International Transport Forum

Balancing Efficiency and Resilience in Multimodal Supply Chains

171 Roundtable

Summary and Conclusions

OECD

International Transport Forum

Balancing Efficiency and Resilience in Multimodal Supply Chains

Summary and Conclusions

171 Roundtable

OECD

The International Transport Forum

The International Transport Forum is an intergovernmental organisation with 59 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. The ITF is politically autonomous and administratively integrated with the OECD.

The ITF works for transport policies that improve peoples' lives. Our mission is to foster a deeper understanding of the role of transport in economic growth, environmental sustainability and social inclusion and to raise the public profile of transport policy.

The ITF organises global dialogue for better transport. We act as a platform for discussion and pre-negotiation of policy issues across all transport modes. We analyse trends, share knowledge and promote exchange among transport decision-makers and civil society. The ITF's Annual Summit is the world's largest gathering of transport ministers and the leading global platform for dialogue on transport policy.

The Members of the Forum are: Albania, Armenia, Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Chile, China (People's Republic of), Croatia, Czech Republic, Denmark, Estonia, Finland, France, Former Yugoslav Republic of Macedonia, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Mexico, Republic of Moldova, Montenegro, Morocco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Arab Emirates, the United Kingdom and the United States.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

ITF Discussion Papers

ITF Discussion Papers make economic research, commissioned or carried out in-house at ITF, available to researchers and practitioners. They describe preliminary results or research in progress by the author(s) and are published to stimulate discussion on a broad range of issues on which the ITF works. Any findings, interpretations and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the International Transport Forum or the OECD. Neither the OECD, ITF nor the authors guarantee the accuracy of any data or other information contained in this publication and accept no responsibility whatsoever for any consequence of their use. This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. Comments on Discussion Papers are welcome.

Cite this work as: McKinnon, A. (2018) "Balancing Efficiency and Resilience in Multimodal Supply Chains", *International Transport Forum Discussion Papers*, OECD Publishing, Paris.

Table of contents

Introduction

Over the past twenty years, supply chain resilience has become a hot topic in industrial, government and academic circles - for good reason. Business surveys and a mass of anecdotal evidence have revealed that supply chains have become more vulnerable to disruptions and the consequences of these disruptions become more severe. This has led many companies to conduct risk audits at a supply chain level and to adopt measures that minimise their exposure to supply chain risk and enhance their ability to recover if and when a supply chain failure occurs. Some of the more serious supply chain failures have attracted extensive media coverage sensitising the public and politicians to the subject. It has also become a fertile area of academic research and has generated a substantial literature. According to the Web of Science, the annual number of journal papers published on supply chain resilience rose from four in 2007 to around 150 in 2017[1].

Despite this attention and research efforts, many companies are still at an early stage in the development and implementation of supply chain risk management strategies. In the meantime, supply chain risk profiles have been changing as, among other things, climate change and cyber-crime have come to pose greater threats. Also, as supply chains have become more inter-connected and geographically expansive, the negative effects of disruptions, whatever their cause, can now spread much more widely and rapidly than before.

It is against this background that the ITF / OECD, in consultation with two of its member states (Canada and France), decided to organise a Roundtable to review current thinking on supply chain resilience, particularly as it relates to the movement of freight by different transport modes. It also wanted to explore an aspect of the subject that has not featured prominently in previous research and discussions, namely the three-way inter-relationship between resilience, efficiency and sustainability[2]. In an ideal world all supply chains would have minimal risk exposure, recover rapidly in the rare event of disruption and be fully sustainable in economic, environmental and social terms. Regrettably, in the real world companies often have to make difficult choices between these various supply chain performance criteria. The trade-off between resilience and economic efficiency has been much discussed and modelled but typically with little reference to sustainability. Interest in the environmental and social sustainability of supply chains has grown in recent years, particularly with respect to climate change and the safety and welfare of employees. It is increasingly important therefore to factor sustainability into discussions of supply chain risk, resilience and efficiency.

The Roundtable

The main purpose of the Roundtable was to examine ways of improving the inter-relationship between resilience, efficiency and sustainability in the management of multimodal supply chains. Four briefing papers were commissioned to review previous research on various aspects of the topic and highlight pertinent issues for discussion during the Roundtable. The first, by Professor Jean-Paul Rodrigue (2018), investigated the relationship between economic efficiency and sustainability in the development of multimodal supply chains. The second, by Professor Martin Christopher (2018), provided a detailed overview of the mitigation of risk and management of resilience in supply chains. The other two papers focused on developments likely to facilitate more effective co-ordination of resilience, efficiency and

sustainability objectives. One, by Professor Lori Tavasszy (2018), addressed the impact of innovation and new technology, while the other by Professor Ruth Banomyong (2018) explored the contribution that collaboration between supply chain partners can make to improved outcomes across the three dimensions.

A total of 35 specialists from 17 countries participated in the Roundtable which was held in Paris on the 12th and 13th April 2018. An introductory presentation was given by Dr. Igor Linkov on 'planning for efficiency, risk and resilience in supply chains' drawing initially on military experience and practices but then adopting broader transport planning and business perspectives on the subject. The authors of the four briefing papers also gave short summary presentations. Each of the presentations was followed by a Q&A session which broadened out into a wider discussion of related issues. These basically addressed four issues:

How can efforts to improve the economic efficiency, resilience and sustainability of supply chains be more closely aligned?

What are currently the main conflicts between supply chain efficiency, resilience and sustainability goals?

To what extent can enablers such as new technology, supply chain collaboration and intermodality help to reconcile these conflicting pressures?

What role, if any, should government play in balancing supply chain efficiency, resilience and sustainability objectives?

Multimodality and connectivity

Globalisation has substantially increased the number of nodes and links in supply chains. The associated fragmentation of value-adding processes has resulted in value being added incrementally in many more locations and more movement of products between these locations, much of it across international borders. The average distance between the nodes at which products are processed, assembled, customised, stored and handled has also substantially increased. Other things being equal, this increase in the length and complexity of supply chains is likely to have increased their vulnerability. However, other things have not been equal, however. The locations through which many of the chains are now routed are inherently more risky because of their climate, geophysics, political instability, poor infrastructure, etc. Much more of the freight has to cross international frontiers where it can be held up, sometimes for several days, by administrative procedures. The globalisation of supply chains has also increased companies' dependence on multimodality as no single transport mode can handle the end-to-end journey. This introduces another set of risk factors associated with the co-ordination of the different modes and the physical transfer of the goods between vehicles, vessels and aircraft.

These intermodal transfers are taking place at a smaller number of larger hubs as logistics providers move to hub-satellite systems and as the latest generation of ships and aircraft have outgrown many existing ports and airports. While concentrating investment in hubs and consolidating flows on the routes connecting them makes good economic sense it also alters supply chain risk profiles. As the hubs

have become points of convergence for tens of thousands of separate supply chains any disruption to their operation can have a huge economic and social impact over a wide area. The centralisation of logistics capacity has been one of the main trends increasing the vulnerability of supply networks.

On the other hand, if used effectively, multimodality and intermodality can improve supply chain resilience by giving carriers and shippers more modal options when disaster strikes. If only one modal network or service is disrupted, it may be possible to divert traffic to another at short notice, particularly where the principles of synchromodality have been applied. The greater the inter-connectivity between different modal networks the more robust should be the supply chains using them. A Dutch study has modelled the relationship between the density of links in transport networks and the degree of network resilience.

Delegates noted, however, that much more could be done to improve cross-modal inter-connectivity. It was suggested, for example, that the nine inter-modal corridors that the EU has established as part of its Trans-European Transport Network (TEN-T) programme could be more closely integrated. Linking these corridors at strategic locations could create a 'real network'. Inter-connection does not simply entail increasing the number of physical links and modal interchanges. It can also involve improving the inter-operability of the vehicles, handling equipment and IT systems on different networks, something the European Commission (EC) has been prioritising for many years. Inter-operability is not only defined in technical terms; it can also involve regulatory, organisational and infrastructural modifications. This can be a slow and difficult process, however, as exemplified by the standard dimensions of ISO containers which although less than ideal for particular types of freight traffic and transport operations are now fairly immutable. This was presented as a form of 'path dependency' where standards set at an early stage in the development of a new system become locked-in and constrain future efforts to improve system performance, possibly with respect to resilience, efficiency and sustainability. Learning from past experience, care should be taken when establishing the ground rules for new logistics systems, such as the Physical Internet (PI) (discussed p. 16), building in flexibility and resilience from the start.

Supply chain risk and resilience

The adoption of what were, and still are, deemed to be good business practices such as the wider sourcing of supplies, single-sourcing, just-in-time replenishment and centralisation has made supply networks more vulnerable over a period when the world has become a more dangerous place. Various surveys have revealed that the frequency and intensity of a range of natural disasters is increasing, while geopolitical, cyber and financial threats are also multiplying. The negative impacts on company supply chains have been regularly monitored by Business Continuity Institute (BCI) / Zurich and others for many years. According to this empirical evidence there is little sign of the situation improving, despite the fact that there have now been over twenty years of research on supply chain risk and resilience and numerous business campaigns to alert companies to the damaging effects of supply chain disruptions. Some companies may not be getting the message, but many others are aware of the issue and know what needs to be done, but are still wedded to business models that are, in supply chain terms, intrinsically risky. Many businesses are still firmly committed to the 'lean' management of production

and logistics operations, despite numerous examples it constraining their ability to respond to disruptions.

Over the past couple of decades, other trends have complicated the management of supply chains while extending the economic impact of any interruption to freight flows. Supply chain processes have been complicated by increases in the degree of product customisation, with more goods being made to order and having to be delivered to specific customers. In some sectors the process of 'servitisation' is linking products to a broader range of value-adding services, strengthening the connection between the physical flow of goods and an array of service activities. Disruption of that flow can cause negative impacts to ripple across the service sector.

Some of the participants at the roundtable characterised the situation today as a "VUCA era" characterised by volatility, uncertainty, complexity and ambiguity. This acronym, first used over thirty years ago, neatly encapsulates the challenges facing companies endeavouring to make their supply chains less risky and more resilient. Many economic and physical systems with a global reach are becoming more unstable and less predictable. There is increasing uncertainty about future trends in a range of variables that directly impact on supply chains, such as energy prices, trade liberalisation, currency exchange rates and weather conditions. Nor is there an historical precedent for many of the recent developments which, individually and collectively, have been dislocating supply networks. In the case of climate change, for example, the World Meteorological Organisation (WMO) concedes that '*we are now in truly uncharted territory*'.

Most of the risk to which businesses are exposed is systemic and comes from external sources mostly within their supply networks. Much supply chain risk emanates from upper tiers of supplier with which the company has no direct connection and of which it has little knowledge. Supply chain risk audits often do not extend this far upstream, leaving companies reliant on the risk management and resilience strategies of the tiers immediately above them in the chain. According to the old proverb, a chain is only as strong as its weakest link. This link can be far back along the chain but sometimes lie in a 'critical path' that cannot be duplicated or diverted in the short term. Examples were quoted of firms in the computing and automotive sectors not 'looking beyond first-tier suppliers' and having inbound supplies of vital components disrupted at upper tiers. They demonstrate the need for risk transparency and co-ordinated action across the whole supply chain, though in world of complex multi-dimensional supply networks both can be very difficult to achieve.

This difficulty is often compounded by suppliers' unwillingness to disclose sensitive information about their risk exposure to potential customers as this can jeopardise their chances of securing and retaining contracts. Securing the necessary degree of openness and honesty in the sharing of risk data requires high levels of trust and mutual support which take significant time and management to establish. It is hard to incentivise companies to invest this time and effort when they are preoccupied with short term commercial pressures and often perceive the risks of serious disruption to be low. Several delegates referred to companies having to 'learn the hard way' by actually suffering a supply chain failure. Rather perversely, a major incident which paralyses a whole supply network and adversely affects a great many businesses might therefore yield a longer term benefit if it catalyses wider adoption of risk management principles. This, however, is a costly way of getting the business world to devote enough time, effort and money to securing supply networks.

How, too, should we define the term 'enough' in this context. This is where potential trade-offs with other business goals relating to economic efficiency and sustainability become relevant. The next three sections summarise views expressed during the Roundtable on the three sets of trade-offs between resilience and efficiency, efficiency and sustainability and resilience and sustainability.

Trade-off 1: Resilience-efficiency

There was wide agreement that in the management of supply chains, there is an inverse relationship between economic efficiency and resilience. Analysis of the relationship between traffic flows and resilience on the road networks of major US cities has also shown that in a transport planning context '*resilience and efficiency are not correlated*'.

Central to the resilience-efficiency trade-off in business is the management of inventory. For several decades, companies have been driving down inventory levels, partly to reduce working capital and related financing costs, but also to exploit a range of co-benefits, including higher productivity, improved product quality and lower space requirements, etc. Inventory has come to be regarded as a form of waste that needs to be minimised. As a result its important role as a buffer against supply chain disruptions has often been under-valued, something that companies discover to their cost when the inbound flow of supplies is interrupted. One delegate explained that companies need to determine the 'right' rather than 'minimal' amount of inventory taking account of such eventualities. The term '*agility*' is now widely used to describe this more cautious and holistic approach to inventory management. It not only offers greater protection against downside risks; it also allows companies to take advantage of 'upside' risks such as an unexpected surge in demand. Under these circumstances inventory can become a '*force for good*'.

Another key variable in the resilience-efficiency trade-off is capacity. In response to cost-cutting pressures managers have also been scaling down capacity, but this also reduces the amount of slack in supply chains. This can deprive companies of the 'headroom' they need to build up inventory and production levels in anticipation of a supply chain disruption or to accommodate a surge in demand.

Professor Christopher (2018) in his briefing paper argues that what companies need is '*structural flexibility*', in other words '*the ability to quickly change the shape of a supply / demand network*'. This has a whole series of pre-requisites or enablers: the right corporate mind-set, close collaboration with supply chain partners, supply chain visibility, access to capacity, access to knowledge / talent, inter-operability of processes and IT systems and '*network orchestration*' (i.e. the co-ordination and synchronisation of activities across the supply network). This is in keeping with a move from the traditional '*plan and execute*' approach to supply chain management to a more flexible '*sense and response*' approach. Planning inventory levels and capacity in accordance with the principles of structural flexibility should help companies to achieve a superior trade-off between efficiency and resilience, effectively '*pushing out the efficiency-resilience frontier*'. This frontier is steadily moving to the right as a result of advances in information and communication technology (ICT). It has long been acknowledged that companies can '*substitute information for inventory*' as more rapid updating supply chain data reduces the need for safety stock. With the deployment of advanced ICT and real-time data sharing across a supply chain, it may be possible to reduce inventory levels while increasing resilience, gaining essentially '*the best of both worlds*'. This led some delegates to argue that resilience and efficiency goals could be reconciled, avoiding the need for trade-offs.

In placing greater emphasis on resilience companies should guard against returning to the sloppy inventory management practices of the past. Inventory still needs to be rigorously controlled to ensure that any increase is justified by the supply chain risk and resilience benefits it brings. Quantifying these benefits involves identifying disruptive supply chain events, estimating their probability of occurrence and assessing and costing their potential impact on the business. This is not an easy task, particularly in

the case of high impact low probability (HILP) events which occur so rarely that it is not possible to construct probability distributions for them. Analysis has then to rely heavily on expert judgement.

Trade-off 2: Efficiency-sustainability

As supply chain objectives sustainability and efficiency, unlike resilience and efficiency, were seen to be closely aligned. They are not being accorded equal importance, however. Economic efficiency is again the key driver, with sustainability in a subordinate role. Environmental sustainability was variously described as a 'by-product of', 'contingent upon' and 'derived from' improvements in supply chain efficiency. Efficiency improvements which cut energy consumption typically result lower emissions. The main motivation may be the reduction in energy costs but this yields an environmental co-benefit. Reference was made to companies rather hypocritically claiming credit for greening their operations and supply chains when the dominant motive for the changes was commercial. The slow steaming of container ships since 2008 was cited as an example of a measure implemented primarily to cut costs and yet often portrayed by shipping lines as mainly a fuel- and CO_2-reducing initiative.

This close correlation between improvements to efficiency and environmental improvement suggests that there is no need to trade-off these variables. Where internal and external costs can be simultaneously reduced, the challenge is to decide which environmental initiatives offer the highest net return once financial and environmental cost reductions have both been factored into the calculation. This observed alignment of economic and environmental objectives requires two qualifications however.

First, it is far from complete. It is not difficult to find examples of efficiency and sustainability goals in conflict. The pressures of just-in-time replenishment, a major cause of supply chain vulnerability, also carry an environmental penalty where they depress vehicle load factors thereby increasing vehicle-kms, fuel consumption and emissions for a given amount of freight movement. Minimising procurement costs by sourcing supplies from low labour cost countries greatly increases the distances over which goods are moved generally to the detriment of the environment.

Second, the close alignment may only be temporary. Harvesting all this so-called '*low hanging fruit*' may not yield the required level of environmental improvement. In terms of climate change mitigation, it will not reduce logistics-related emissions by amounts consistent with the limit on global temperature increases set by the 2015 Paris Accord. At some point, therefore, companies may have to sacrifice economic performance, measured by profit margins, return on assets etc., to meet environmental imperatives, many of which may have to be enforced by government regulation or the internalisation of environmental costs by user charging, taxation or emissions trading.

There was some disagreement over the amount of low hanging fruit still available to logistics and supply chain managers. Some delegates felt that it was largely exhausted, while others felt that there was much more to be exploited. It is clearly difficult to generalise about this issue as the situation will vary by sector, geography, the size and type of business etc. The boundary between self-financing green measures and those incurring a net cost is also constantly shifting with the development of new technology, IT solutions and business practices. In addition, supply chain collaboration can open up new

'orchards' of low hanging fruit for companies already 'maxing out' logistics efficiency internally and willing to share their logistics assets.

The impact of environmental certification and environmental management programmes on the relationship between efficiency and sustainability was also discussed. Within a supply chain certification can take various forms. For example, the certification / labelling of products and suppliers can help to 'green' procurement operations while various schemes exist to rate the environmental performance of logistics providers, such as SmartWay in the US. Important differences exist between certification schemes / standards enforced by regulation and those adopted voluntarily. Overall both types of scheme have significantly improved the sustainability of supply chains in environmental and social terms, though they have not always done so in the most economically efficient way. No similar rating schemes exist for the comparative resilience of logistics services.

The circular economy was described as an '*emergent paradigm'* offering the potential to transform many supply chains, though it will demand quite radical behavioural change on the part of businesses and consumers. To recapture a much higher proportion of the value in end-of-life products, supply chains will have to be substantially reconfigured. Research suggests that this would yield large economic and environmental benefit, some of it accruing from the shortening of supply lines, a trend that should also increase supply chain resilience.

Trade-off 3: Resilience-sustainability

Of the three trade-offs, this one has received the least attention and research. One might infer that if there is a positive correlation between environmental sustainability and economic efficiency and an inverse one between efficiency and resilience, then sustainability and resilience must also be inversely related. Such an inference would over-simplify what is in practice a fairly complex inter-relationship. As mentioned above, efficiency-driven practices like just-in-time (JIT) and global sourcing are usually detrimental to the environment. Curbing or reversing them would simultaneously enhance resilience and sustainability, suggesting close alignment between these objectives.

It also depends on how the term sustainability is defined. As discussed in the Annex, environmental sustainability has both mitigation and adaptation dimensions, particularly with respect to climate change. Among sustainable supply chain specialists, mitigation is currently the dominant concern, though as extreme weather events multiply it is likely that interest in the adaptation of supply chains to climate change will grow. In many parts of the world, the climate-proofing of transport infrastructure is already underway, though the adaptation of supply networks to the direct and indirect effects of climate change is still at an early stage. The main goals of this adaptation will be to minimise exposure to climate-related risk and maximise resilience in the event of a weather-induced disruption. These goals are perfectly aligned with objective of improving supply chain resilience.

The impact of environmental mitigation measures on supply chain resilience is more variable. These measures fall into several categories:

Shifting freight to greener transport modes: in principle spreading freight flows between modes and reducing their dependence on any particular mode should spread the risk of disruption. Effective use of intermodality and synchromodality should also facilitate modal transfers at short notice improving the overall resilience of a supply network. If, however, greener modes, such as rail and waterborne services, are inherently less reliable becoming more dependent on them will increase the probability of disruption. For example, modal infrastructures differ in their relative vulnerability to different forms of extreme weather.

Improving vehicle, vessel and aircraft utilisation: where freight is consolidated in a smaller number of journeys made by more fully laden vehicles, the supply chain impact of a single vehicle being delayed would be greater. On the other hand, as discussed earlier, easing the JIT pressures that tend to fragment freight deliveries is likely to have a greater beneficial effect on the supply chain resilience overall.

Increasing energy efficiency: several measures which raise fuel efficiency in the road freight sector, such as improved driver training, preventative maintenance and the aerodynamic profiling of vehicles, also bring risk and resilience co-benefits. There is evidence too that the slow-steaming of container shipping, which has proved an effective means of cutting fuel and emissions, has reduced transit time variability in maritime supply chains, though this needs to be more fully researched.

Switching to greener energy sources: in the logistics sector this is being done mainly by electrification with cleaner, lower carbon electricity and the use of biofuels. Electrification exposes much more of the freight transport sector[3] to risks associated with the generation and transmission of electricity, such as power outages at electrical generating plants and damage to power lines. Highway trials are currently underway in Sweden to test the reliability of powering 'trolley trucks' with electricity drawn from overhead catenary. The robustness of the biofuel supply chain, relative to that of conventional diesel, depends on where the raw materials are sourced (e.g. palm oil from the Tropics or locally sourced rape seed) and the nature of the industry supplying them. The net effect of the repowering of logistics operations with cleaner, low carbon fuels on supply chain risk and resilience has still to be fully investigated.

Metrics

The modelling and management of these three trade-offs is frustrated by the lack of a common metric. Efficiency is extensively and rigorously measured using a suite of operational and monetary indicators. The environmental impacts of supply chain activities are typically assessed in terms of emission levels, waste, accidents, frequency of non-compliance with regulations etc. Monitoring of supply chain resilience is much less common and uses variables such as probability of disruption and average recovery time, though cost impacts may also be calculated.

If efficiency, sustainability and resilience are all to be measured against a common metric, than the obvious candidate is money. Efficiency is already expressed in monetary terms. Numerous studies have investigated the monetary valuation of environmental effects and directories exist, mainly for the benefit of public policy-makers, which quote monetary values for transport externalities. Recent studies have

indicated carbon prices consistent with the COP21 climate change agreement and many companies are already factoring shadow prices at these levels into their investment appraisal.

The monetising of resilience presents a more formidable challenge. For businesses that have already experienced a supply chain failure, it should be possible to collect *ex post* data on additional costs incurred, lost sales, share price devaluations etc. Some of the direct monetary impacts can easily be calculated; others such as the erosion of customer loyalty are clearly more difficult to quantify. As the economic consequences of disruptions can diffuse quite widely across supply networks, care must be taken when drawing a boundary around the calculation. Where a company is in the fortunate position of not having experienced a serious supply chain disruption, monetary estimates would have to be calculated on an ex-ante basis, possibly with reference to publicly availability data based on other companies' experiences. Multiplying estimates of the cost of various levels of supply chain disruption by estimates of the probability of occurrence can give companies a sense of their impact on the balance sheet. This cost data can then be set against the cost of investing in risk mitigation and resilience measures.

The Roundtable also considered the possible use of government transport data to calibrate the modelling of supply chain resilience. Transport Canada, for example, collects data on the 'fluidity' international freight movements, tracking transit time variability on particular routes. Pooling similar data across several countries might offer a means of measuring the performance of international supply chains at a macro-level.

Impact of collaboration

The critical importance of collaboration has been recognised since the early days of supply chain risk management. All companies in a supply chain are exposed to risk. Disruptive events can occur at any point in the chain and their impact is seldom confined to a single node or business. The prospect of adverse effects cascading across the chain gives all its members a vested interest in working together. By collaborating, companies can gain awareness of potential upstream and downstream risks, try collectively to minimise these risks and co-ordinate contingency planning to improve the resilience of the supply chain as a whole. According to the literature, the success of such a collaboration depends on five things: trust, a willingness to share data, co-ordinated planning, recognition of mutual interdependence and a fair distribution of the resulting benefits.

The absence of one or more of these conditions may partly explain the limited development of supply chain collaboration. In most industries it is still the exception rather than the rule, despite a long history of initiatives extolling the virtues of collaborative working. Where collaborative relationships have been established this has been done more for commercial reasons than to co-ordinate the management of risk and resilience or to improve sustainability. Once such a relationship is in place, however, it can form the basis for joint planning of resilience and sustainability initiatives. Sometimes it takes a supply chain failure to make companies realise the closeness of their inter-dependence and/or their joint exposure to the same systemic risks.

Delegates reported numerous supply chain collaboration success stories in the business world (e.g. in the case of an Italian food manufacturer), across the public sector (e.g. in a relief effort following the Chilean earthquake) and involving the public and private sectors (e.g. following the Thai floods). The humanitarian logistics sector contains good examples of public and private agencies working together to manage flows of life-saving products in high-risk environments. It was suggested the commercial world of logistics might learn useful lessons from this sector.

Discussions of risk and resilience issues tend to focus on supply chain collaboration in a vertical sense, examining how different tiers of producer, wholesaler and logistics provider can work together. In the field of supply chain sustainability there is greater interest in horizontal collaboration between companies at the same level in a supply chain. There have, for example, been some celebrated European examples in recent years of manufacturers in the fast moving consumer goods sector sharing vehicles, and in some cases warehousing, to improve vehicle fill and thereby reduce energy use and emissions. An integration of the resilience and sustainability agendas might promote greater supply chain collaboration in both vertical and horizontal dimensions. As explained in section 4, the concept of a two-dimensional supply network now more accurately reflects the complex pattern of business relationship and freight flows than the traditional concept of a linear supply chain. Companies should be looking horizontally as well as vertically for possible partners when forging new collaborations to manage risk and resilience.

Despite the slow development of supply chain collaboration to date, delegates expected it to significantly expand and evolve in future decades. Indeed, this would have to happen for logistics to achieve the necessary reductions in CO_2 emissions. Worsening of the VUCA conditions, outlined earlier, would also encourage companies to work more closely together. The legal basis for supply chain collaboration has been clarified in Europe and elsewhere, easing the fears of some businesses that it might infringe competition laws. Advances in ICT are also promoting collaboration by greatly reducing transaction costs, facilitating data sharing and encouraging the development of new digital business models. These advances are discussed in the next section.

Impact of technical innovation

There was general consensus that technical innovation was helping businesses to achieve superior trade-offs between resilience, efficiency and sustainability. To use the earlier terminology, this was '*pushing out the frontier'* for each of these trade-offs. In the course of the discussion reference was made to a variety of new technologies but the ones considered to be the most influential were those associated with ICT. They were said to be *'redefining the interface between the physical and digital worlds*' and fundamentally transforming the management of supply chains. Big data, cloud computing, the Internet of Things (IoT), artificial intelligence (AI), predictive analytics, crowdsourcing platforms, etc. are greatly increasing supply chain visibility and giving companies new tools to plan, manage and optimise their supply chain operations. There was optimism that the combined effect of these developments would be to make supply chains more efficient, resilient and sustainable.

Digitalisation, which was portrayed as a collection of 10 mini-ICT revolutions, is also transforming the logistics services market allowing new entrants to shake-up the traditional freight forwarding business.

This was proving economically beneficial in reducing freight rates, but could bring environmental and resilience disbenefits further down the line. Lower transport costs could reinforce freight traffic growth making it harder to meet emission reduction targets; while a further squeezing of margins in already commercially vulnerable sectors of the freight market, such as container shipping, might push more carriers into bankruptcy. The aftermath of the Hanjin shipping line collapse in 2019 provides a salutary lesson on how damaging this can be to global supply chains.

Under the innovation heading, frequent reference was made to possible supply chain applications of blockchain, though no clear consensus emerged on its likely impact on supply chain resilience. Opinions ranged from a claim that it was being seriously over-hyped to a suggestion that it would be game-changing.

The more optimistic view was that by offering a new, secure, low-cost, standardised means of exchanging large amounts of supply chain data, blockchain would eliminate paper-based processes that have been a traditional source of delay and create much-needed visibility for the management of risk and resilience. It may also facilitate carbon auditing at a supply chain level.

The wider economic impact of new technologies, many considered to be part of a *4th Industrial Revolution*, will have supply chain implications. For example, factory automation and the development of new forms of additive manufacturing may promote the reshoring of production operations to Europe and North America. The resulting compression of supply chains would make them more efficient, less environmentally damaging and less-risk prone – a win-win situation. The rapid growth of business-to-consumer (B2C) e-commerce is also causing a dramatic restructuring of supply chains within urban areas. This is currently proving a very fertile area for innovation with new transport modes (e.g. drones and droids), new business models (e.g. crowdshipping and 'Uberization'), new fulfilment options (e.g. lockerbanks and click-and-collect) and new land use patterns (e.g conversion of shopping malls to distribution centres) transforming city logistics. 'Last mile logistics' was identified as an important topic for future research on the relationship between efficiency, resilience and sustainability.

Although ICT-related innovations dominated the discussion of innovation, reference was also made to new forms of logistics hardware. In addition to drones and droids, there is the hyperloop, airships, platooning, autonomous trucks and catenary-powered electric trolley trucks, all of which have a different risk profile to most of the freight vehicles used today. Materials handling operations within factories and warehouses are also undergoing major changes as levels of mechanisation and automation increase and new modularised forms of handling equipment are implemented. The increasing degree of automation across supply chains may help to ease one major threat – namely the shortage of skilled logistics staff. This is now particularly acute in the road haulage sectors of countries, such as the US, Germany, the UK, France and Brazil, where a shortage of truck drivers is beginning to impair supply chain performance.

The Roundtable briefly discussed the prospects of a Physical Internet (PI) being established over the next few decades. This would be a physical manifestation of the digital internet (DI) operating on similar principles of open access, shared use of assets, standardised 'packaging' and decentralised control. This was seen a long term vision of the development of logistics. If it proves to be practical and workable, it could be an effective means of reconciling the objectives of efficiency, sustainability and resilience.

Role of government

Views expressed during the Roundtable on this issue can be briefly summarised as follows: governments have a critical role to play in improving supply chain resilience but do not always exercise it very effectively. They can exert influence on resilience in various ways: through general risk monitoring and contingency planning at a national level; the planning, funding and management of transport infrastructure; their responsibility for emergency, security and law enforcement services; consultation with business on strategic threats. Governments vary in their preparedness for dealing with disruptions to key supply chains delivering products such as food, fuel and medical supplies. They also vary in their ability to deal with supply chain crises while they are in progress and to learn the appropriate lessons after the event. Some governments were accused of being themselves a major source of uncertainty and disruption. Short term changes in policy, regulation and taxation can frustrate the smooth running of supply chains. Current uncertainties about the Brexit settlement, for example, have become a major source OF consternation for companies heavily dependent on UK-EU supply links.

In their defence, governments can find it difficult to decide how much slack or redundancy to build into infrastructure and public services to enhance their resilience. Factoring resilience into the appraisal of an infrastructural investment is analytically challenging. There must, after all, be some sharing of risk between infrastructure providers and users. Where these users are moving freight, the management of supply chain risk becomes relevant. For example, a company operating a lean supply chain with minimal inventory and very short order lead-times expects the infrastructure provider to invest sufficiently in capacity and weather-proofing to keep freight services operating reliably all year-round. As extreme weather events become more frequent and intense and infrastructural weather-proofing becomes more costly, business users could be expected to relax their schedules and hold more inventory at certain times of the year to carry some of the risk burden. In the case of other threats, such as cyber crime, the expectation is that government and business will jointly try to manage the risk.

The efficiency and resilience of international supply chains partly depends on governments' management of national borders. Border checks and customs controls have traditionally been a major source of delays within these supply chains. Major advances are currently underway in trade facilitation following ratification of the 2013 Bali agreement which should translate into improved supply chain resilience.

Generally speaking, governments could work more closely with businesses to assess the exposure of critical supply chains to disruption and prepare joint contingency plans.

Conclusions

Supply chain resilience has been much researched, written-about and discussed for many years but many supply chains remain relatively fragile and would take a long time to recover from a major disruption. Many companies and governments are still not doing enough to monitor changing supply chain risk profiles and to update their contingency planning. Organisations such as the ITF have a key role to play in keeping risk and resilience high on the agenda of senior executives and public policy makers.

The Roundtable extended previous discussion of the subject into a closer examination of the trade-offs between resilience, efficiency and sustainability. The title of the event referred to the 'balancing' of these objectives, suggesting that they might be given equal weight. In practice, their relative weighting has to vary in the light of economic and operational circumstances, making the term 'trade-off' more appropriate. Much of the discussion focused on factors affecting the three-way trade-off. There was general agreement that the trade-offs between resilience, efficiency and sustainability could be enhanced and would be raised to an even higher level if companies across the supply chain were prepared to collaborate to a greater extent. It was also felt that a range of technical and business innovations could help companies more effectively reconcile the three objectives and in some cases avoid the need for trade-offs.

In the course of the discussions, several topics were identified as important areas of future research. These included the inter-relationship between supply chain resilience and sustainability, particularly as it relates to climate change; the contribution that blockchain can make to improving supply chain resilience; the interaction of resilience, efficiency and sustainability at the front end of the supply chain where the growth of online retailing is transforming city logistics; and the net effect on supply chain resilience of transferring freight to intermodal services.

Notes

1 This still represented only 2.5% of journal papers published on supply chain topics in 2017. Statistics quoted in presentation delivered at the Roundtable by Dr. Igor Linkov entitled 'Planning for Efficiency, Risk and Resilience in Supply Chains'.

2 Sustainability was not in the original title of the Roundtable though was covered in one of the briefing papers and generated a significant amount of discussion during the event.

3 Beyond the sections of rail network already electrified and the use of electric vans in urban areas.

References

Banomyong, R. (2018), "Collaboration in Supply Chain Management: A Resilience Perspective", Discussion Paper, International Transport Forum, Paris.

Christopher, M. (2018), "Risk Mitigation in Resilient Supply Chains", Discussion Paper, International Transport Forum, Paris.

Rodrigue, J.P. (2018), "Efficiency and Sustainability in Multimodal Supply Chains", Discussion Paper, International Transport Forum, Paris.

Tavasszy, L. (2018), "Innovation and Technology in Multimodal Supply Chains", Discussion Paper, International Transport Forum, Paris.

Annex: Definitions

At an early stage in the proceedings one delegate declared that '*terminology in this field is a mess'* as key terms are open to differing interpretations. It was important therefore to clarify the definitions of some of the technical terms that were much used during the Roundtable discussion.

A **supply chain** can be conceived in physical terms as a linear sequence of nodes and links connecting raw material sources or point of productions with customer locations. It can be viewed in organisational terms as the sequence of companies through which the ownership of products is transferred and value is added. The word 'supply' gives the impression that the product flow is driven by upstream processes, whereas in reality goods are increasingly being pulled along the chain by the force of consumer demand. As chains have become more demand-responsive the expression **demand chain** has become more widely used. These traditional uni-dimensional views of products moving along chains are also being replaced by the concept of a **supply network** composed of many inter-linked supply chains. This concept is particularly relevant to the discussion of risk and resilience because, such is the degree of inter-connectivity in modern economies that the adverse effects of disruptions spread horizontally across supply networks as well as up and down the vertical logistics channel.

The Oxford Dictionary definitions of risk and resilience were considered to be quite clear and concise and applicable to supply chain management. **Risk** is a '*situation involving exposure to danger or a threat*'. **Resilience** is the '*capacity to recover quickly from difficulties'*, in other words the ability to recover rapidly from a disruption and rapidly restore a system to its original state.

Efficiency was defined as '*achieving maximum productivity with minimum wasted effort*'. Productivity in turn is generally considered to the ratio of outputs to inputs, in other words the amount of economic benefit obtained from each unit of resource expended, be that labour, energy, equipment, materials etc.

Sustainability is now widely considered to have environmental, social and economic dimensions. This is reflected in the UN's 17 'Sustainable Development Goals' (SDGs) declared in 2015. For the purposes of the Roundtable, economic efficiency was considered a separate goal, allowing delegates to relate sustainability more narrowly to the environmental and social impacts. The environmental aspects featured much more prominently in the discussion than the social ones. Of the range of environmental externalities considered by the group, climate change received the greatest attention mainly because it influences the critical supply chain trade-offs from different directions. **Climate change mitigation**, i.e. efforts to reduce carbon emissions from supply chains, now dominates the sustainability agenda in many countries and businesses, but climate change is also a major risk factor for supply chains and will require their **adaptation** to more extreme weather conditions and rising sea-levels.

There has been a proliferation of terms containing the word 'modality', including multimodality, intermodality, co-modality and sychromodality. **Multimodality**, the expression used in the title of the Roundtable, is the most general and simply means the use of different transport modes in a supply chain. The EU's expression **Co-modality** also has a similar meaning. **Intermodality** refers to the use of different transport modes on a single freight journey, while **synchromodality** (or '*synchronised intermodality*') involves scheduling the services provided by various transport modes to minimise the end-to-end transit time In some countries, the Netherlands for example, we have seen an evolution in the focus of logistics planning from multimodality to intermodality to synchromodality

International Transport Forum

Balancing Efficiency and Resilience in Multimodal Supply Chains

This report examines how efficiency and resilience can be balanced in the management of multimodal supply chains. It investigates the trade-off between supply chain resilience and efficiency, the approaches to sustainability in supply chain management, innovation and technological development, collaboration and alliances and risk mitigation. The report summarises findings from an ITF Roundtable held in April 2018.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
+33 (0)1 45 24 97 10
contact@itf-oecd.org
www.itf-oecd.org