Supply Chain Forum: An International Journal

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tscf20

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**To cite this article:** Trudy Brookes, Konstantinos Nikolopoulos, Konstantia Litsiou & Waleed Alghassab (14 Feb 2024): Forecasting and planning for special events in the pulp and paper supply chains, Supply Chain Forum: An International Journal, DOI: 10.1080/16258312.2024.2315029

**To link to this article:** https://doi.org/10.1080/16258312.2024.2315029

SUPPLY CHAIN FORUM: AN INTERNATIONAL JOURNAL
https://doi.org/10.1080/16258312.2024.2315029



# Forecasting and planning for special events in the pulp and paper supply chains

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**ABSTRACT**

Due to global warming, flood is an increasing threat to companies operating in the pulp and paper industry. The impact of this threat needs to be managed. We deploy a qualitative investigation into how paper manufacturers can forecast and mitigate the impact of special events, most notably floods, across their supply chains. A grounded theory approach using semi-structured interviews held with supply chain consultants in three stages allowed for topic categories emerging during previous interviews to be explored. Analysis of these interviews uncovered tactics unique to the pulp and paper industry. The findings are three-fold. First, paper manufacturers should focus on basic forecasting methods which they are capable of, such as subscribing to flood warnings, rather than poorly executing advance machine learning forecasts. Second, planning is of equal importance to forecasting: integrated business planning should guide the process. Third, business execution should involve a proactive approach to decision-making which trusts data and has people that nurture and drive the process.

**KEYWORDS**

Forecasting; mitigation; special events; supply chain; pulp and paper

## Introduction

Since the turn of the century – and especially in the eve of the pandemic, there has been an increased academic focus on managing the threat of unknown events that have a disruptive effect on the supply chain (Kara et al. 2023; Nikolopoulos et al. 2021; Preindl, Nikolopoulos, and Litsiou 2020; Simmers et al. 2023; Upadhyay, Tewari, and Tiwari 2022). Similarly, forecasting the impact of unknown events began to gain focus within the past 20 years. Academics have noticed the rise in occurrence of unplanned events such as natural disasters, terrorist attacks, financial collapse and strikes (Blackhurst et al. 2005; Dubrovski 2004; Goodwin and Wright 2010; Jüttner, Peck, and Christopher 2003; Kleindorfer and Saad 2005; Nikolopoulos 2010, 2021; Nikolopoulos et al. 2021; Papadakis 2006; Sheffi and Rice 2005; Sodhi, Tang, and Son 2012; Tomlin 2006). Subsequently, a number of mitigation tactics and forecasting methods (Assimakopoulos and Nikolopoulos 2000; Petropoulos et al. 2022) have been analysed and prescribed to remove the financial and operational burden these events have (Craighead et al. 2007).

In the pulp and paper industry (PPI), many special events can create great challenges: from natural catastrophes to economic crisis and supply chain disruptions. Special events are rare, but still more or less expected to happen with in a (large) period – like an earthquake or a flood, yet most often unpredictable (at least the timing of) and with devastating impact (Nikolopoulos 2021; Petropoulos et al. 2022). These are not, however, extreme events like black swans (Taleb 2007), that are considered totally unpredictable (Taleb 2007), like the recent pandemic, for example, and its respective supply chain disruptions (Nikolopoulos et al. 2021). This paper focuses on special events and the impact of them in PPI supply chains, and not the forecasting of PPI trends per se, that could be dealt with standard statistical forecasting models as well as machine learning approaches (Petropoulos et al. 2022)

Of all the special events affecting PPI, flood is a major risk. Global warming has resulted in a proven increase in flooding (Wasko and Sharma 2017). Also, pulp manufacturers and paper manufacturers operate mills which have a heavy reliance on water for production so are located next to a large water source. To provide perspective on the scope of the industry, in Europe there are approximately 500 pulp, paper and board companies who produced 92.2 million tonnes of paper and board in 2018. To do so, the industry consumed 3457 billion litres of water, which averages at 6941 million litres per company (CEPI 2019). Figure 1

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*Disclaimer: All views expressed in this article are Miss's Brookes and do not reflect Kinaxis' view on this topic.

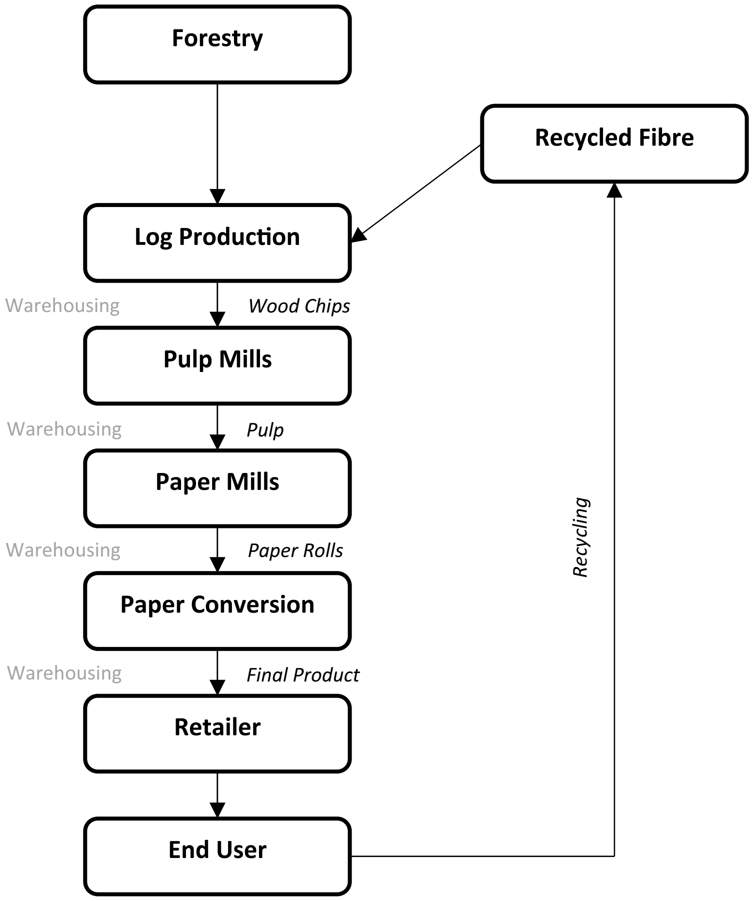


**Figure 1.** The typical PPI supply chain.

highlights the chains of the PPI supply chain likely to be impacted by flood.

No previous study has focused on the impact of flood in the PPI. Whilst some forecasting academics have presented methods to forecast the impact of flood, these typically reside in hydrology (Dale et al. 2014; Verbunt et al. 2007). Furthermore, there is an absence of studies modelling the floods as a special event in a typical time-series fashion (Nikolopoulos 2021). Other researchers have performed quantitative research to address the different forecasting methods to predict the impact of unplanned events (Goodwin and Wright 2010; W. Y. Lee et al. 2007; Nikolopoulos 2010; Nikolopoulos, Goodwin, et al. 2007; Nikolopoulos et al. 2015). However, the events modelled are promotions and marketing impact.

Furthermore, supply chain literature predominantly focuses on either the stages required to mitigate the impact of unplanned events (Blackhurst et al. 2005; Corsi and Macdonald 2013; Ponomarov and Holcomb 2009; Stecke and Kumar 2009) or the principles needed (Chopra and Sodhi 2004; Christopher and Peck 2004; Rice and Caniato 2003; Sheffi and Rice 2005; Skipper and Hanna 2009; Tang 2006). However, issues exist as articles either lack focus on a specific type of event, neglect targeting specific industries or are not based on actual practical research. These deficiencies are areas in which this study contributes.

In Figure 1 we illustrate a typical setting of the PPI supply chain. The first critical supply is that in the Forrest and the and the production of logs and is the one least affected by Floods. Then wood chips are produced and stored, respectively, and moved to the Pulp mills where pulp is produced. Wood chips are boiled with chemicals in large boilers and turn into pulp of thin fibres. As this is a process that requires large amounts of water, typically such facilities are located near rivers so as to have continuous supply of water and thus are subject to the risk of flooding. Following that, the next chain in the PPI supply chain is the paper mills and the paper conversion that results in the final products that are also prone to flooding – to a lesser extent though; and finally then through the wholesalers and the retailers, paper ends up to the final customer.

The intent of this research was to develop a generalisable best practice approach to forecast and mitigate the impact of special events in the PPI supply chain. Special events are defined as sporadic events, such as a strike or extreme weather (Armstrong 2001). Flooding – as the special event – is the focus of this study from the perspective of a paper manufacturer. A paper manufacturer was chosen since they suffer from a flood risk at its own paper mill site and at its supplier's pulp mill site. The reason for this focus was to gain a rich understanding within the time constraints to conduct this research, rather than generating superficial findings.

The study contributes to the current academic field by providing a unique perspective for the PPI as well as an understanding of expert opinions. Speaking to supply chain consultants of various expertise's, who have mostly worked with paper manufacturers, suggests the PPI is looking to improve its supply chain and business performance. Additionally, conducting this research should improve the current decision-making of companies in the PPI since they will understand their options for forecasting and the mitigation possibilities likely to be successful.

The rest of this paper is structured as follows. First, the conceptual background and literature review are presented. Second, the research questions are posed, and the methodology followed is explored. Third, results from consultant interviews are addressed. Fourth, a discussion of the findings is presented to highlight best practice. Finally, conclusions are made alongside limitations, practical implications, and future research avenues.

## Conceptual background and literature review

Supply chain disruption management has ballooned in research since Sheffi's (2001) article was published after the September 2001 terror attacks in New York. In practice, many consultancies and companies are increasingly focusing on how to manage potential disruptions. PPI is not exception to this, and these supply chains are seriously affected by special events. In this section, we focus on the special events affecting PPI supply chains, i.e. floods, and the respective supply chain disruptions, rather than generic forecasting articles on forecasting the trends of the PPI industry or probabilistic models for extreme events.

### *The impact of special events on the supply chain*

The impact of a special event, or disruption, within a supply chain can be explained in monetary terms and as the dissemination of impact throughout the supply chain. The negative effect on stock performance is a monetary measurement. A glitch announcement can cause an average of approximately 40% abnormal stock returns, a rise of 13.5% in equity risk (Hendricks and Singhal 2009) and result in up to a 10.28% decrease in shareholder value. Moreover, firms with high growth levels will suffer most negatively (Hendricks and Singhal 2003). Similarly, personal computer companies with pull systems, such as Dell, are thought by investors to considerably lose profitability after the 1991 earthquake in Taiwan compared to companies with push-type supply chain designs (Papadakis 2006). This demonstrates that disruption severity is dependent upon firm's size, maturity and supply chain design.

Another monetary measurement is the relationship between supply chain risk sources and performance. Wagner and Bode (2008) show supply chain risk can only somewhat affect supply chain performance. This contradicts Hendricks and Singhal (2003, 2009) and Papadakis (2006). However, the measurement in these studies was stock performance; not risks that directly impact supply chain performance. The standpoint of this author is that an announcement or event will negatively affect performance if companies are not appropriately prepared. This logic fuels reasoning for the research as to whether a paper manufacturer is capable of mitigating flood impact.

As aforementioned, the severity of a special event can be shown by the dissemination of impact throughout the supply chain, or the Ripple Effect (Ivanov, Sokolov, and Dolgui 2014). Schulte in den Bäumen et al. (2015) explain Germany's 2013 floods impacted the production possibilities of regions directly affected and indirectly affected by €42.4 million to €3.1 billion and €33.8 million, respectively. Subsequently, all directly and indirectly affected regions meant the flooded area lost demand. Therefore, the ripple effect must be managed.

### *Mitigation stages*

To mitigate a disruption's impact, numerous academics identify three stages, albeit named differently. For example, Ponomarov and Holcomb (2009) name the stages readiness, response and recovery. Blackhurst et al. (2005) term the stages discovery, supply chain redesign and recovery. In this research, the stages are summarised as detection, prevention and recovery. The literature also refers to these steps as readiness/discovery, response/redesign, and recovery so in this article we use these terms interchangeably.

Stecke and Kumar's 2009 catastrophe classification framework provides methods to use at each stage. Detection entails advance warning strategies, prevention requires a proactive strategy, whereas recovery maintains having coping strategies. The importance of each stage is emphasised by Craighead et al. (2007). They stress the severity of a disruption will be greater if the supply chain design is complex, dense and has many critical nodes. Also warning and recovery capabilities must be strong to detect and recover quickly to normal levels of product flows. Therefore, each stage must be well executed. For successful execution, Corsi and Macdonald (2013) explain managers' key factors for engaging in each mitigation stage. Managers believe detection is vital as it aids the initial disruption management decision. For successful prevention and recovery, a stable planning team of few decision makers is essential. The plan should be distributed and rehearsed with scenarios. After playing out these plans during a disruption, the quantitative (such as cost) and qualitative (such as recovery speed) impact on performance needs to be assessed. This emphasises the significance of ensuring time is spent planning how to best engage in each stage.

### *Mitigation principles*

To successfully mitigate the impact of disruptions, companies must build resilience in their supply chain (Ali and Gölgeci 2019; Bueno-Solano and Cedillo-Campos 2014; Christopher and Peck 2004; Dolgui, Ivanov, and Sokolov 2018; Ponomarov and Holcomb 2009; Rice and Caniato 2003; Santoso et al. 2005; Sheffi and Rice 2005; Tang 2006). The mitigation stages are one way of building resilience. Two principles are correlated to these stages: flexibility and redundancy. Flexibility is the ability of a company to generate internal capabilities for response. Whereas redundancy is investment in capital and additional reserve capacity to manage disruptions (Rice and Caniato 2003). Similarly, Ivanov et al. (2014) suggests using a reactive approach when an unexpected event is likely (i.e. flexibility) and a proactive approach to protect against the shock of an unexpected event (i.e. redundancy).

The methods of building flexibility and redundancy in the supply chain at a high level are undisputed by academics. Sheffi and Rice (2005) believe flexibility is most important and includes methods such as control systems and culture. Comparatively, little can be done in terms of redundancy, which involves building safety stocks, having strategic inventories, back-up suppliers and information technology back-ups. In their research, Stecke and Kumar (2009) show flexibility and redundancy occur in the mitigation stages. For detection, flexibility is required, whereas prevention links to redundancy and recovery necessitate having flexibility. Below are other studies that build on the two principles explored below.

### *Flexibility*

Skipper and Hanna (2009) studied the link between contingency planning and flexibility. Results show flexibility reduces risk exposure when there is top management support, resource alignment, IT use, information sharing, internal and external collaborations. Likewise, Rice and Caniato (2003) found flexibility involves investments made into resource and infrastructure prior to their need of use. This involves particular sourcing strategies, supplier transparency and a multi-skilled workforce. Based on this, explored below are three major factors that contribute to flexibility.

#### *Collaboration, coordination and visibility*

Companies must build relationships with their supply chain partners to successfully detect a disruption. Christopher and Peck (2004) explain collaboration will minimise uncertainty through information exchange and attaining a high level of supply chain intelligence. It is also proposed agility is installed to maximise visibility and shorten material and product velocities that increase response times. Similarly, Sheffi (2001) explains it is a necessity to have greater shipment visibility, more collaborative relationships and improved forecasting using risk pooling across the supply chain. Rather than prescribing untested recommendations, Jüttner (2005) addresses the requirement, philosophy. That is, a requirement for risk infromation to be shared with all supply chain partners and risks accepted as joint. In comparison, Zsidisin and Ellram (2003) suggest involvement in behaviour-based management happens naturally since purchasing organisations heighten their involvement with suppliers when the supply risk is high. Hence, collaborating on risk management is another necessity.

#### *Supplier selection*

The supply chain network needs to be designed in a way that it deflects a disruptions impact rather than stopping material flows. This is often termed re-engineering or redesign. It involves having a supply base strategy of multiple suppliers who are selected based on their risk awareness (Christopher and Peck 2004), ability to reduce lead time (Tang 2006) and whether they have increased capacity to absorb risk interruptions (Kleindorfer and Saad 2005). This describes what multiple suppliers can do.

Other studies have explored the locations of multiple suppliers. Sarkar and Mohapatra (2009) deduce the optimal supply base size using a model with similarities to a decision-tree. Sarkar et al. (2012) performed a similar, yet more complex, study. In both studies, they find multiple sourcing is always the optimal strategy.

Academics also perform modelling with a scenario planning basis. Scenario planning is a technique which removes typical decision-making errors by imagining possible futures (Schoemaker 1995) of situations with high uncertainty and complexity (Schoemaker 2004). Klibi and Martel (2012) explicated scenario-based risk modelling alongside a Monte Carlo method is able to generate future scenarios including worst-case ones. Hence, modelling with factors such as potential vulnerabilities and recovery times can guide reengineering strategies.

In a similar vein, Santoso et al. (2005) tested a stochastic programming model that is able to deal with a high number of scenarios in global and US supply chain networks with uncertainty. They find solutions that increase resilience. Likewise, Snyder et al. (2006) find using strategic planning models that analyse expected costs and worst-case scenarios can help mitigate disruption risk by having a more reliable supply chain network. Using these models, it is determined that multiple suppliers in multiple locations is an optimal choice where no contractual obligations exist. For the latter, redundancy is required.

### *Company culture*

Some academics have referred to having a supply chain risk management culture. This involves having strict 'employee screening and hiring practices' (Rice and Caniato 2003, 25) to remove all internal threat. Additionally, training employees will increase improve their recovery abilities (Riley et al. 2016). Another more common method is linked to supply chain expertise at board level. Jüttner (2005) finds it is imperative that supply chain risk management is integrated within the business and incorparted throughout the business, including at board level.

## *Redundancy*

The analysis on flexibility highlighted redundancy is something all companies can easily use without supply chain expertise on boards. It is a fall-back option to maintain the flow of materials and products (Christopher and Peck 2004). Chopra and Sodhi (2004) believe redundancy is most important. They suggest either building inventory when an impending disruption's prediction entails a sensible level of confidence. Alternatively, redundant suppliers should be used when materials or products holding costs and obsolescence rate are high. Hence, the main difference of redundancy to flexibility is that it involves having additional capacity that can be used to replace capacity lost in disruption (Rice and Caniato 2003). Flexibility involves redistributing already dedicated capacity. Therefore, inventory holding and supply chain design are key methods of building redundancy.

### *Inventory*

Inventory-related methods refer to holding safety stock or having strategic inventories (Sheffi and Rice 2005). Doing so means there are buffers which purchasing organisations mostly have even when there is little or no risk (Jüttner 2005). As alluded to above, how much inventory to hold is dependent on the disruption severity. Bueno-Solano and Cedillo-Campos (2014) studied this using a systems dynamic model for a terrorist attack. Their findings show a strong link exists between supply chain resilience and performance since one automotive case study held inventory for 5 days which enabled them to fulfil customer orders as usual. However, few companies are this well prepared and supply chain inventory levels increased by 600% due to heightened international border security. This reiterates the difficulty of knowing how much inventory to hold.

Although inventory-holding predictions are difficult, there are a vareity of academics explicating how choices can be made. Arreola-risa and DeCroix (1998) present a strategy for optimal inventory for stochastic-demand systems. Ultimately, they find when backorders cost more than lost sales, managers will place more effort to protect against supply disruptions using inventory. Whilst this addresses the motivation to build inventory, others address how to make a decision between inventory and sourcing strategies. Chopra and Sodhi (2004) suggest stress testing with scenario planning to address possible disruptions, the impact on operations and how to go about mitigation. In contrast, Tomlin (2006) addresses the best strategies to adopt in a single product setting with a reliable and an unreliable supplier. Hence, a variety of factors come into play when choosing between sourcing, supplier and inventory strategies.

### *Supply chain design*

Supply chain design refers to redundant suppliers. A way of minimising disruption impact is creating a supply alliance network with suppliers in other countries to act as a fall-back in event of disruption (Tang 2006). The reason for this is shown in Wagner and Bode's (2006) study which surveyed logistics and supply chain executives. They found supply-side risk is higher in single and global sourcing where heavy dependence is placed on the supplier. Therefore, it is beneficial to have redundant suppliers.

Consolidating the research gaps of the literature review to this point, and especially the mitigation capabilities for such extreme special events as floods and the respective impact on PPI supply chains, our first Research Questions naturally evolves as the following:

**RQ1:** To what extent can the impact of flood on the PPI supply chain be mitigated?

## *Methods to forecast impact*

Many researchers have called for future studies on methods for forecasting the impact of special events. For example, Stecke and Kumar (2009) suggest academics 'develop models to understand and estimate the impact of catastrophes' (p.219). This is a logical requirement for the detection stage explored above. While the focus of forecasting academics is mostly marketing and promotions, their work provides some clarity on various methods.

### *Forecasting with judgement*

Judgemental forecasting is when individuals adjust forecasts using their own judgement of an upcoming event (Nikolopoulos 2010). However, many disadvantages exist such as human bias to certain situations or outcomes. Also, the accuracy of humans' uncertainty assessment is low since they lean towards positive outcomes (Makridakis and Taleb 2009). Additionally, humans tend to be inconsistent when interpreting data and making judgements (Goodwin 2002). In comparison, there is an advantage that under certain circumstances judgemental forecasts can outperform multiple linear regression (Nikolopoulos, Goodwin, et al. 2007).

The prominent use of judgemental forecasting by practitioners is due to a lack of capability in sophisticated quantitative methods (Mady 2000) and has resulted in the method being improved by researchers (Fildes and Hastings 1994). Lee et al. (2007) ran a simulation to forecast the effect of sales promotions by supermarkets on manufacturers' demand using management judgement. They find management judgement can be significantly improved with a forecast support system. However, the improvements depend on the promotions. Likewise, Goodwin (2002) proposed forecasting the support systems used should involve statistical methods as guidance. Correspondingly, Önkal et al. (2013) find using scenarios as advice for judgemental forecasters can improve the accuracy of forecasts. Thus, forecasting with judgement can be improved with supporting information.

In comparison, Nikolopoulos et al. (2015) compare unaided judgement to methods that aid judgement when forecasting the impact of policy implementations. It is found that the Delphi method performs best with interaction groups and structured analogies while still improving accuracy. The Delphi method is when multiple questionnaires are sent to professionals in rounds until consensus is met. Interactions groups are those comprising various experts who debate and discuss to reach consensus. In comparison, structured analogies refer to forecasting with templates, or analogies, created by manipulating similar characteristics of past events. This shows that human judgement can be improved by group consensus.

### *Sophisticated forecasting methods*

Sophisticated forecasting methods mostly refer to multiple linear regression (MLR) as a standard benchmark (Petropoulos et al. 2022), and artificial neural networks (ANN) and the nearest neighbour approach (NN) as common choices in the presence of non-linearities (Nikolopoulos 2010). MLR is a common and easily interpretable forecasting method that predicts a variable based on at least two independent variables (Makridakis, Wheelrwright, and Hyndman 1998).

Nevertheless, it is dependent on time-series data; therefore, it often results in low accuracy forecasts due to only being capable of representing linear relationships (Chu and Zhang 2003). In the case of special events, normal relationships change temporarily due to alterations in the environment. Therefore, a different model is needed for that time period because different independent variable relationships and outcomes arise. For this reason, aided human judgement has been found to outperform MLR. However, ANN and NN perform considerably better (Nikolopoulos, Goodwin, et al. 2007). This is because the two methods can address non-linearities.

NN is conceptually simple with forecasts based on the similarities of independent variables for past events (Nikolopoulos, Goodwin, et al. 2007). ANNs are based on the human brain and can be trained to recognise patterns since they learn and generalise experiences. This makes them a valuable forecasting tool in research and business when historical data exist and reliable data can outweigh a theoretical guess (Zhang, Patuwo, and Hu 1998). In a simulation ran by Nikolopoulos, Bougioukos et al. (2007) to forecast the impact of irregular events they found ANN performs best in complex non-linear situations, but MLR is better in simpler cases. Similarly, Nikolopoulos (2010) used a simulation to forecast the impact a special TV event, like sporting events, would have on TV ratings. It is found that ANN performs best in highly complex non-linear situations. However, an expert approach developed that combines the benefits of MLR in predicting linear relationships and ANN in predicting non-linear relationships offers considerably more accuracy if linearities are found.

### *Forecasting accuracy for special events*

The academic literature provides useful insight into how judgemental forecasting can be improved and some guidance on how sophisticated methods perform. However, other than ANN performing well in two studies, there are not enough studies predicting the impact of special events to make concrete assumptions. In fact, Makridakis and Taleb (2009) prove that in situations where uncertainty is high there is limited ability to make accurate forecasts using the three bases of prediction. These include patterns such as ANN and NN, relationships and human judgement. They believe the least accurate is judgemental forecasting due to the disadvantages previously addressed.

Similarly, Goodwin and Wright (2010) find all forecasting methods are flawed when predicting the impact of rare and high impact events. They consider numerous forecasting methods as well as a non-forecasting method, scenario planning. They suggest ways to ensure protection against rare events are increasing redundancy, flexibility and diversity. The other remedy is to 'challenge one's own thinking' (Goodwin and Wright 2010, 367) to improve anticipation. Alike their 2010 research, Wright and Goodwin

(2009) express improvements for scenario planning which often disadvantage from human bias. Thus, improvements should involve mental frames being challenged; human motivations being understood; adding the crisis management approach; and analysing strategic options. Hence, thought provoking methods that increase anticipation are important.

Reflecting on the research gaps of the latter part of the literature review, and especially the forecasting capabilities for such extreme special events as floods and the respective impact on PPI supply chains, our second Research Questions naturally evolve as the following:

**RQ1:** What methods can be used to forecast the impact of flood?

## Methodology

The current research is – by all means – not exhaustive; nevertheless, we do believe our research questions and relative insight to be brough as re of critical importance, especially in the new normal we live in nowadays. To the authors' best knowledge and understanding, there is no article that has addressed PPI. It seems logical that such a special event should be addressed in an industry whereby pulp production and paper production is heavily reliant on being located next to large water sources.

This essential gap has been suggested by Stecke and Kumar (2009). The authors explain that learning from companies within an industry who have experienced disruptions can help shape future strategies and subsequently guide other companies' strategies. Sodhi et al. (2012) in their research also found that practitioners are calling for research to be conducted which works with companies who have experienced disruptions.

Concluding, and following the targeted literature review, and in reference to the aforementioned research gaps, the research questions become:

**RQ1:** To what extent can the impact of flood on the PPI supply chain be mitigated?

**RQ2:** What methods can be used to forecast the impact of flood?

To address these research questions, a qualitative approach seemed far more appropriate and thus this applied research embodied the interpretivist one (Hudson and Ozanne 1988), and sought to understand phenomena (Antwi and Hamza 2015). This aligns to the inductive approach taken (Saunders, Lewis, and Thornhill 2016) as well as the qualitative method. Since this research is the first of its kind for the PPI, there were no known concepts to which data can be collected and measured (Neuman 2014). Therefore, the qualitative method means more conclusive research can be conducted in the future on this unexplored issue (Singh 2007). The researcher also used a constructivist grounded theory strategy as it allowed for emergent development of theory and has been stated the only grounded theory accurate for interpretivists (Charmaz 2006).

### Data collection

Consultants were purposively selected for their abundance[1] of information (Patton 2002). To do so, a snowball technique was used which involved reaching participants through other participants (Noy 2008). Semi-structured interviews which have flexibility to converse with different interviewees were used (Noor 2008). Broad topic areas that were to be discussed in each interview were placed on an interview schedule; yet a specific set of questions were not used so there was free discussion (Barriball and While 1994). Each interview was held over the telephone to accommodate the consultant's busy schedules (Barriball and While 1994). Whilst telephone interviews are sometimes seen as inappropriate for semi-structured interviews (Fontana and Frey 2005), Sturges and Hanrahan's (2004) research comparing telephone and face-to-face interviews found no significant differences between transcripts. Thus, semi-structured interviews obtained a breadth of understanding.

### Data analysis

Coding involved an initial stage to highlight all possible theories (Charmaz 2006) and a focused stage to identify the most significant. The very nature of grounded theory requires coding to happen after each interview (Corbin and Strauss 1990). This means the interviewee's who can provide the most information regarding specific topic categories that emerge in a previous interview can be selected. Grounded theory in this instance is applied in its generic form where theoretical propositions are organically evolving from the free thoughts of the interviews and the interviewees.

## Empirical findings

This section presents the findings from all consultant interviews. Beforehand, pilot interviews were held so questions could be trialled (Majid et al. 2017) and practical issues identified (van Teijlingen and Hundley 2002) that would improve interview protocols (Castillo-Montoya 2016). The pilot interviews finalised the key question areas. These topic areas allowed for greater focus in interviews as they progress so the grounded theory can be established (Bryant and Charmaz 2007).

## Consultant interview findings

All nine[2] consultants[3] were executives from different companies. This meant saturation would receive a higher level of legitimacy. Upon completing all interviews, the categories and the order in which they emerged are: 'Inventory Strategy', 'Sourcing Strategy', 'Forecasting Methods', 'Planning', 'Site Protection' and 'Business Execution'. These are explored below using key focused codes for each. However, before going into detail, the chain of evidence is presented in Table 1. It provides an overview of the findings and highlights how they are representative of all data, rather than only occurring once (Urquhart 2013). The categories of this research are presented alongside key topics of discussion.

## Inventory strategy

The term 'Inventory Strategy' was given to this category as it refers to how different types of inventory can be used to minimise flooding impact across the supply chain.

### Inventory options

This focused code refers to the type of inventory to hold and at what times to hold it. Notably, this type of inventory is related to protecting raw materials and/or finished goods, which was spoken about by most consultants who addressed this code. In comparison, the time at which the inventory should be held, such as before an anticipated event or high flood risk periods, was only alluded to by four consultants. It is also interesting that C1, C5 and C6 gave this type of inventory holding a specific name to stress the difference to normal inventory. These were 'strategic safety stock', 'factory flood damage limitation inventory' and 'short term overflow storage'.

### Customer relationship management

There are multitude of methods for the way in which inventory should be held to continue to serve customers. The most used line-by-line codes are shown in Table 2 alongside the consultants who used each. Please note some line-by-line codes have been merged at this point for presentation purposes.

## Sourcing strategy

Consultants would address how different sourcing possibilities with suppliers could be used to minimise the impact of flood across the supply chain.

Table 1. Chain of evidence.

| Category ↓ / Topic → | Minimising impact of supplier flooding | Minimising flood impact on production | Minimising flood impact on customers | Weather Forecasts | AI and Machines Learning | Traditional Forecasts | Scenario Planning | End-to-End Supply Chain Strategy |
|---|---|---|---|---|---|---|---|---|
| Inventory Strategy | C1, C2, C5, C7 | C1, C3, C5, C6, C9 | C1, C2, C3, C4, C5, C6, C7 | | | | C1, C2, C4, C7, C9 | |
| Sourcing Strategy | C1, C2, C3, C4, C5, C6, C7 | C5 | | | | | C1, C2, C7 | |
| Forecasting Methods | | | | C1, C3, C5, C6, C7, C8 | C1, C2, C4, C5, C6, C7, C8, C9 | C6, C8, C9 | C2, C4 | |
| Planning | | C1, C6 | | | | | C1, C2, C4, C5, C6, C7, C9 | |
| Site Protection | | C1, C2, C3, C4, C5, C6, C7, C9 | | | | | C1, C7 | |
| Business Execution | | | | C1, C5, C6, C7, C8 | C1, C2, C4, C6, C8 | C9 | C1, C2, C4, C6, C7 | C1, C6, C7, C8 |

Table 2. Common customer relationship management line-by-line codes.

| Line-by-line code | Consultants |
|---|---|
| Using Vendor Management Inventory (VMI) | C1, C2 |
| Using Distribution Centres (DCs) and hubs | C2, C5, C6 |
| Holding away from flood risk/close to customer | C1, C2, C3, C4, C5, C6, C7 |
| Storing above ground level | C3, C5 |
| Performing customer segmentation | C1, C6 |
| Understanding customer inventories | C1, C4, C6, C7 |
| Considering cost-service trade-offs | C1, C6, C7 |

### *Multi sourcing*

C1, C3, C4 and C6 all expressed having 'multiple' or 'dual' sources of supply to minimise the impact of flood when a supplier is flooded. In addition, C1 made it clear that suppliers should be from different geographical areas, so both are less likely to be impacted by flood at the same time. Whilst C5 did not express enough to fit into the multi sourcing focused code, they did state 'with our supply chain partners that are geographically located differently so we aren't all threatened by the same thing at the same time'. It is realised that other consultants did not explicitly state that when using multisourcing the suppliers should be from different areas, it was their intention. For example, C6 had previously addressed holding inventory 'away from the manufacturing site sufficiently, so it doesn't shut down your ability to supply or receive'.

### *Multi sourcing: implications*

Many consultants have expressed that multi or dual sourcing is not necessarily an action to take, rather it is dependent on certain factors. C6 articulated switching supply is a difficult task that requires flexibility. Similarly, C3 expressed many companies do not properly execute dual sourcing meaning each raw material is not sourced from multiple suppliers. Instead, each raw material is sourced with a single supplier. In such a situation C3 suggests managing the impact by building a strong relationship where 'all the right areas covered and therefore they get it right'. Often companies will 'choose two suppliers and effectively not being vested in either'.

C1 and C3 also explained how when one supplier floods the other is not likely to have enough capacity to deliver what the other supplier does. C1 explains this positively while C3 attaches a negative connotation. These connotations are in *italics* whereas the limited capacity of another supplier is underlined.

**C1:** So, in the event that one material supplier did have issues to do with flooding, then they could still get supply, *whilst it might be limited*, from another supplier, which would mean they could then reduce the amount of raw materials safety stock and keep the plant running.

**C3:** If I have two suppliers and one goes *down then it is just as bad* because if one supplier goes down, then the other supplier is very <u>unlikely to be able to pick up on the output</u>.

C1 and C6 explicated that the decision to multi-source is dependent on other factors. C1 explained multi-sourcing is reliant on 'whether the local roads were running as well because if they had other suppliers and roads were shut then it wouldn't have any benefit'. C6 expressed multi sourcing is expensive and therefore companies must 'think about the cost-service trade-offs'. She went on to explain how if holding inventory costs less, then it would be preferable.

### *Forecasting methods*

All consultants believed forecasting was an integral aspect of building the capability to mitigate. For example, a line-by-line code in the C6 interview was 'stressing forecast and mitigation interdependencies'. Whilst the first two focused codes below seem similar, the use of AI and machine learning compared to its implications for company's using it appeared as two distinct arenas.

### *AI Algorithms and Machine Learning*

All consultants apart from C3, no matter what their level of expertise in the area, believed in using AI algorithms and machine learning in some form. Interestingly, when it came to the actual algorithms only C8 mentioned 'Neural Networks'. However, even though C8 suggested this, alike C2 the consultants placed most emphasis on finding the best algorithms.

All consultants apart from C3 and C5 addressed the use of and how to perform forecasts using AI algorithms and machine learning. This involves gathering data from multiple sources with have an impact on flood, such as weather. C9 took this further, as outlined below.

**C9:** You could attempt to build a predictive model around timing and size and impact on different portions of the manufacturing process/supply chain.

Consultants also addressed what the forecasts could calculate. C1, C2 and C5 explained calculating the likelihood of a flood of a certain impact is possible. I contrast, C9 explain the probability, in terms of timing and size, of a flood occurring and the subsequent impact it has can be calculated.

### *AI Algorithms and machine learning: implications*

Consultants addressed how this forecasting is not used from their experience. They also explained how it could be accurate, but the abundance of historical and real-time data required is often not accessible and difficult to obtain. Consultant's additionally aired views on the difficulty of forecasting weather itself.

### *Human adjustments*

This focused code was less popular than the previous, however something that C2, C8 and C9 believe to be more viable given their experience. For example, C2 stated 'there is a good reason for finding the right level of combining both'. It was also something C6 addressed as a possibility. However, what C2 suggests is different to C6, C8 and C9's. This was clear in line-by-line coding with C2's codes being 'using human experience', 'combining with technology' (where technology means AI and Machine Learning). Key line-by-line codes for C6 were 'performing demand sensing', 'assessing weather' and 'adjusting traditional forecasts'. Similarly, C8's codes were 'adjusting traditional forecasts' and 'inputting reliable data' and C9's codes included 'using experience' and 'using analogies'.

However, C2 and C8 did address problems of human input. C2 explains technology is required as it 'leaves you less exposed to what happens in case you lose that experience'. Whereas C8 addresses human bias and tendency to have a high-risk adversity. For this reason, C9 suggests how to overcome problems by minimising bias from multiple expert forecasts. They suggest using Delphi method and Structured Analogies.

### *Weather forecasts: long-term*

Interestingly, using weather forecasts was used with most certainty by those who addressed it (C1, C3, C5, C6 and C8). For example, C8 addressed that this was due to the 'huge immaturity of business forecasts'. Long-term use of weather forecasts refers to making statistical predictions based on past weather and flooding events to predict the likelihood over the next x years.

### *Short-term forecasts*

Short-term forecasts imply receiving triggers. This could be from online and weather services or from more sophisticated forecasts using machine learning. C1, C6, C7 explain calculating triggers through means of statistical calculations based on weather data. Whereas C2 proposes using comparisons between 'real time sensor data' and historical data alongside AI and machine learning. While C6, C7 and C8 suggest subscribing to alerts such as those from the Environment Agency or MET Office.

## *Planning*

Planning encompasses a wide variety of actions. The first three focused codes involve methods and actions required, whereas the last denotes the reasons for companies beginning to start planning for disruptive events.

### *Scenario planning*

This is one of the two most important actions for C7. Not only did it appear as a focused code in five interviews, but also as a line-by-line code in the interviews conducted with C5 and C6. The line-by-line codes were 'using scenarios' and 'running scenarios', respectively. During interviews where this focused code applied, consultants would suggest possible scenarios that could be run and these varied based on the context in which they were speaking. There are so many possibilities it was not expected for the same specific scenario examples to be bought up by different consultants. It is also worth noting that C2 and C4 explained this as a way to forecast the impact, but also addressed it as a planning method and therefore is placed in this category. The two experts below explain the benefits and use of scenario planning.

**C1:** Using a scenario and saying if this happened in the next one, two, 3 years, then this is the action we would take. So that they have it already understood, the cost of it modelled, and they know exactly what the impact would be

**C7:** A forward simulation … probably at least over a twelve-month period … Then, kind of building up the scenarios … what's the impact and then given the impact what's the mitigating actions I can take, and, you know, what's the consequences and implications of those.

### *Integrated Business Planning*

C1 and C6 explicitly referred to IBP, C4 and C5 did not but it was the process referred to. C4 believed IBP was the most important action. This involves generating a long-term plan and requires forecasting and likelihood predictions to be fed into the process. This involves scenario planning and as explained by C1, having scenarios 'signed off' to be entirely prepared for future possibilities.

## *Site protection*

After speaking to all consultants, it became clear that the first step to minimising the impact of flood is to protect buildings and minimise the impact to sites.

### *Flood defences*

This focused code refers to the protection of buildings with boundaries and infrastructure that help the flow of water around a site. Although this may seem basic, many consultants suggest its use to minimise the impact of flood on production. There are three views on its necessity. C4 and C6 believe flood defences are always necessary. C2 suggests having flood defences only in extremely predictable flood period. Comparatively, C1, C3, C5 and C9 believe flood defences should be installed if it is a worthwhile investment.

### *Relocation*

Relocating the production site was addressed by four consultants. C2 and C5 believe it is a plausible action whereas C4 and C6 addressed relocating negatively. C2 suggests considering relocation as part of a 'long-term strategy' if flood occurs too frequently. C5 similarly suggests if the water table is rising and that is proven from historical trends then an option is to 'move'. In contrast, C4 explains a 'mill cannot be replicated' as it is 'too expensive'. C6 also expresses there is 'limited ability to move'.

### *Business execution*

This category addresses how companies should be using forecasts in line with appropriate procedures to mitigate the impact of flood. It also encompasses how the business should be ran and its focus for success in minimising flood impact in the supply chain. While some focused codes below seem similar, each has a specific focus meaning two could not be merged.

### *Responding to triggers*

This was something C6 and C8 regarded as the most important factor to minimise floods impact on the supply chain. Responding to triggers indicates either using pre-defined scenarios, such as pulling those addressed as part of IBP (C1, C2, and C7) or the tactics to deploy after a trigger is hit (C5, C6, C7, C8 and C9).

### *End-to-end supply chain strategy*

C1 and C7 specifically addressed this code but others (C4 and C6) would talk about visibility or collaboration with supply chain partners. C1 and C8 explain how forecasts can feed into the end-to-end strategy as well as explaining its importance in planning, knowing a flood is imminent and responding, like C4, C6 and C7.

### *Business processes*

Business Processes refers to how a company should operate to successfully identify and remove any flood risk. This involves having a proactive approach throughout the company in terms of decision-making and processes. This is something that C2, C6 and C9 stressed as being most important. Additionally, C5 addresses the requirement. It is worth noting that C8's account for end-to-end strategy also links to trusting forecasts and acting on them. C2 states 'process and people, and technology is the third one that's important. Any of those three fail, the whole construct is going to fail'. Hence, there is a big emphasis on having *supporting people* in management positions and throughout the company, a *process* that identifies and acts upon the likely impact of flood and having as well as trusting *technology/data.*

Overall, this chapter has highlighted differences in perceptions about codes as well as meanings and explanations of phenomena. These are analysed below.

## Discussion

Results gathered from the consultant interviews show the many ways in which the impact of flood can be forecasted and mitigated for a paper manufacturer, and indeed, in the PPI supply chain. Adopting the final categories used to present the grounded theory results meant memos made could be sorted to understand category associations and then be placed on a diagram (see Figure 2). Diagramming in this way enables relationships between categories to be easily shown (Charmaz 2006; Urquhart 2013) as well as the relative positions expressed (Clarke 2005). Since

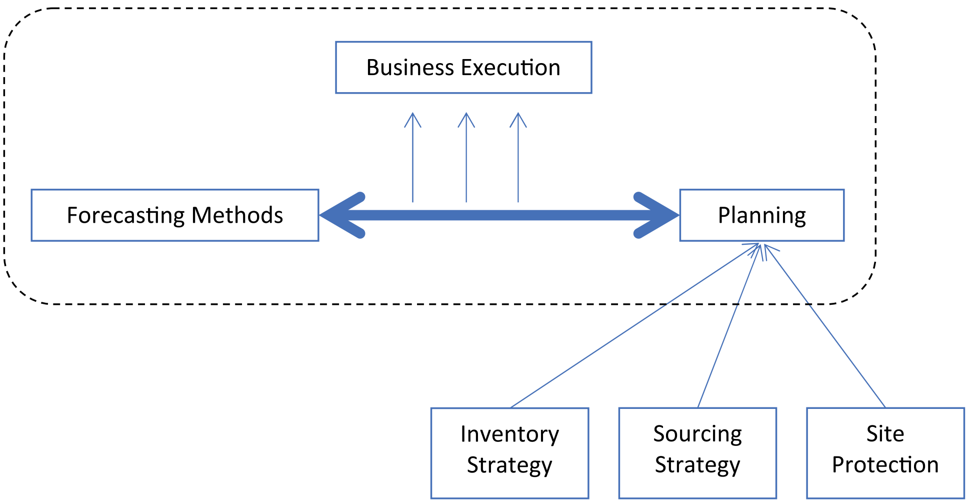


Figure 2. Conceptual map showing category relationships.

Business Execution is most important, it is the starting point of analysis.

### *Business execution*

It is important that triggers received from weather or more sophisticated forecasts should be used to put in play a set of pre-defined tactics or scenarios. Business Execution lies between the detection and recovery stages explained in the conceptual background. Although previous supply chain research generally refers to gaining visibility and responding when a disruption hits rather than before impact; Blackhurst et al'.s (2005) explanation of having real-time information available in discovery and then pursuing real-time reconfiguration of the supply-chain to recover is the most similar. Whilst the researcher agrees with this recommendation to an extent, it fails to address when to reconfigure which was paramount for minimising the impact of flood in the PPI.

Comparatively, further exploration into flood forecasting literature brought up Dale et al'.s (2014) paper which presents a risk-based decision support solution. They use probabilistic flood forecasting to aid decision-making in the government by creating triggers that require action based on the probability of flood and its potential impact. Verbunt et al. (2007) explain probabilistic forecasting is when uncertainty in a flood prediction is quantified. They also justify how such forecasts can support decision-making. Therefore, these models are similar to the 'triggers' consultants explain, yet not specific to businesses.

Second, an end-to-end supply chain strategy is paramount for successful business execution. All entities within the supply chain should not be focusing within the confines of their own walls. Therefore, similarities to the literature are present with many addressing flexibility through visibility (Blackhurst et al. 2005; Christopher and Peck 2004; Sheffi 2001; Stecke and Kumar 2009; Tang 2006) and coordination (Christopher and Peck 2004; Jüttner 2005; Stecke and Kumar 2009; Tang 2006; Zsidisin and Ellram 2003). Hence, visibility and coordination across the supply chain is a necessity in the PPI.

Third, Business Processes that exhibit a proactive approach must be considered. This is an interesting finding as business processes are about the entire company decision-making process, supporting people and trust in data from forecasts. This builds on existing literature that indicates having a risk management culture (Christopher and Peck 2004; Sheffi and Rice 2005), the requirements of having supply chain managers on boards (Christopher and Peck 2004; Jüttner 2005; Peck 2005) and having strict employee screening processes (Rice and Caniato 2003). However, no researcher combines all three, nor is the dependency of trusting data and having a robust planning process stressed. Therefore, to mitigate or minimise flood impact in the supply chain, it is argued critical that paper manufacturers implement a change in entire company practice to be more proactive.

### *Forecasting methods*

Forecasting methods were found to have a similarity with Business Execution. Forecasts generate triggers, feed into the end-to-end supply chain strategy and are the foundation of business processes. However, forecasts are not the only foundation as Planning is of equal importance. First, it is fascinating that C2 and C4, when questioned on forecasting the impact of flood responded with using scenario planning. Alike Goodwin and Wright (2010), this addresses those 'non-forecasting' methods. Research has not addressed using forecasts to improve scenario planning like C1 and C2 do, instead Önkal et al. (2013) suggests the opposite. The two may have interdependencies as an accurate forecast can refine scenarios yet understanding a variety of possibilities can improve judgement forecast accuracy.

Second, consultants with greater forecasting comprehension are apprehensive of paper manufacturer's capability for forecast flood impact. This highlights theforecasting gap between research and practice explained by Sanders and Manrodt (2003). Nevertheless, C8 did say Neural Networks can be used, like Nikolopoulos et al. (2007) and Nikolopoulos (2010) in their research. However, almost half the consultants claim it is more about finding the right algorithm and/or model rather than being so prescriptive. It is stressed that having access to historical and real-time data is also important. This builds on Lechler et al'.s (2019) research which explains real-time data can reduce supply chain uncertainties. It is therefore suggested paper manufacturers assess their forecasting capability.

Third, for Human Adjustments, it is suggested to combine human experience with machine learning forecasts, adjust traditional forecasts such as moving average and use structured analogies plus the Delphi method with various expert forecasts to gain consensus. This is similar to those academics who recommend methods of improvement for judgemental forecasting.

Fourth is Weather Forecasts: Long-Term. There was little similarity to literature found in the initial review. That being said, there is some similarity to probabilistic forecasting previously discussed. Similarly, short-term forecasts are not addressed in literature explicitly. While Stecke and Kumar (2009) do suggest monitoring the weather, they do not explain why. Since no previous literature has specifically focused on flooding, the researcher argues that in the detection mitigation stage, companies address a number of forecasts. The random nature of weather, in particular in parts of the world such as North Eastern Europe, means companies need to be constantly looking ahead to predict likely flooding they need to protect against, for example through flood defences.

In addition, companies must quickly respond to short-term forecasts they may receive 5 days out, for example. Paper manufacturers must understand what they are capable of doing to minimise floods impact at that point.

### Planning

An integral category for consultants that is not so explicitly outlined in the literature. This category is similar to forecasting in that there is some similarity to business execution. The difference is that planning is grounded in preparation and being ready for the occurrence of flood, as briefly alluded to alongside short- and long-term forecasts.

Within Planning came a significant insight of this research, IBP. IBP is the development of sales and operations planning into a 'fully integrated management and supply chain collaboration process' (Oliver Wight International 2012b, 1). It involves 'the technologies, applications and processes of connecting the planning function across the enterprise to improve organizational alignment and financial performance' (Toor and Dhir 2011, 276). Notably, IBP is an integral factor that builds the Business Processes focused code. Although only four consultants referred to IBP, they were all from different companies signifying its importance.

Surprisingly, IBP is yet to feature in supply chain disruption management literature, with only two journal articles found that are generally descriptive of what IBP can do. One of these is 'Strategy and Portfolio Management Aspects of Integrated Business Planning' (Jurečka 2013). The other is 'Benefits of integrated business planning, forecasting, and process management' (Toor and Dhir 2011). In comparison, many white papers by consultancies such as Oliver Wight, Ernst and Young and Tata exist. Some of these do have a focus on disruption managementfor example, 'Managing Vulnerabilities and Opportunities with Integrated Business Planning' (Oliver Wight International 2012a).

Contingency planning was another focused code that does not feature heavily in supply chain disruption management literature, yet a well-known term. The three consultants who referred to contingency planning made it clear that contingencies were factors such as back-up suppliers or movement of inventories. In the initial literature review, Skipper and Hanna's (2009) study addressed the links between contingency planning and flexibility to manage risks. It is difficult to find other similar research, although an article by Jüttner et al. (2003) has suggested further research that explores different industry or supply chain risks from a contingency perspective. Hence, this is an area important for the PPI.

Scenario planning was a frequently used code. In a planning sense, the term is used to calculate sourcing strategies in disruption management literature (Klibi and Martel 2012; Santoso et al. 2005; Sarkar and Mohapatra 2009; Sarkar et al. 2012) and as a recommendation for businesses to run tests prior to implementation (e.g. Corsi and Macdonald 2013). Like the entire Planning category, it does not seem to be an as important task to academics as it does to consultants. However, for a disruption such as flood which is extremely hard to forecast, scenario planning is arguably invaluable to minimise the impact of flood and, in less severe cases, mitigate.

### Inventory strategy

This category refers to the contingencies or scenarios that need to be in place to pre-empt future flooding. In terms of holding safety stock of raw materials or finished goods, this was expected from the initial conceptual review. Inventory options can be used to minimise the impact of the supplier flooding, minimise flood impact on production and play a key role in customer relationship management.

Customer Relationship Management appeared in most interviews, suggesting its importance for paper manufacturers. This is not stressed as heavily in literature with only Sheffi and Rice (2005) really addressing the importance of maintaining customer relationships. Additionally, Corsi and Macdonald (2013) touched on the need by addressing the impact to customers and Bueno-Solano and Cedillo-Campos (2014) stressed fulfilling orders as usual. Consequently, it is argued mitigating flood's impact on customers, in particular those strategic ones, is extremely important. For the PPI as a whole, this would be an interesting avenue for research: to understand how other entities down the supply chain prioritise customer impact.

### Sourcing strategy

Sourcing Strategy is the same as Inventory Strategy in terms of relation to Planning. Whether or not, and when inventory and sourcing strategies are used is dependent on company capability and the specific flood mitigation. Having multiple suppliers can minimise risk of suppliers flooding. Intriguingly, some scepticism exists around multi sourcing since many companies perform it incorrectly or poorly. In these situations, good relationships can be built with a single supplier that manages risk well. Single sourcing with a strong relationship was alluded to by Tomlin (2006) for frequent and long disruptions. While this could mitigate some risk based on safety stock stored if the flood is detected far enough in advance, a flood of unforeseen impact at a pulp manufacturer could leave a paper manufacturer without supply. Of course, this depends on the level of planning a paper manufacturer had engaged in. On the other hand, it was expressed to only use multiple suppliers if it is a worthwhile investment. Unlike many academics who suggest multiple suppliers is always a better strategy (e.g. Sarkar et al. 2012), it is argued more feasible from a capability perspective to calculate whether or not it is cheaper to hold higher safety stocks.

### *Site protection*

Site Protection is the same as inventory and sourcing as it feeds into planning, but it is not a contingency. While site protection is specific to extreme weather events often referred to in the literature, Rice and Caniato (2003) are the only academics who recommend investing in infrastructure. However, they provide no specific details. Additionally, whilst relocation was suggested, other consultants explain it is not viable. Based on the fact paper mills are located next to high-quality water sources this is an extremely unlikely option; that is, before considering the financial impact.

## Conclusions, implications for practice, limitations, and the future

The key insights from this timely qualitative study are:

- First, advanced AI-driven forecasting methods are perceived of limited benefit to practitioners in the field. Instead, paper manufacturers seem to believe they can have more accurate forecasts via standard statistical forecasting on past weather forecasts and, respectively, predict the likelihood of specific impacts of flood. They can use these predictions and official flood warning subscriptions to generate alerts. This conclusion solidifies why Stecke and Kumar (2009) and Sodhi et al. (2012) proposed the need for industry-specific research.
- Second, in PPI supply chains you should always plan. Being prepared is something the consultants found of equal importance to forecasting. Within the planning realm, this research shed light on two issues. One was that research into the use of contingency planning for disruption management is still in its infancy despite consultants stressing its importance; and this avenue of research being requested by many academics. The second finding is that paper manufacturers should be engaging in IBP. Having a long-term view of the strategic horizon and using scenario planning to be prepared for possible future impact, as well as making investments prior to flood, will minimise the severity of flood on a business. Of course, these scenarios will involve deciphering for a specific flood impact the sourcing strategies, inventory strategies and site protection investments are worthwhile pursuing.
- Third, business execution and an entire end-to-end supply chain strategy is extremely important, including constant monitoring so triggers are received from forecasts that have pre-defined responses (set from IBP).

We also strongly believe our results are generalisable to most paper manufacturers since the consultants in our sample have worked with multiple different companies. Similarly, many findings are not paper manufacturer specific, although this was the intention. The same principles can be applied across the supply chain, in particular with pulp mills who sit in a very similar situation when it comes to flooding. The comparison is they need to consider their customers more than suppliers. However, the strategy is similar. The latter two main insights on the importance of planning and appropriate business execution are generalisable to most supply chains and supply chain disruptions.

### *Implications for practice*

Capitalising on the research findings in this study, some clear recommendations for practitioners in the field are surfacing. Consultants should:

(1) Develop a forecasting model.
(2) Assess the business' scenario planning capability to cover all possible scenarios for the different sourcing, inventory and site protection strategies.
(3) Bring together the forecasting and scenario model to run evaluations on feasible decisions.
(4) Assess and, if required, implement the IBP process to provide visibility across the relevant future horizons for the company (based specifically on the company).

### *Research limitations*

This research comes with one main limitation: the small sample size. However, having a niche and narrow focus to the research (i.e. paper manufacturing and flooding) means the theory could be built from fewer interviews to the saturation point. Plus, Armstrong (2007) has long advocated for the importance of insights coming out form small sample studies and the need to obliterate the obsession on statistical significance.

### *Future research*

Our results show very promising future avenues of research. Future studies could be performed on a larger scale with more consultants and addressing each supply chain partner. This would provide further validation of the generalisability of these results. Additionally, the findings of this research should be implemented over a longitudinal time horizon in multiple paper manufacturing case studies to see if they benefit business performance. This can include actual quantitative results (e.g. financial impact) in addition to qualitative accounts from the companies. Finally, further research needs to be conducted on IBP. Ideally, this would show the changes in business performance before and after IBP has been implemented. Performing this research with a paper manufacturer to see its benefit for flood mitigation would be advantageous.

## Notes

1. We have selected to use experienced consultants for our interviews, resulting in a smaller sample but more rich content and information per interview. Expert consultants come with a consolidated abundance of information, but it needs to be mentioned that this does not necessarily mean expertise or decision-making experience in PPI supply chains as in any other sampling process.
2. As this is a study aiming for insight and not statistical significance we focused on rich interviews and not higher number per se; the literature does not suggest a minimum number of interviewees for such qualitative studies and thus as long as saturation s has been achieved, we consider we used a sufficient number of experts.
3. Due to GDPR and confidentiality reasons we cannot reveal the identities of the interviewees.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## References

Ali, I., and I. Gölgeci. 2019. "Where is Supply Chain Resilience Research Heading? A Systematic and Co-Occurrence Analysis." *International Journal of Physical Distribution and Logistics Management* 49 (8): 793–815. https://doi.org/10.1108/IJPDLM-02-2019-0038.

Antwi, S. K., and K. Hamza. 2015. "Qualitative and Quantitative Research Paradigms in Business Research: A Philosophical Reflection." *European Journal of Business and Management* 7 (3): 217–225.

Armstrong, J. S. 2001. "Extrapolation for Time-Series and Cross-Sectional Data." In *Principles of Forecasting: A Handbook for Researchers and Practitioners*, edited by Armstrong, J. S., 217–243. Dordrecht: Kluwer Academic Publishers Group.

Armstrong, J. S. 2007. "Statistical Significance Tests are Unnecessary Even When Properly Done and Properly Interpreted: Reply to Commentaries." *International Journal of Forecasting* 23 (2): 335–336. https://doi.org/10.1016/j.ijforecast.2007.01.010.

Arreola-Risa, A., and G. A. DeCroix. 1998. "Inventory Management Under Random Supply Disruptions and Partial Backorders." *Naval Research Logistics* 45 (7): 687–703. https://doi.org/10.1002/(SICI)1520-6750(199810)45:7<687:AID-NAV3>3.0.CO;2-7.

Assimakopoulos, V., and K. Nikolopoulos. 2000. "The Theta Model: A Decomposition Approach to Forecasting." *International Journal of Forecasting* 16 (4): 521–530. https://doi.org/10.1016/S0169-2070(00)00066-2.

Barriball, L., and A. While. 1994. "Collecting data using a semi-structured interview: a discussion paper." *Journal of Advanced Nursing* 19 (2): 328–335. https://doi.org/10.1111/j.1365-2648.1994.tb01088.x.

Blackhurst, J., C. W. Craighead, D. Elkins, and R. B. Handfield. 2005. "An Empirically Derived Agenda of Critical Research Issues for Managing Supply-Chain Disruptions." *International Journal of Production Research* 43 (19): 4067–4081. https://doi.org/10.1080/00207540500151549.

Bryant, A., and K. Charmaz. 2007. "Introduction: Grounded Theory Research: Methods and Practices." In *The SAGE Handbook of Grounded Theory*, edited by Bryant, A. and K. Charmaz, 1–28. Los Angeles: SAGE Publications Ltd.

Bueno-Solano, A., and M. G. Cedillo-Campos. 2014. "Dynamic Impact on Global Supply Chains Performance of Disruptions Propagation Produced by Terrorist Acts." *Transportation Research Part E: Logistics & Transportation Review* 61:1–12. https://doi.org/10.1016/j.tre.2013.09.005.

Castillo-Montoya, M. 2016. "Preparing for Interview Research: The Interview Protocol Refinement Framework." *The Qualitative Report* 21 (5): 811–831. https://doi.org/10.46743/2160-3715/2016.2337.

CEPI. 2019. Accessed Febrary 12, 2024. https://www.cepi.org/key-statistics-2019/.

Charmaz, K. 2006. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. London: SAGE Publications Ltd.

Chopra, S., and M. S. Sodhi. 2004. "Managing Risk To Avoid Supply-Chain Breakdown." *International Journal of Operations and Production Management* 46 (1): 53–61.

Christopher, M., and H. Peck. 2004. "Building the Resilient Supply Chain." *The International Journal of Logistics Management* 15 (2): 1–13. https://doi.org/10.1108/09574090410700275.

Chu, C. W., and G. Zhang. 2003. "A Comparative Study of Linear and Nonlinear Models for Aggregate Retail Sales Forecasting." *International Journal of Production Economics* 86 (3): 217–231. https://doi.org/10.1016/S0925-5273(03)00068-9.

Clarke, A. E. 2005. *Situational Analysis: Grounded Theory After the Postmodern Turn*. Thousand Oaks: SAGE Publications Ltd.

Corbin, J., and A. Strauss. 1990. "Grounded Theory Research: Procedures, Canons, and Evaluative Criteria." *Qualitative*

*Sociology* 13 (1): 3–21. https://doi.org/10.1007/BF00988593.
Corsi, T. M., and J. R. Macdonald. 2013. "Supply Chain Disruption Management: Severe Events, Recovery, and Performance." *Journal of Business Logistics* 34 (4): 270–288. https://doi.org/10.1111/jbl.12026.
Craighead, C. W., J. Blackhurst, M. J. Rungtusanatham, and R. B. Handfield. 2007. "The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities." *Decision Sciences* 38 (1): 131–156. https://doi.org/10.1111/j.1540-5915.2007.00151.x.
Dale, M., J. Wicks, K. Mylne, F. Pappenberger, S. Laeger, and S. Taylor. 2014. "Probabilistic Flood Forecasting and Decision-Making: An Innovative Risk-Based Approach." *Natural Hazards* 70 (1): 159–172. https://doi.org/10.1007/s11069-012-0483-z.
Dolgui, A., D. Ivanov, and B. Sokolov. 2018. "Ripple Effect in the Supply Chain: An Analysis and Recent Literature." *International Journal of Production Research* 56 (1–2): 414–430. https://doi.org/10.1080/00207543.2017.1387680.
Dubrovski, D. 2004. "Peculiarities of Managing a Company in Crisis." *Total Quality Management and Business Excellence* 15 (9–10): 1199–1207. https://doi.org/10.1080/1478336042000255578.
Fildes, R., and R. Hastings. 1994. "The Organization and Improvement of Market Forecasting." *The Journal of the Operational Research Society* 45 (1): 1–16. https://doi.org/10.1057/jors.1994.1.
Fontana, A., and J. Frey. 2005. "The INTERVIEW: From Neutral Stance to Political Involvement." In *The Sage Handbook of Qualitative Research*, edited by Denzin, N. K. and Y. S. Lincoln, 695–728. London: SAGE Publications Ltd.
Goodwin, P. 2002. "Integrating Management Judgment and Statistical Methods to Improve Short-Term Forecasts." *Omega* 30 (2): 127–135. https://doi.org/10.1016/S0305-0483(01)00062-7.
Goodwin, P., and G. Wright. 2010. "The Limits of Forecasting Methods in Anticipating Rare Events." *Technological Forecasting and Social Change* 77 (3): 355–368. https://doi.org/10.1016/j.techfore.2009.10.008.
Hendricks, K. B., and V. R. Singhal. 2003. "The Effect of Supply Chain Glitches on Shareholder Wealth." *Journal of Operations Management* 21 (5): 501–522. https://doi.org/10.1016/j.jom.2003.02.003.
Hendricks, K. B., and V. R. Singhal. 2009. "An Empirical Analysis of the Effect of Supply Chain Disruptions on Long-Run Stock Price Performance and Equity Risk of the Firm." *Production and Operations Management* 14 (1): 35–52. https://doi.org/10.1111/j.1937-5956.2005.tb00008.x.
Hudson, L. A., and J. L. Ozanne. 1988. "Alternative Ways of Seeking Knowledge in Consumer Research." *Journal of Consumer Research* 14 (4): 508–521. https://doi.org/10.1086/209132.
Ivanov, D., B. Sokolov, and A. Dolgui. 2014. "The Ripple Effect in Supply Chains: Trade-Off 'Efficiency-Flexibility- resilience' in Disruption Management." *International Journal of Production Research* 52 (7): 2154–2172. https://doi.org/10.1080/00207543.2013.858836.
Jurečka, P. 2013. "Strategy and Portfolio Management Aspects of Integrated Business Planning." *Central European Business Review* 2 (1): 28–34. https://doi.org/10.18267/j.cebr.36.
Jüttner, U. 2005. "Supply Chain Risk Management: Understanding the Business Requirements from a Practitioner Perspective." *The International Journal of Logistics Management* 16 (1): 120–141. https://doi.org/10.1108/09574090510617385.
Jüttner, U., H. Peck, and M. Christopher. 2003. "Supply Chain Risk Management: Outlining an Agenda for Future Research." *International Journal of Logistics: Research & Applications* 6 (4): 197–210. https://doi.org/10.1080/13675560310001627016.
Kara, A., J. E. Spillan, G. Acikdilli, and E. Kirkbesoglu. 2023. "Re-Evaluation of Logistics Strategy During COVID-19 Pandemic Environment: Reduced Customer Service Commitment." *Supply Chain Forum: An International Journal* 1–12. https://doi.org/10.1080/16258312.2023.2253522.
Kleindorfer, P. R., and G. H. Saad. 2005. "Managing Disruption Risks in Supply Chains." *Production & Operations Management* 14 (1): 53–68. https://doi.org/10.1111/j.1937-5956.2005.tb00009.x.
Klibi, W., and A. Martel. 2012. "Scenario-Based Supply Chain Network Risk Modeling." *European Journal of Operational Research* 223 (3): 644–658. https://doi.org/10.1016/j.ejor.2012.06.027.
Lechler, S., A. Canzaniello, B. Roβmann, H. A. von der Gracht, and E. Hartmann. 2019. "Real-Time Data Processing in Supply Chain Management: Revealing the Uncertainty Dilemma." *International Journal of Physical Distriution and Logistics Management* 49 (10): 1003–1019. https://doi.org/10.1108/IJPDLM-12-2017-0398.
Lee, W. Y., P. Goodwin, R. Fildes, K. Nikolopoulos, and M. Lawrence. 2007. "Providing Support for the Use of Analogies in Demand Forecasting Tasks." *International Journal of Forecasting* 23 (3): 377–390. https://doi.org/10.1016/j.ijforecast.2007.02.006.
Mady, M. T. 2000. "Sales Forecasting Practices of Egyptian Public Enterprises: Survey Evidence." *International Journal of Forecasting* 16 (3): 359–368. https://doi.org/10.1016/S0169-2070(00)00033-9.
Majid, M. A. A., M. Othman, S. Mohamad, S. A. H. Lim, and A. Yusof. 2017. "Piloting for Interviews in Qualitative Research: Operationalization and Lessons Learnt." *International Journal of Academic Research in Business and Social Science* 7 (4): 1073–1080. https://doi.org/10.6007/IJARBSS/v7-i4/2916.
Makridakis, S., and N. Taleb. 2009. "Decision Making and Planning Under Low Levels of Predictability." *International Journal of Forecasting* 25 (4): 716–733. https://doi.org/10.1016/j.ijforecast.2009.05.013.
Makridakis, S., S. C. Wheelrwright, and R. J. Hyndman. 1998. *Forecasting: Methods and Applications*. 3rd ed. New York: John Wiley & Sons.
Neuman, W. L. 2014. *Social Research Methods: Qualitative and Quantitative Approaches*. 7th ed. Essex: Pearson Education Limited.
Nikolopoulos, K. 2010. "Forecasting with Quantitative Methods: The Impact of Special Events in Time Series." *Applied Economics* 42 (8): 947–955. https://doi.org/10.1080/00036840701721042.
Nikolopoulos, K. 2021. "We Need to Talk About Intermittent Demand Forecasting." *European Journal of Operational Research* 291 (2): 549–559. https://doi.org/10.1016/j.ejor.2019.12.046.
Nikolopoulos, K., N. Bougioukos, K. Giannelos, and V. Assimakopoulos. 2007. "Estimating the Impact of Shocks with Artificial Neural Networks." *Lecture Notes in Computer Science* 4669:516–526.
Nikolopoulos, K., P. Goodwin, A. Patelis, and V. Assimakopoulos. 2007. "Forecasting with Cue Information: A Comparison of Multiple Regression with

Alternative Forecasting Approaches." *European Journal of Operational Research* 180 (1): 354–368. https://doi.org/10.1016/j.ejor.2006.03.047.
Nikolopoulos, K., A. Lista, F. Petropoulos, V. Bougioukos, and M. Khammash. 2015. "Relative Performance of Methods for Forecasting Special Events." *Journal of Business Research* 68 (8): 1785–1791. https://doi.org/10.1016/j.jbusres.2015.03.037.
Nikolopoulos, K., S. Punia, A. Schäfers, C. Tsinopoulos, and C. Vasilakis. 2021. "Forecasting and Planning During a Pandemic: COVID-19 Growth Rates, Supply Chain Disruptions, and Governmental Decisions." *European Journal of Operational Research* 290 (1): 99–115. https://doi.org/10.1016/j.ejor.2020.08.001.
Noor, K. B. M. 2008. "Case Study: A Strategic Research Methodology." *American Journal of Applied Sciences* 5 (11): 1602–1604. https://doi.org/10.3844/ajassp.2008.1602.1604.
Noy, C. 2008. "Sampling Knowledge: The Hermeneutics of Snowball Sampling in Qualitative Research." *International Journal of Social Research Methodology* 11 (4): 327–344. https://doi.org/10.1080/13645570701401305.
Oliver Wight International. (2012a). Managing Vulnerabilities and Opportunities with Integrated Business Planning. *Oliver Wight Paper Series*.
Oliver Wight International. (2012b). Transitioning from S&Op to IBP. *Oliver Wight Paper Series*.
Önkal, D., K. Z. Sayim, and M. S. Gönül. 2013. "Scenarios as Channels of Forecast Advice." *Technological Forecasting and Social Change* 80 (4): 772–788. https://doi.org/10.1016/j.techfore.2012.08.015.
Papadakis, I. S. 2006. "Financial Performance of Supply Chains After Disruptions: An Event Study." *Supply Chain Management: An International Journal* 11 (1): 25–33. https://doi.org/10.1108/13598540610642448.
Patton, M. Q. 2002. *Qualitative Research and Evaluation Methods*. 3rd ed. London: SAGE Publications Ltd.
Petropoulos, F., D. Apiletti, V. Assimakopoulos, M. Z. Babai, D. K. Barrow, S. Ben Taieb, and C. Bergmeir. 2022. "Forecasting: Theory and Practice." *International Journal of Forecasting* 38 (3): 705–871. https://doi.org/10.1016/j.ijforecast.2021.11.001.
Ponomarov, S. Y., and M. C. Holcomb. 2009. "Understanding the Concept of Supply Chain Resilience." *The International Journal of Logistics Management* 20 (1): 124–143. https://doi.org/10.1108/09574090910954873.
Preindl, R., K. Nikolopoulos, and K. Litsiou. 2020. "Transformation Strategies for the Supply Chain: The Impact of Industry 4.0 and Digital Transformation, Supply Chain Forum." *Supply Chain Forum: An International Journal* 21 (1): 26–34. https://doi.org/10.1080/16258312.2020.1716633.
Rice, J. B., and F. Caniato. 2003. "Building a Secure and Resilient Supply Network." *Supply Chain Management Review* 7 (5): 22–30.
Riley, J. M., R. Klein, J. Miller, and V. Sridharan. 2016. "How Internal Integration, Information Sharing, and Training Affect Supply Chain Risk Management Capabilities." *International Journal of Physical Distribution and Logistics Management* 46 (10): 953–980. https://doi.org/10.1108/IJPDLM-10-2015-0246.
Sanders, N. R., and K. B. Manrodt. 2003. "The Efficacy of Using Judgmental versus Quantitative Forecasting Methods in Practice." *Omega* 31 (6): 511–522. https://doi.org/10.1016/j.omega.2003.08.007.
Santoso, T., S. Ahmed, M. Goetschalckx, and A. Shapiro. 2005. "A Stochastic Programming Approach for Supply Chain Network Design Under Uncertainty." *European Journal of Operational Research* 167 (1): 96–115. https://doi.org/10.1016/j.ejor.2004.01.046.
Sarkar, A., and P. K. J. Mohapatra. 2009. "Determining the Optimal Size of Supply Base with the Consideration of Risks of Supply Disruptions." *International Journal of Production Economics* 119 (1): 122–135. https://doi.org/10.1016/j.ijpe.2008.12.019.
Sarkar, A., P. K. J. Mohapatra, A. Chaudhary, A. Agrawal, A. Mandal, and S. S. Padhi. 2012. "Single or Multiple Sourcing: A Method for Determining the Optimal Size of the Supply Base." *Technology Operation Management* 3 (1–2): 17–31. https://doi.org/10.1007/s13727-013-0013-6.
Saunders, M., P. Lewis, and A. Thornhill. 2016. *Research Methods for Business Students*. 7th ed. Essex: Pearson Education Limited.
Schoemaker, P. J. H. 1995. "Scenario Planning: A Tool for Strategic Thinking." *MIT Sloan Management Review* 36 (2): 25–40.
Schoemaker, P. J. H. 2004. "Forecasting and Scenario Planning: The Challenges of Uncertainty and Complexity." In *Blackwell Handbook of Judgement and Decision Making*, edited by Koehler, J. D. and N. Harvey, 274–296. Malden: Blackwell Publishing Ltd.
Schulte in den Bäumen, H., J. Többen, and M. Lenzen. 2015. "Labour Forced Impacts and Production Losses Due to the 2013 Flood in Germany." *Journal of Hydrology* 527:142–150. https://doi.org/10.1016/j.jhydrol.2015.04.030.
Sheffi, Y. 2001. "Supply Chain Management Under the Threat of International Terrorism." *The International Journal of Logistics Management* 12 (2): 1–11. https://doi.org/10.1108/09574090110806262.
Sheffi, Y., and J. B. Rice. 2005. "A Supply Chain View of the Resilient Enterprise." *MIT Sloan Management Review* 47 (1): 41–49. https://doi.org/10.1111/j.1055-6001.2005.04103005.x.
Simmers, C. S., R. Rast, A. D. Schaefer, and D. Hammons. 2023. "Risk Aversion Impacts on Need for Transparency and Traceability Pre- and Post-Pandemic, Supply Chain Forum." *An International Journal* 24 (4): 397–405. https://doi.org/10.1080/16258312.2022.2099759.
Singh, K. 2007. *Quantitative Social Research Methods*. New Delhi: SAGE Publications Ltd.
Skipper, J. B., and J. B. Hanna. 2009. "Minimizing Supply Chain Disruption Risk Through Enhanced Flexibility." *International Journal of Physical Distribution and Logistics Management* 39 (5): 404–427. https://doi.org/10.1108/09600030910973742.
Snyder, L. V., M. P. Scaparra, M. S. Daskin, and R. L. Church. 2006. "Planning for Disruptions in Supply Chain Networks." *Models, Methods, and Applications for Innovative Decision Making: INFORMS Tutorials in Operations Research* 234–257. https://doi.org/10.1287/educ.1063.0025.
Sodhi, M. S., C. S. Tang, and B.-G. Son. 2012. "Researchers ' Perspectives on Supply Chain Risk Management." *Production and Operations Management* 21 (1): 1–13. https://doi.org/10.1111/j.1937-5956.2011.01251.x.
Stecke, K. E., and S. Kumar. 2009. "Sources of Supply Chain Disruptions, Factors That Breed Vulnerability, and Mitigating Strategies." *Journal of Marketing Channels* 16 (3): 193–226. https://doi.org/10.1080/10466690902932551.
Sturges, J. E., and K. J. Hanrahan. 2004. "Comparing Telephone and Face-To-Face Qualitative Interviewing: A Research Note." *Qualitative Research* 4 (1): 107–118. https://doi.org/10.1177/1468794104041110.
Taleb, N. N. 2007. *The Black Swan: The Impact of the Highly Improbable*. 2nd ed. London: Penguin.

Tang, C. S. 2006. “Robust Strategies for Mitigating Supply chain disruptions.” *International Journal of Logistics: Research & Applications* 9 (1): 33–45. https://doi.org/10.1080/13675560500405584.

Tomlin, B. 2006. “On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks.” *Management Science* 52 (5): 639–657. https://doi.org/10.1287/mnsc.1060.0515.

Toor, T. P. S., and T. Dhir. 2011. “Benefits of Integrated Business Planning, Forecasting, and Process Management.” *Business Strategy Series* 12 (6): 275–288. https://doi.org/10.1108/17515631111185914.

Upadhyay, C. K., V. Tewari, and V. Tiwari. 2022. “Does Crowdsourcing Services Moderate Effect on Supply Risk Management Performance in COVID-19 Pandemic: Evidence from India.” *Supply Chain Forum: An International Journal* 1–16. https://doi.org/10.1080/16258312.2022.2090274.

Urquhart, C. 2013. *Grounded Theory for Qualitative Research: A Practical Guide*. London: SAGE Publications Ltd.

van Teijlingen, E., and V. Hundley. 2002. “The Importance of Pilot Studies.” *Nursing Standard* 16 (40): 33–36. https://doi.org/10.7748/ns2002.06.16.40.33.c3214.

Verbunt, M., A. Walser, J. Gurtz, A. Montani, and C. Schär. 2007. “Probabilistic Flood Forecasting with a Limited-Area Ensemble Prediction System: Selected Case Studies.” *Journal of Hydrometeorology* 8 (4): 897–909. https://doi.org/10.1175/JHM594.1.

Wagner, S. M., and C. Bode. 2006. “An Empirical Investigation into supply Chain vulnerability.” *Journal of Purchasing & Supply Management* 12 (6): 301–312. https://doi.org/10.1016/j.pursup.2007.01.004.

Wagner, S. M., and C. Bode. 2008. “An Empirical Examination of Supply Chain Performance Along Several Dimensions of Risk.” *Journal of Business Logistics* 29 (1): 307–325. https://doi.org/10.1002/j.2158-1592.2008.tb00081.x.

Wasko, C., and A. Sharma. 2017. “Global Assessment of Flood and Storm Extremes with Increased Temperatures.” *Scientific Reports* 7 (7945): 1–8. https://doi.org/10.1038/s41598-017-08481-1.

Wright, G., and P. Goodwin. 2009. “Decision Making and Planning Under Low Levels of Predictability: Enhancing the Scenario Method.” *International Journal of Forecasting* 25 (4): 813–825. https://doi.org/10.1016/j.ijforecast.2009.05.019.

Zhang, G., B. E. Patuwo, and M. Y. Hu. 1998. “Forecasting with Artificial Neural Networks: The State of the Art.” *International Journal of Forecasting* 14 (1): 35–62. https://doi.org/10.1016/S0169-2070(97)00044-7.

Zsidisin, G. A., and L. M. Ellram. 2003. “An Agency Theory Investigation of Supply Risk Management.” *The Journal of Supply Chain Management* 39 (2): 15–27. https://doi.org/10.1111/j.1745-493X.2003.tb00156.x.