Summary of the findings on paint and coating supply chain challenges



(Source: developed by the authors as a visual summary of the research findings)

Lean chains and Global chains

Several authors, starting with (Lamming, 1996), argue that adopting the lean mindset can improve the performance efficiency of supply networks and assist business decision-makers in managing complex SCs on a global scale (Myerson, 2012). Both (Myerson, 2012) and (Slack et al., 2013) see the use of lean management in SCs as a means of increasing revenues. They do not, however, account for the vulnerability of being “lean” as previously pointed out by (Pope, 2012), as disruptions would result in considerable financial losses for a corporation due to out-of-stock items and idle time of manufacturing facilities due to a lack of materials.

Most papers focus on the competition aspect of the relationship between lean principles, particularly lean manufacturing, and globalisation, claiming that it is globalisation that compelled businesses to cut waste to compete in the globalised market (Christopher, 2012), (Myerson, 2012), (Ugochukwu et al, 2012). In other words, authors study these relationships from a cause-and-effect standpoint. Going “lean” is clearly motivated by globalisation. However, there is a void in the research on their coexistence or rather the compatibility of lean concepts with SC globalisation. From the perspective of lean principles, global SCs pose many challenges basically contradicting most lean principles (see Table 1), and although (Pope, 2012) observes certain inconsistencies between globalisation and lean or JIT concepts, very few publications examine the integration of these methodologies within SC management. It is true that (Arunmozhi et al., 2021) state that

global multi-tier chains are incompatible with lean manufacturing. However, they point out that it applies to lean manufacturing but not SC management.

Table 1 - Points of waste of 'lean' and globalisation side effects on 'lean'.

Lean points of waste	Globalisation's challenges
Idle / waiting Time	Generally, longer lead times, delays at borders
Unnecessary movements	Transportation at long distances, excessive handling of goods at transshipment points
Increased stock levels	Inventory in transit is still inventory, necessity to have increased safety stocks due to long lead times
Defects	Too complicated to make returns or arrange repairs due to distance and related customs procedures

(Source: based on Pope, J.A., 2012, p.34-35)

The present market trend is the coexistence of globalisation and lean SCs, which do not appear to be compatible. Companies typically employ both strategies concurrently, attempting to maintain as little stock as possible while also expanding the territory for getting raw materials through global marketplaces. This causes inconsistency since most of the time global SCs imply additional movements, overstocking, and significant lead time overall (Pope, 2012), making "raising inventory" a must to minimise interruptions connected with global sourcing. All of these do not fit into the "lean" principles.

Attempting to balance "lean" with global has recently proven to be an ineffective strategy during the COVID-19 pandemic. Because the JIT approach has virtually no inventory contingency, both production and SC networks have been disrupted as COVID-19 has effectively paralysed the globalised SCs. This was also demonstrated by the survey findings, in which 90% of respondents stated that they needed to enhance the levels of safety stocks.

As a result, it may be concluded that one of the root causes of the raw materials SC crises in the paint industry is the enterprises' attempt to combine incompatible strategies. However, despite the identified incompatibilities, SC managers should adopt from lean management the notion of lowering the complexity of the SC (Productivity Press, 2017), eliminating those areas that do not add value but lengthen the chain, exposing it to higher risks. In this respect, SC mapping is a useful tool for locating such components of the SCs (Productivity Press, 2017).

Transparency and visibility of the SC, as well as knowledge of not only Tier-1 but also Tier-*n* suppliers, have always been advised as crucial strategies when outsourcing. SC mapping, by visualising, assists in identifying areas of inefficiency or risk, which can then be used as a basis for restructuring or modifying the chain (Gardner & Cooper, 2003).

Modern supply networks are distinguished by their tremendous complexity, particularly in the manufacture of items requiring several components, where the SC is geographically stretched and the network is multi-tiered when a supplier also outsources elsewhere, and so on. As a result, buying companies lose visibility, putting the system's sustainability at risk. Consequently, firms are unable to adapt appropriately to disturbances (Mubarik et al, 2021). Paint formulas contain a wide range of chemicals imported from around the world, and mapping is vital for building a resilient chain, according to (Mubarik, et al. 2021; Gardner & Cooper, 2003).

The SC resilience approach implemented a decade ago by one of the world's largest chemical producers, Dow Chemical Co., can be advised to all organisations wishing to avoid interruptions in the current environment. The company focused on risk assessment (SupplyChainBrain, 2011). Dow Chemicals Co. has been having supply issues with glycol ether, a chemical utilised in solvents

as well as the automotive, industrial, and architectural sectors. They have mapped both internal and external production, local and international alternative sources, exports and distribution channels, terminals, warehouses, and so on, using the SCRAM Model (Supply Chain Resilience Assessment Management) developed by Ohio State University, which has then been simulated to reveal potential disruptions.

Dow Chemicals Co. claims that this has enabled them to discover previously unknown vulnerabilities. Though this strategy cannot eliminate a company's vulnerability to the unexpected, it has advanced in better understanding methods for alternate sourcing (SupplyChainBrain, 2011). In the framework of this research, practitioners in the paint and coatings industries were asked about the level of visibility they have over their raw materials SC. Half of the respondents are aware of at least one of their Tier-2 suppliers, and 35% have complete visibility up to the origin source. Another half is only familiar with their Tier-1 suppliers. All of them, however, are experiencing raw material supply problems. As a result, it is possible to conclude that this strategy does not solve the problem. Nonetheless, Supply Chain Mapping enables risk assessment, allowing businesses to anticipate problems and establish contingency plans.

As clear in the literature, to prevent interruptions, companies increase their stock levels, multi-source and spread manufacturing points within different locations (Chopra & Sudhi, 2014), however, while these are valid functional solutions, businesses should first build SC networks in a way that simplifies and increases visibility while decreasing interdependence between its components. Keeping the big picture in mind is critical when managing global chains. The survey confirms this since none of the respondents rely on third-party logistics suppliers to outsource materials for them. According to (Trager, 2021), the pandemic, as well as plant incidents, have demonstrated to manufacturers the significance of stockpiling intermediate items and components, such as chemicals and resins, to avoid SC interruptions.

According to the findings of the survey conducted as part of this research, 90% of respondents needed to boost their safety stock levels for bottleneck items to protect their operations from disruptions and provide an uninterrupted flow of materials for their production demands. Paint manufacturers across the world are rethinking their strategies and reorganising their SCs. The JIT strategy is being reconsidered, as it is no longer viable to have a low inventory and only purchase what is needed to complete orders (Wiseman & Krisher, 2021). However, this involves extra costs, therefore, this mitigation strategy for dealing with the problem has limitations. At the same time, it is important to note that if one company buys as much as it can to stock up, it causes more acute shortages for others. Furthermore, chemical components have a certain shelf life, which limits the effectiveness of this method. Nonetheless, this is an effective strategy, albeit with certain technological and economic constraints. Alternative sourcing, as well as multi-sourcing, if possible, is one of the most evident solutions. 80% of respondents are looking for other providers. Multi-sourcing may increase supply stability (Slack et al, 2013), however finding another source may be challenging.

Only one respondent joined the Raw Materials Alliance, which aims to provide sustainable access to materials, and became a member of trade associations such as BASA (British Adhesives and Sealants Association), BCF (British Coatings Association), and CIA (Chemical Industry Association) in their search for alternative sources. This could be advised to others because professional bodies are better knowledgeable about where to obtain alternatives and what substitute products are available. Only 15% of responders can assure future supplies by signing long-term contracts. This strategy is not available to most businesses since suppliers are reluctant to do so due to market instability as well as supplier dominance, as stated previously in this

Chapter. Due to substance shortages and unavailability, most manufacturers' labs change formulations to discover substitutes (60% of respondents).

Conclusion

Due to the inconsistencies between the two strategies, the research gap revealed by the literature review in investigating the coexistence of globalisation and lean principles in SC management could be one of the underlying causes of raw material shortages in the sector. Lean Supply Chain Management considers minimal to no inventory holding, which contradicts global supply networks, which require a buffer to compensate for extended lead times. Globalisation allows purchasers to diversify their supply sources, which is useful during times of scarcity, as well as the flexibility of multi-sourcing. Buyers discover alternative suppliers on worldwide markets, ensuring the continuity of their business. At the same time, generally, businesses seek to adhere to lean concepts in their SCs, particularly in terms of inventory. What characterises a normal worldwide chain, for example, numerous movements and handling, overstocking, and overall longer waiting time, in the lean approach, is considered waste (Pope, 2012). Therefore, companies' SCs are more likely to fail when these two tactics are used concurrently.

In contrast to other drivers that originate from the external environment (Brexit or COVID-19), this source of the crisis relates to the strategy level and hence, the internal level of a company. As a result of the crisis, industry players changed their tactics and rethought raw materials supply networks, realising that lean principles imply a high degree of risk of disrupting the inbound SC and consequently disrupting production processes (Wiseman & Krisher, 2021).

The geography of supply networks and the location of production facilities should be altered because of the crisis. The epidemic exposed the SCs to geopolitical and economic concerns. Though the survey found that even enterprises with complete chain visibility are nevertheless harmed by disruptions, they would have suffered even more damage if their SCs had not been adequately monitored (Arunmozhi et al, 2021). As a result, SC mapping and the SCRAM framework are among the tools that may be used to strengthen resilience by analysing and thereby minimising SC risks when working with third-party vendors in particular, as well as developing contingency plans to ensure the ongoing flow of goods. It should be mentioned that to get suitable outcomes, these strategies necessitate rigorous information gathering regarding Tier-*n* suppliers as well as the operational environment.

Since the literature indicates that most material disruptions are not due to resource depletion, but rather to logistical, geopolitical, and economic constraints, it is important to highlight that all of these causes are significantly geographical. As a result, localization and vertical integration would be among the most effective mitigation options, as they consider moving production in-house or at least closer to the paint-manufacturing plant, and therefore, eliminating geopolitical concerns. However, a “*Make-it*” approach (Slack et al, 2013) is exceedingly expensive and thus available mainly to the larger industry players. Localisation brings certain benefits in terms of risk occurrence. Local sources are much less likely to be affected by geopolitical risks. However, due to the wide variety of components required to formulate coatings (Mannari, V. & Patel, C. J., 2015), this is not always a suitable option for the industry as it might depend on natural resources availability (Arunmozhi et al, 2021).

According to (Ellingrud, 2020), it is necessary to invest more in digital solutions to provide more resilience, as the digital ability to monitor, communicate, track, and collaborate within the SC will provide more transparency and visibility and lessen the negative effect of extensive networks, where a problem may lie not in the closest Tier, but in the supplier's supplier. At the same time, SC mapping is a useful digital tool that can be used not only to monitor current chains but also to

pre-qualify suppliers during the supplier selection process, allowing for the selection of the supplier with the fewest associated risks. Ellingrud (2020), Rezai (2020), and HPS (2022) view the future in sustainable practises targeted at boosting an organization's efficiency by lowering waste and raw material usage, and therefore acquiring less.

Given the specific intricacy of each SC, it is highly suggested to design “Customised” SCs for each problematic product as the “old school” concept of “one supply chain fits all” is no longer practicable (Treschau, 2021).

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