Resilient Agility Under the Practice-Based View

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Abstract

Researchers must understand how agile and resilient practices work together as 'resilient agility' in impacting performance and seek empirical support. In this research, a conceptual model of 'resilient agility' is proposed using three constructs of operational practices -- 'agile-only', 'resilient-only', and 'shared' practices –and four constructs of performance: 'cost', 'delivery', 'flexibility', and 'time to recovery'. The practice bundles are then linked to appropriate performance objectives using the literature and the practice-based view. Finally, the conceptual model was tested using data from a survey of Tier-1 suppliers to auto manufacturers in Iran. Confirmatory factor analysis (CFA) was used for the measurement model and structural equation modelling (SEM) for the structural model to link agility and resilience to performance. The SEM results showed several significant links in the structural model, suggesting how agility and resilience work together to achieve desired performance objectives. Researchers will find this research helpful in building mid-range theory tying practices associated with resilient agility to operational performance.

Keywords: Agility; resilience; operational practices; performance objectives; structural equation modelling; auto industry.

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1. Introduction

COVID-19 has shown the need for supply chain agility and resilience for businesses to survive (Chopra, Sodhi, & Lücker, 2021; Schatteman, Woodhouse, & Terino, 2020). For instance, Spanish apparel manufacturer Zara, the poster child for agility, recovered from disruptions caused by its stores being closed in spring 2020 in critical markets and thrived to become a world leader in online apparel sales by the end of the year. One reason was the additional investments parent Inditex made in agility across all the brands, including Zara, over 2010-2019 (Dombey, 2021).

One challenge is that the research literature provides many competing definitions and constituent 'dimensions' of agility and resilience. Gölgeci and Gligor (2021) have noted the need for theory-building for agility and resilience taken together as *resilient agility*, particularly middle-range theories (Stank, Pellathy, In, Mollenkopf, & Bell, 2017). In particular, Gölgeci, Arslan, Dikova, and Gligor (2019) encourage further inquiry into resilient agility with empirical testing.

This paper seeks to further such theorisation by proposing a conceptual model for resilient agility, linking operational practices to performance with indicative empirical support from the auto industry in Iran. We conceptualise resilient agility using our lens through the practice-based view (PBV) (Bromiley and Rau, 2014). Companies adopt *imitable practices* for performance in this view rather than *inimitable resources* for sustainable competitive advantage as in the resource-based view (RBV). We view resilient agility in terms of standard practices that are linked to relevant performance objectives. Some operational practices are tied only to agile or resilient approaches in the literature, while others are connected to both (Gligor, Gligor, Holcomb, & Bozkurt, 2019). We carried out the conceptualisation in this paper in two steps. *First*, we proposed resilient agility as bundled sets of agile-only, resilient-only, and 'shared' practices linked to cost, delivery, flexibility, and time-to-recovery as operational performance objectives. *Next*, we tested this conceptual model with survey data from Tier-1 suppliers in the Iranian auto industry on their use of different practices and performance. We tested the *measurement model* for each construct using confirmatory factor analysis (CFA) and the *structural model* using structural equation modelling (SEM).

Our results show the measurement models for each construct and the structural model linking the constructs to be valid. Thus, the practice-based view allows us to propose a middle-range theory for resilient agility to help understand the performance objectives using practices that can usefully separate into 'agile-only', 'resilience-only', and 'shared' practices. Notably, the empirical results indicate the importance of shared practices, which we see as positively linked to all performance objectives. Furthermore, the results show the need to study agility and resilience together, thus providing some empirical validation of the concept of resilient agility.

Our contribution to the research stream in the operations literature by viewing agility and resilience together (Gligor et al., 2019; Gölgeci et al., 2019; Ismail, Poolton, & Sharifi, 2011) is twofold. (1) Primarily, we contribute with a conceptual model proposing a middle-range theory on *resilient agility*, underpinned by the *practice-based view*. The proposed model shows *how* different agile and resilient practices target performance objectives. The empirical results indicate the importance of shared practices for performance, including the time to recovery following a disruption. Our paper builds on Gligor et al. (2019), although we consider bundles of practice rather than concepts or attributes of agility and resilience. (2) Secondarily, we add empirical support for the concepts related to resilient agility and their links with performance to this literature.

Furthermore, our research has practical implications in indicating what practices companies should develop to improve performance along with desired objectives. However, there is a need for further empirical work to overcome the limitations of our study.

The rest of the paper is structured as follows: Section 2 builds a conceptual model of resilient agility using the practice-based view from the literature. Next, our methodology for empirical testing appears in Section

3, and results follow in Section 4. Finally, we discuss the implications and limitations of this research and avenues for further study in Section 5.

2. Conceptualizing Resilient Agility

In the literature, there is a need to understand agility and resilience together, possibly as resilient agility, and to extend empirical support for such understanding. This paper takes a practice-based view approach (§2.1). To narrow this twofold gap by conceptualising resilient agility as constructs of related agile or resilient practices (§2.2) linked to performance (§2.3). The purpose is to make the conceptual model both comprehensive and testable.

2.1. Theoretical Lens: Practice-Based View

We take the firm's practice-based view (PBV) to understand performance with imitable activities or practices, amenable to transfer across firms (Bromiley & Rau, 2014, 2016; Carter, Kosmol, & Kaufmann, 2017; Silva, Pereira, & Gold, 2018). Firms adopt *imitable practices* to achieve higher performance under PBV. Such a view contrasts with the RBV, where firms seek *inimitable resources* for sustainable competitive advantage. A practice is a "defined activity or set of activities that various firms might execute" (Bromiley and Rau, 2014, p.1249). Adopting standard practices is motivated by improvement in firm performance, so their use sheds light on current firm performance. Focusing on practices can help managers advance their firm's performance and help researchers explain it (Bromiley and Rau, 2014). Furthermore, the practices can transfer across firms (Silva et al., 2018).

Accordingly, we have identified practices related to resilient agility and pertinent performance objectives, which we will discuss next.

2.2. Agility, Resilience, and Resilient Agility

We consider agility and resilience approaches to guide certain practices' development, selection, and implementation towards various performance objectives. The literature provides many practices associated with agility and resilience. Furthermore, it links agility and resilience to the different performance objectives.

Agility: Previous research views agility as a capability to sense change and flexibly respond to changes (Altay, Gunasekaran, Dubey, & Childe, 2018). Accordingly, an agile organisation can anticipate (Gunasekaran, Yusuf, Adeleye, & Papadopoulos, 2018) and react quickly to unpredictable changes in the demand or supply (Rodríguez-Espíndola, Despoudi, Albores, & Sivarajah, 2021; Christopher & Peck, 2004; Gligor, Esmark, & Holcomb, 2015); markets (Braunscheidel & Suresh, 2009; Gunasekaran & Yusuf, 2002); market demand (Brown & Bessant, 2003); marketplace opportunities (Swafford, Ghosh, & Murthy, 2006); or the business environment (Sharifi & Zhang, 2001). Furthermore, Van Hoek, Harrison, and Christopher (2001) view agility as linked to customer sensitivity, virtual integration, process integration, and network integration, whereas Van der Vorst, Dijk, and Beulens (2001) view agility as market-sensitive, integrated, and network-based. At a more abstract level, Prince and Kay (2003) view agility as the capability of a system to reconfigure itself in response to sudden changes in ways that are cost-effective, timely, robust, and of broad scope. Yet others see agility as a way to maximise customer service while minimising the cost of goods (Vázquez - Bustelo, Avella, & Fernández, 2007).

Resilience: Mensah and Merkuryev (2014) and Hohenstein, Feisel, Hartmann, and Giunipero (2015) note the absence of a concrete accepted definition for (supply chain) resilience. One set of definitions focuses on the ability of an organisation (or supply chain) "to return to its original state or to move to a new, more desirable state after being disturbed" (Christopher and Peck 2004); "to bounce back from a disruption" (Sheffi & Rice Jr, 2005); "to react to unexpected events" (Carvalho & Cruz-Machado, 2011; Rice & Caniato, 2003) or just "to cope with change" (Wieland & Wallenburg, 2012) and "continuously evolve and thrive over time" (Demmer, Vickery, & Calantone, 2011). Some researchers view it as the capacity of firms to quickly react to an erratic change in supply and demand (Singh, Soni, & Badhotiya, 2019) and recover supply chain operations from unforeseen disruptions (Wong, Lirn, Yang, & Shang, 2020). Some researchers describe resilience as "maintaining continuity of operations at the desired level of connectedness and control over structure and function" (Ali, Nagalingam, & Gurd, 2017; Ponomarov & Holcomb, 2009). Or resilience is the means to achieve these objectives, such as "creating redundancy and increasing flexibility" (Sheffi and Rice, 2005) or "dynamically reinventing business models and strategies as circumstances change" (Hamel & Valikangas, 2004). As regards means for achieving resilience, Wieland and Wallenburg (2013) distinguish between the *proactive* capacity to "take action before it is a final necessity" and the *reactive* capacity to "recover after experiencing a crisis." Pettit, Fiksel, and Croxton (2010) seek to combine "the engineering, ecological and organisational leadership definitions of resilience."

Resilient agility: The literature provides an inconsistent picture of agility and resilience. Agility is the ability of a company to respond rapidly to unpredictable changes in variety and volume (Agarwal, Shankar, & Tiwari, 2006). As such, many researchers point out that agility is a factor or a capability in supply chains becoming resilient (Christopher & Peck, 2004; Ponomarov & Holcomb, 2009; Purvis, Spall, Naim, & Spiegler, 2016): resilience is provided reactively by *agility* and proactively by *robustness* (Wieland and Wallenburg, 2012). However, agile may even oppose resilience if an agile organisation emphasizes speed so much that severe shocks and disruptions threaten its survival (Towill, 2005). Some studies examine supply chain agility and resilience jointly (Altay et al., 2018; Cabral, Grilo, & Cruz-Machado, 2012; Gligor et al., 2019; Gölgeci et al., 2019; Ismail et al., 2011). For example, Gligor et al. (2019) examined the complex relationship between the two concepts and found that supply chain agility and resilience share some dimensions. A recent attempt to combine resilience and agility into resilient agility (Gölgeci et al., 2019) calls for further inquiry and empirical testing. In their call for papers, Gölgeci and Gligor (2021) have noted the need to extend studies in this stream "to answer better the question of whether firms should pursue both agility and resilience."

Research question: Therefore, our motivation is to understand agility and resilience together, i.e., the concept of resilient agility. Furthermore, we are motivated to find the links between practice and performance in the practice-based view. The motivating research question for this paper is, therefore

> *How can we understand the concept of resilient agility in terms of practices and performance*?"

As we investigate resilient approaches as bundles of practices, one challenge we face is that some practices, say, just-in-time (JIT), entail several sub-practices and are 'approaches' in themselves. The same applies to performance comprising different objectives, each with key performance indicators (KPI), but with some KPIs, in turn, containing lower-level KPIs. We treat each 'practice' in the literature as a single item for this paper. Using only a single item is justified if different practices are mutually exclusive regarding their respective sub-practices. If the sub-practices for a particular practice area are aligned, we can treat the sub-practices as a unitary bundle. We do the same for KPIs, leaving any investigation of a multi-level pyramid of practices or performance for future research.

Another challenge for this research is that the *unit of analysis* is not consistent in the literature. For example, agility is used more for supply chains than manufacturing operations (Christopher and Peck, 2004), although it could also apply to an organisation (cf. Prince and Kay, 2003). Likewise, researchers view resilience diversely, whether for organizationsorganisations alone or supply chains. However, the focus is almost always on the company regarding performance. Consequently, we have a consistency problem across the approaches and performance in the literature. Given our interest in linking practices to the organisation's performance, this paper *takes the unit of analysis to be the organisation* — this is in line with the PBV — while also considering links to immediate suppliers and customers that the organisation controls. Doing so keeps the study tractable by focusing on the critical processes in a firm's internal supply chain" (Swafford et al., 2006) while considering the "immediate supply chain neighbourhood of the firm" with critical suppliers and customers (Braunscheidel and Suresh, 2009).

In the remainder of this section, we draw upon the broad literature to identify agile or resilient practices (§2.3), appropriate performance objectives (§2.4), and link practices to these performance objectives (§2.5) to complete the conceptual model.

2.3. Agile and Resilient Practices

We find many practices associated with **agility** but not resilience in the literature. These include *computer-based technologies* to manage manufacturing processes, *customise the final product* for individual end-customers, *introduce new products quickly*, *respond quickly to rapidly changing situations* in the supply chain, and *integrate different functions* in the company. Other practices are *just in time* (JIT), *concurrent engineering* for product design, *knowledge management*; *total quality management* (TQM); *implementing new technologies*, and *reducing process downtime* between product changeovers. However, the list is not exhaustive; for instance, there is *new product introduction* (Hallgren & Olhager, 2009; Qamar, Hall, & Collinson, 2018; Sharifi & Zhang, 2001) in the case of Zara mentioned earlier. For our empirical testing, we used ten practices (**Table 1**).

Table 1. Agile-only practices

Agile-only practices	References
Computer-based technologies to manage manufacturing processes	(Abdallah & Nabass, 2018); (Prince & Kay, 2003); (Power, Sohal, & Rahman, 2001)
Customizing the final product for individual end-customers	(Hallgren & Olhager, 2009); (Braunscheidel & Suresh, 2009); (Swafford et al., 2006); (Holweg, 2005)
Responding quickly to rapidly changing situations somewhere in the supply chain	(Sharma et al., 2021); (Tarafdar & Qrunfleh, 2017); (Rodríguez-Espíndola et al., 2021);(Altay et al., 2018)
Integrating different functions in the company	(Abdallah & Nabass, 2018) ;(Gligor et al., 2019) ; (Narasimhan, Swink, & Kim, 2006)
Just in time (JIT)	(Abdallah & Nabass, 2018); (Narasimhan et al., 2006) ; (Brown & Bessant, 2003)
Concurrent engineering for overlapping activities in product design to achieve simultaneous development	(Qamar et al., 2018); (Vázquez-Bustelo et al., 2007)
Knowledge management	(Vázquez-Bustelo et al., 2007); (Jin-Hai, Anderson, & Harrison, 2003)
Total quality management (TQM)	(Abdallah & Nabass, 2018) ; (Narasimhan et al., 2006) ; (Power et al., 2001)
Implementing new technologies	(Yusuf, Menhat, Abubakar, & Ogbuke, 2020) ; (Centobelli, Cerchione, & Ertz, 2020) ; (Vázquez-Bustelo et al., 2007)
Reducing process downtime between product changeovers	(Swafford et al., 2006) ; (Sharifi & Zhang, 2001)

For **resilience**, but not agility, practices identified in the literature include *alternative modes of transportation*, *having business continuity teams*, *and making contingency plans. Other practices have detection systems* to detect any supply chain disruption, *decentralise physical assets* in multiple locations, and provide *security against deliberate intrusion. Establishing communication lines* in case of a disruption in the supply chain is another resilient practice in this category (**Table 2**).

Table 2. Resilient-only practices

Resilient-only practices	References
Alternative modes of transportation	(Hosseini, Ivanov, & Dolgui, 2019); (Pettit et al., 2010); (Ponomarov & Holcomb, 2009); (Sheffi & Rice Jr, 2005)
Business continuity teams	(Azadegan & Dooley, 2021); (Tukamuhabwa, Stevenson, Busby, & Zorzini, 2015); (Sheffi & Rice Jr, 2005);(Colicchia, Dallari, & Melacini, 2010)
Contingency plans made	(Tukamuhabwa et al., 2015); (Tang, 2006), (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007);(Colicchia et al., 2010)
Detection systems in place to detect any supply chain disruption	(Pettit et al., 2010); (Ponomarov & Holcomb, 2009); (Sheffi & Rice Jr, 2005)
Decentralization of physical assets in multiple locations of assets	(Hosseini et al., 2019); (Pettit et al., 2010); (Manuj & Mentzer, 2008)
Security against deliberate intrusion	(Singh et al., 2019) ; (Tukamuhabwa et al., 2015) ; (Pettit et al., 2010)
Establishing communication lines in case of a disruption in the supply chain	(Jüttner, 2005); (Christopher & Peck, 2004)

Shared agile-resilient practices include having *redundant suppliers* for the same part with these suppliers capable of substituting each other; having *flexible manufacturing equipment* to produce different products with the same facilities; having *excess capacity* in the supply chain to absorb sudden increases in demand, and ensuring *visibility*. A *cross-functional workforce* and *collaboration* are also in the literature for all three resilient agility concepts (**Table 3**).

Table 3. Shared agile-resilience practices

Shared practices	Literature for resilience	Literature for agile
Redundant supplier for the same part with these suppliers being capable to substitute each other	(Chowdhury, Quaddus, & Agarwal, 2019); (Hohenstein et al., 2015); (Kochan & Nowicki, 2018); (Sheffi & Rice Jr, 2005); (Ali et al., 2017)	(Cheng & Ye, 2011); (Lee, 2004)
Flexible manufacturing equipment to produce different products with the same facilities	(Chowdhury et al., 2019); (Hohenstein et al., 2015); (Kochan & Nowicki, 2018); (Pettit et al., 2010);(Ali et al., 2017)	(Kochan & Nowicki, 2018); (Altay et al., 2018); (Swafford et al., 2006); (Naughton, Golgeci, & Arslan, 2020)

Excess capacity in the supply chain to absorb sudden increases in demand	(Sharma et al., 2021); (Hohenstein et al., 2015); (Pettit et al., 2010)	(Tarafdar & Qrunfleh, 2017); (Swafford et al., 2006); (Bruce, Daly, & Towers, 2004)
Visibility	(Chowdhury et al., 2019); (Hohenstein et al., 2015); (Hosseini et al., 2019); (Pettit et al., 2010); (Ali et al., 2017)	(Sharma et al., 2021); (Tukamuhabwa et al., 2015); (Braunscheidel & Suresh, 2009)
Cross-functional workforce	(Hohenstein et al., 2015); (Pettit et al., 2010); (Sheffi and Rice Jr, 2005)	(Abdallah & Nabass, 2018); (Narasimhan et al., 2006); (Vázquez-Bustelo et al., 2007)
Collaboration…with customers	(Sharma et al., 2021); (Chowdhury et al., 2019); (Hosseini et al., 2019); (Ponomarov & Holcomb, 2009)	(Sharma et al., 2021); (Yusuf et al., 2020);(Carvalho, Azevedo, & Cruz-Machado, 2012)
Collaboration…with suppliers		

Based on the literature, we can identify the concept of resilient agility with three potential constructs corresponding to different bundles of practices: *agile-only*, *resilience-only*, and *shared* practices.

2.4. Performance Objectives

We now seek to conceptualize operational performance as constructs based on different performance objectives in the literature. For example, many researchers consider *cost*, *delivery*, and *flexibility* as operational performance objectives (Carvalho & Cruz-Machado, 2011; Hallgren & Olhager, 2009; Narasimhan et al., 2006). To these, we can add *time-to-recovery* as a performance construct for resilience (Sodhi and Tang 2012).

The literature provides several cost, delivery, flexibility, and time-to-recovery measures. *Cost* as a construct includes distribution-, manufacturing- and inventory-related costs (**Table 4**). *Delivery*-related measures include on-time delivery, fill rate, and customer response time. *Flexibility*, the company's adaptability to respond to diversity or change, consists of volume, product mix, delivery, and new product introduction.

Finally, measures for *time-to-recovery* include time to detect an undesirable risk event, time to design a solution, and time to deploy the solution. Note that the measures from the literature on the different aspects of performance do not overlap (**Table 4**).

Table 4. Measures for the different performance objectives

Performance objective	Measure	Source
Cost	*Distribution cost per unit*: Transportation and handling costs	(Yusuf et al., 2020); (Chowdhury et al., 2019); (Singh et al., 2019); (Shepherd & Günter, 2010)
	Manufacturing cost per unit: Labour, maintenance and rework costs	
	Inventory cost per unit: Work-in-process and finished goods inventories; inventory obsolescence	
Delivery	*Orders delivered* at the right time as a percentage of total orders: On-time delivery (percentage of orders delivered on or before the due date)	(Srinivasan, Srivastava, & Iyer, 2020); (Chowdhury et al., 2019);(Fullerton & Wempe, 2009); (Gunasekaran & Kobu, 2007)
	Fill rate: The proportion of orders that can be filled immediately	
	Order cycle time of customer: Customer response time: the amount of time between an order and its corresponding delivery. It includes the reaction time, manufacturing time, and transportation time.	
	Orders with the right quantity as a percentage of total orders: Delivery dependability (meeting quoted or anticipated delivery quantities on a consistent basis)	
Flexibility	*Volume flexibility*: Percentage change possible in demand volume of specific products without incurring high incremental costs: demand volume may change, and organizations need to respond quickly and efficiently to either increases or decreases in aggregate demand levels	(Yusuf et al., 2020); (Shepherd & Günter, 2010); (Vázquez-Bustelo et al., 2007)
	Mix flexibility: Number of products from this supply chain without incurring high costs: the number and variety of products which can be produced without incurring high costs or large changes in performance outcomes	(Yusuf et al., 2020); (Gunasekaran & Kobu, 2007); (Shepherd & Günter, 2010); (Neely, Gregory, & Platts, 2005)
	Number of new products introduced in response to customer demand without incurring high incremental costs	

	Delivery flexibility: Percentage change possible in customer lead time in response to changes in the delivery schedule without incurring high incremental costs; the ability to move planned delivery dates forward to accommodate rush orders or special orders.	
	Customer service level: Post-transaction customer service	
Time to recovery	*Time to detect* an undesirable risk event in the plant or supply side in a timely manner	(Dubey et al., 2017); (Sodhi & Tang, 2012); (Altay et al., 2018)
	Time to design a solution when an undesirable event occurs in the supply chain	
	Time to deploy a solution in a timely manner when an undesirable event occurred in the plant or supply-side.	
	Time to Recovery from risk incidence or disruptions and to return to normal operational state rapidly	

2.5. Linking Practices to Performance

Agility as a whole, whether viewed as agile-only or shared agile-resilience practices, is positively linked in the literature with *cost reduction*, *flexibility*, *quality*, and *delivery* (Gligor et al., 2015; Hallgren & Olhager, 2009; Inman, Sale, Green Jr, & Whitten, 2011; Narasimhan et al., 2006; Vázquez‐Bustelo et al., 2007). Agility leads to performance improvements in responsiveness, shorter product lead-time, and lower manufacturing cost (Narasimhan et al., 2006). In addition, agile practices such as customisation, visibility, excess capacity, and redundant suppliers help ensure delivery and flexibility regarding changes in order volumes or customer lead-time (Swafford et al., 2006). Researchers have linked agile practices, but not resilience-related ones, to all four performance objectives: *cost* (Gligor et al., 2015; Hallgren & Olhager, 2009; Vázquez‐Bustelo et al., 2007); *delivery* (Abdallah & Nabass, 2018; Inman et al., 2011; Sangari & Razmi, 2015); *flexibility* (Hallgren & Olhager, 2009; Inman et al., 2011; Vázquez-Bustelo et al., 2007); and even *recovery time* (Christopher & Peck, 2004; Hohenstein et al., 2015; Lee, 2004). Therefore, we can propose:

> **Proposition 1**: *Agile-only practices* are linked positively with (a) *cost (reduction)*, (b) *fast delivery*, (c) *flexibility*, and (d) *time to recovery (reduction).*

Some researchers have linked agility to *resilience* (Christopher and Peck 2004; Pettit et al. 2010) on its own or as a 'formative element of resilience' Ponomarov and Holcomb (2009). However, we will link agile practices directly to *time to recovery* instead of resilience because an agile company reacts quickly, thus speeding up recovery (Christopher and Peck 2004; Lee 2004).

Researchers have conceptually linked specific resilience practices with performance outcomes regarding resilience- including resilience-only and agile-resilience practices. The link to time to recovery for resilience is part of the definition (Hohenstein et al., 2015; Munoz & Dunbar, 2015; Sodhi & Tang, 2012). In addition, some researchers have linked resilience to *cost*, *delivery*, and *flexibility* (Chowdhury et al., 2019; Manuj & Mentzer, 2008; Pettit, Croxton, & Fiksel, 2019; Singh et al., 2019). However, we associate such links to the implicit connection between agility and resilience practices. Therefore, we propose a link only to recovery time.

> **Proposition 2**: *Resilience-only* practices are linked positively with *time to recovery.*

the aim being the reduction of the latter. Not surprisingly, **shared practices** are linked to all four performance objectives in the literature. There are links to cost, delivery, flexibility, and time to recovery (Altay et al., 2018; Cabral et al., 2012; Sharma et al., 2021). According to Carvalho et al. (2012), redundancy of suppliers and alternative modes of transportation in resilient supply chains supports lower costs and quicker response to demand in a turbulent business environment. Having a cross-functional workforce improves the ability to cope with bottlenecks in processes and changes in due dates, affecting customer lead time in response to changes in delivery schedule as a measure of flexibility performance

(Jüttner et al., 2005). Many related resilience practices such as redundant suppliers, alternative modes of transportation, excess capacity, and collaboration with suppliers can improve volume or delivery flexibility, and collaboration can improve delivery (Carvalho et al., 2012). Redundancy through multiple suppliers and safety stock can also help improve delivery (Rice & Caniato, 2003; Sheffi & Rice Jr, 2005; Thun & Hoenig, 2011). Carvalho et al. (2012) argue that redundancy of suppliers and alternative modes of transportation results in lower cost and quicker response to demand, hence delivery, in a turbulent business environment. Finally, agile and resilient practices enable an organisation to reduce the time to recovery. As such, we propose

> **Proposition 3**: *Shared* agile and resilience practices are positively linked with (a) *cost*, (b) *fast delivery*, (c) *flexibility*, and (d) *time to recovery*.

where, as stated before, the aim is to reduce *cost* and *time to recovery*. We assume that the practice constructs would not be completely independent of agile-resilient practices, so we propose covariance between the errors for the equations explaining the performance objectives between cost, delivery and flexibility, and flexibility and recovery time. Finally, researchers will have manifest variables that can serve as control variables (**Figure 1**).

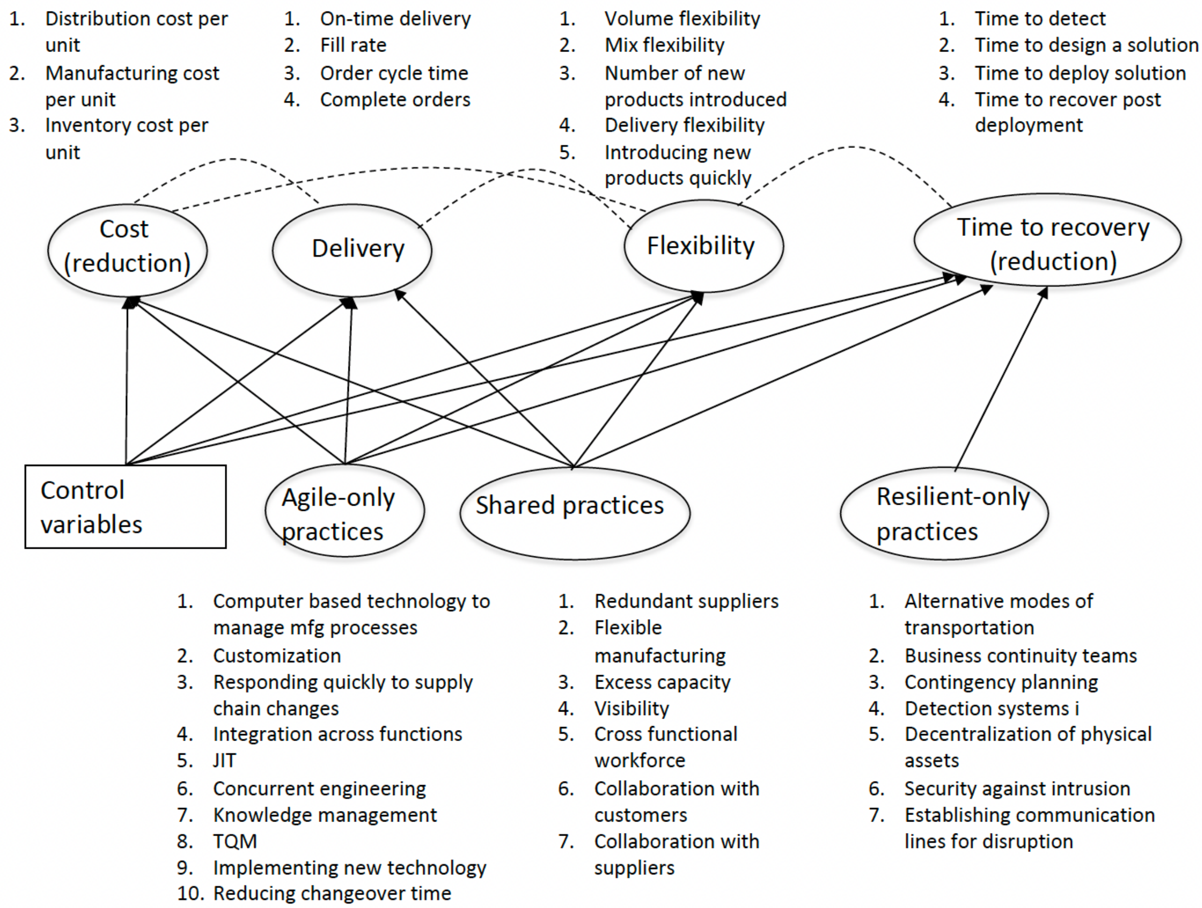

Figure 1: Conceptual model with propositions as one-way links; dashed lines represent error covariances

3. Methodology for Empirical Validation

To test the conceptual model (Figure 1), we obtained data from the auto industry in Iran using a survey. Iran has a sizeable automotive industry among the top 20 countries worldwide (OICA, 2020). The Iranian auto industry has been under particular pressure due to disruptions caused by economic sanctions for more than a decade at the time of writing. Despite 24 auto companies in Iran, the bulk of cars comes from just two domestic manufacturers, Iran Khodro Co (IKCO) and Saipa. Although generalizability from this setting even to the auto industry is questionable, the Thai floods and the Japanese tsunami in 2011, followed by the chip shortage in 2021, significantly increased the need for resilience practices in the auto industry worldwide. Thus, the Iranian auto industry context is not exceptional in requiring the industry to adopt resilience.

3.1 Questionnaire Design and Data Collection

We drafted a questionnaire in English (Appendix 1) asking managers to rate their companies using 24 agile and resilient practices (Tables 1-3) relative to other similar Tier 1 suppliers. Likewise, the questionnaire also asked the respondents to rate their performance on sixteen measures related to cost, delivery, flexibility, and time to recovery (Table 4). All questions required a 7-point Likert scale response. A cover letter and questions about demographic information were included. Before gathering data, the questionnaire was translated into Farsi by a native speaker and then back into English by a different person to ensure that the intent of the questions was preserved. We pre-tested the survey with five supply chain managers and four academics for readability, ambiguity, and completeness. This pre-testing resulted in minor changes.

Our sample comprises Tier-1 automotive parts suppliers to the two leading domestic auto companies, Iran Khodro (IKCO) and Saipa. Motivation for this research was presented to the procurement groups at these two companies for their support to ensure a decent return rate to the relatively long questionnaire. With their help, the purchasing departments of the two companies sent the questionnaires to 609 suppliers. The questionnaire cover letter was personalised by the job title and the manager's name, whose response we sought. A pre-addressed postage-paid envelope was included. We followed up by email and phone calls to the target respondents.

We received 165 of the 609 questionnaires sent out, of which 151 were usable, resulting in an acceptable response rate of just over 25%. For *non-response bias*, we compared key demographic characteristics such as the number of employees and annual sales across the first 30 and the last 30 received survey responses and did not find significant differences. *Common methods variance* is also not a problem as factor analysis revealed that the first factor explains only 31.5% of the variance, and the first five factors together explain 80.6%.

We collected demographic data and information about the size of the company. About 52% of the respondents were president/VP, while about 58% had worked in their present company for more than ten years. Among the rest, 12% were directors, and 22.5% were supply chain, procurement, and logistics managers. As such, we believe the respondents to be reliable sources about the practices and performance of their respective companies. Data on the respondents' companies included *annual sales* and the *number of plants*. We used these as control variables.

3.2 Analysis

Our conceptual model has three latent variables for resilient agility with 24 practices and four performance objectives with 16 performance measures. We have many variables in our dataset, not including the demographic variables. However, the number of observations is only 151, so we separated the measurement and the structural models rather than attempting the entire model as a monolith.

To test the *measurement model*, we tested the links between the measures and the corresponding construct for practices or operational performance objectives using Cronbach's alpha for the reliability of internal consistency and *confirmatory factor analysis* (CFA) to check the validity of each of the constructs in the conceptual model. *Next*, we replaced each construct with the standardized average of its items to test the structural model. Then we tested the model with the resulting three sets of operational practices and the four bundles of performance objectives using *structural equation modelling* (SEM) run as multiple simultaneous equations.

For CFA, we used the *sem* module in Stata 15.1, using the default maximum likelihood option. We also used the sem module for SEM, but with the *mlvl* option to impute missing values and the *stand* option to obtain standardised coefficients. The default goodness-of-fit statistic reported by SEM is influenced by sample size, correlations, variance unrelated to the model, and multivariate non-normality (Kline 2011: p.201). Therefore, we use test statistics beyond the default ones reported by *sem* and avoid the temptation of reporting only statistics that confirm our models, ignoring others. Here, we chose (a) the comparison of the *chi-squared statistic* given our models (measurement or structural) and the respective baseline and saturated models, (b) *root mean squared error of approximation* (RMSEA), (c) *competitive fit index* (CFI), and for the size of residuals, (d) *coefficient of determination* (CD). While the first three are affected by the violation of the multivariate normality assumption, the last one is more robust. For the structural model tests, given the nature of the derived variables, violation of normality is not a concern owing to the aggregation of variables. Therefore, we used the same goodness-of-fit statistics for boththe measurement and structural models.

4. Results

Measurement models: We found solid support for each measurement model for the constructs using a high value of Cronbach's alpha. In all cases, the chi-square values for the "tested model vs the saturated model" are much lower than those for the "base model vs the saturated model". Coefficients are significant for all items of all constructs at the 0.1% level. Although the values for root mean squared error of approximation (RMSE) does not indicate a good fit with values exceeding 0.1, CFI and CD are close to 1 for all constructs, so we need not reject the models for any of our constructs (**Table 5**).

Table 5. Results of reliability test and confirmatory factor analysis for constructs

Construct	Measures with the significance of their respective coefficients in the measurement model	Cronbach's alpha	Chi-sq base vs. sat.	Chi-sq model vs sat	Prob> chi-sq (model vs sat)	RM SEA	CFI	CD
Agile-only	CBT***,	.862	711.27	140.49	.000	.155	.842	.918

	Customization***, IncreasingResponse***, Integration***, JIT***, ConcurrentEngg***, KM***, TQM***, NewTech*** QuickChangeover***,							
Resilient-only	AltModesTransp***, BCTeam***, Contingency***, Detection***, Decentral***, Security***, Communication***	.959	400.87	46.66	.000	.132	.914	.879
Shared agile and resilient	RedundantSup***, FlexMfgEq***, Capacity**, Visibility*** CrosstrainedWforce**, CollaborationCust***, CollaborationSup***	.782	398.97	181.11	.000	.289	.558	.822
Cost	DistrCost***, MfgCost***, InvCost***	.788	141.92	0.00	-	.000	1.000	.942
Delivery	OrdersRightTime*** FillRate***, OrderCycleTime***, OrdersRightQuantity***,	.829	233.12	19.3	.000	.240	.924	.834
Flexibility	TimeToMarket*, MixFlex***, VolumeFlexibility***,	.825	456.85	82.86	.000	.321	.826	.944

	DeliveryFlexibility***, NumNewProducts***							
RecoveryTime	TimeToDetect***, TimeToDesignSol***, TimeToDeploySol***, TimeToRecover***	.877	367.38	5.58	.062	.109	.990	.930

$^{0}p< 0.10$, $^{*}p < 0.05$, $^{**}p<0.01$, $^{***}p<0.001$, N=151

Given the correlations between the standardised variables derived by adding the items for agile-only, resilient-only, and shared constructs (**Table 6**), we also carried out a *three-factor CFA* to account for pairwise covariance. The results are very much in line with the single-factor CFA for these constructs in Table 5. The CD value is relatively high (0.973), although RMSEA (.137) and CFI values of 0.705 are only indicative at best. Still, the chi-squared value of model vs saturated (774) is much smaller than that of baseline vs saturated (2058). All three covariances for these three constructs are high: 0.74 for agile and shared, 0.58 for agile and resilience, and 0.82 for shared and resilience. The coefficients of all 24 items are significant at a 0.1% level. The standardised variables corresponding to the other four constructs for performance objectives did not correlate much (**Table 6**), so, rather than carry out a four-factor or higher CFA, we stayed with the single factor CFA for all four constructs (**Table 5**).

The measurement models' results indicate that all three resilient agility constructs and all four performance objectives constructs are valid.

Structural model: Next, we standardised the sum of the measures as a proxy for the value of the latent variables used as ordinary variables. The results show that the (latent) variables are somewhat correlated but not overly so. Note that for all these variables, the mean is zero and the standard deviation is one by construction (**Table 6**).

Table 6. Summary of standardised variables (mean, min, max, and correlations) corresponding to (a) practice and (b) performance constructs

Practices	N	Min	Max	zAgile Only	zRes Only	zAgile Res	
zAgileOnly	126	-3.31	1.58	1			
zResOnly	133	-3.19	1.94	.82	1		
zAgileRes	143	-4.16	2.10	.79	.80	1	
Performance	**N**	**Min**	**Max**	**zCost**	**zDelivery**	**zFlexi-bility**	**zReco-very-Time**
zCost	146	-2.95	2.20	1			
zDelivery	147	-3.94	1.55	.51	1		
zFlexiblity	142	-2.28	2.12	.45	.53	1	
zRecovTime	146	-2.98	2.23	.53	.55	.65	1

"z" prefix signifies variable is standardized with mean=0, SD=1.

The results for the structural model (**Fig. 2**) have been presented in **Table 7**. The results show the central role of *shared* practices in positively impacting *cost*, *delivery*, *flexibility*, and *time to recovery*. On the one hand, agile-only practices were found to be significantly linked to *cost*, *delivery*, and *time to recovery*, although not *flexibility*. On the other hand, quite surprisingly, resilience-only practices were not linked significantly to *time to recovery*. We believe this is because our questions on time to recovery were, in retrospect, too general in not referring to any specific disruption. Notably, *shared* practices are positively linked to all four performance objectives, *cost reduction*, *delivery*, *flexibility*, and *time to recovery*. One interpretation of the lack of significance between resilience-only and time to recovery may be that resilience requires agility to take effect. Overall, the results suggest that *resilient agility* as a concept has empirical standing.

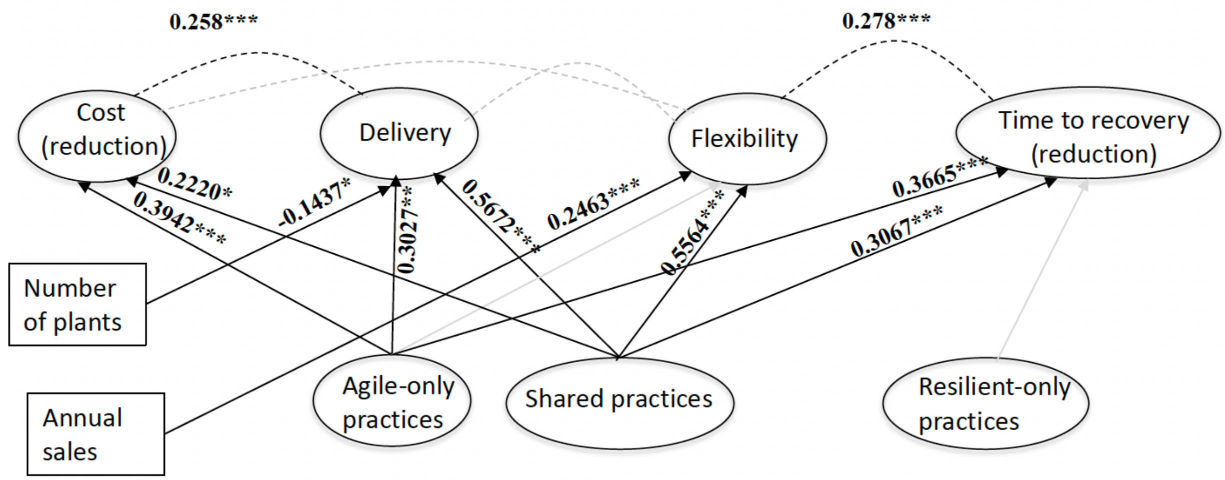

Figure 2: Results of SEM

Table 7. Coefficients (and p-values) from SEM analysis of the structural model with standardized variables for constructs

	zCost	zDelivery	zFlexibility	zRecovTime	
zAgileOnly	.3942*** (.110)	.3027** (.002)	-	.3665*** (.000)	
zResOnly	-	-	-	-	
zShared	.2220* (.113)	.5672*** (.097)	.5564*** (.099)	.3067*** (.104)	
AvgAnnualSale			.2463*** (.067)		
NumPlants		-.1437* (.067)	-		
		Covariance of errors			
	e.zCost	**e.zDelivery**	**e.zFlexibility**	**e.zRecovTime**	
e.zCost	.648				

e.zDelivery	.258***	.548			
e.zFlexibility	-.130	.074	.516		
e.zRecovTime	-	-	.278***	.487	
		Fit statistics			
Chi-sq base vs. sat.	**Chi-sq model vs sat**	**Prob> chi-sq (model vs sat)**	**RM SEA**	**CFI**	**CD**
385.35	14.77	0.000	.114	.973	.780

^{0}p< 0.10, *p < 0.05, **p<0.01, ***p<0.001, N=151

“z” prefix signifies the variable is standardized with mean=0, SD=1

SRMR is not reported because of missing values.

5. Discussion and Areas for Further Research

This research was motivated by the literature highlighting the challenge of how operational improvement practices associated with agile and resilience work together to achieve performance objectives. We sought to develop a conceptual model and provide empirical support. Despite all the academic works on agility and resilience separately in the context of supply chains and their effects on supply chain performance, less has been done empirically on how they affect supply chain performance. We sought to narrow the gap highlighted by (Gölgeci et al., 2019) with regards to the call for more research on resilient agility on (1) empirical research on resilient-agility in a particular industry and (2) investigating volatile economies with a different source of volatility (in our study, economic sanctions) than those typically studied in the literature. Furthermore, our research responds to the need reflected by Altay et al. (2018) to extend the studies to understand the effect of supply chain agility and resilience on performance.

We reviewed the literature at the level of specific practices to build the conceptual model to unpack resilient agility as 'bundles of practices' associated with agile and resilience approaches. First, we partitioned all related operational practices into non-overlapping bundles: agile-only, resilience-only, and shared agile-resilience practices. Then we associated specific measures to the different facets of performance – cost, delivery, flexibility, and time to recovery – from the literature. Next, we proposed a conceptual model by linking these bundles of practices to the different aspects of performance.

Finally, we tested this conceptual model using data from Tier 1 suppliers in the sanctions-hit auto industry in Iran. The United States and the European Union have had multiple sanctions on Iran since 2005 over its nuclear program, which includes finance/banking, oil export and trade, leading to a severe toll on the Iranian economy and different industries.[2] The finance sanctions, the ban on US companies from trading with or investing in Iran, and the ban on exports of 'dual use' technology, including automobiles, have directly affected the Iranian auto industry.

All the constructs were validated in the measurement model. In addition, we validated many links in the structural part of the conceptual model, particularly those between performance and shared practices and between performance and agile-only practices. Proposition 1 was partially supported with agile-only practices indicated as being positively linked with (a) cost, (b) fast delivery, and (d) time to recovery, but not (c) flexibility. We didn't find any support for Proposition 2, with little support for resilience-only practices being linked to (d) time to recovery. Proposition 3 was fully supported with *shared* practices linked to all facets of performance: cost , delivery, flexibility, and time to recovery. As we noted earlier, one interpretation of the negative results on Proposition 2 could be that resilience practices improve time to recovery only in the presence of agile practices. Thus, we endorse Gölgeci et al.'s (2019) viewpoint on

[2] Available at: https://www.cfr.org/backgrounder/international-sanctions-iran, Access date, 14 June 2022.

resilient agility as a concept that can overcome the shortcomings of resilience and agility in isolation: resilience alone cannot bring about prosperity during volatile times, while agility cannot by itself help with risk management and long-term hardship.

This research contributes towards developing a middle-range theory on resilient agility, with associated practices linked to different performance objectives. We have provided an initial set of practices and measures from the literature that researchers should find helpful when investigating further or expanding to other approaches such as sustainability and conceptualising and testing their links empirically. Moreover, our work has provided indicative empirical support to the concept of resilient agility. Shared and agile practices are positively linked to various performance objectives, including time to recovery, traditionally tied only to resilience practices. Finally, companies may find our results helpful in prioritising different practices to achieve performance objectives regarding managerial implications.

Further research: Our study has several limitations. The literature review is a relatively small sample of the literature rather than a systemic review. Second, the data we used is from a survey with one manager representing each company and all companies being Tier-1 suppliers in the same industry and country. As such, there are many avenues for further research stemming from this work:

1. *Expanding the literature review to revisit the conceptual model*. A conceptual model depends on the practices chosen, the measures associated with performance constructs, and how the specific practices tie with particular performance measures. While Tables 1-4 provide a starting point, a systematic and more current review would help identify new operational practices and uncover new links between practices (constructs) and performance objectives. Future conceptualisation can investigate robust agility in contrast to resilient agility.
2. *Granularity and hierarchy of practices*: Some practices like JIT are bundles of practices, justifying the development of other constructs for these in further research. Likewise, there may be a hierarchy of performance constructs: lead-time reduction may underlie delivery and recovery time. The

agility-only, resilience-only, and shared constructs are concepts under which various attributes, such as those proposed by (Gölgeci et al., 2019), can capture practices as items. Even the latter could be concepts in turn so that we get a richer conceptualisation.

3. *Exploratory models*: There is a need for further empirical evidence in the conceptual models in the literature for agile and resilience separately before we confidently model the joint impact of practices on operational performance. An alternative way to develop theory would be to use exploratory analysis of data compiled on practices and KPIs, converting to constructs and links using exploratory analysis.
4. *Performance measures*: Researchers perceive inadequacies in measuring performance, not just in the literature but also in practice – this merits further investigation. Gunasekaran and Kobu (2007) have highlighted the incomplete coverage of performance measures in the literature. Moreover, some researchers find that performance measurement systems fail to support continuous improvement and lack systematic thinking (Van Hoek et al., 2001). Even in practice, performance measurement systems are focused narrowly on cost rather than on the value added to the end customer (Chan & Qi, 2003). For a broader perspective, Lin and Ho (2010) suggest financial and non-financial measures, and Gunasekaran et al. (2004) present a detailed 'measurement and metrics classification.' There is also the choice between qualitative versus quantitative measures (Chan, 2003) for customer satisfaction, flexibility, effective risk management and information, and material flow integration is crucial. Finally, there is inconsistency in how performance measures are affected by agility (Gligor et al., 2015) and resilience (Munoz & Dunbar, 2015; Singh et al., 2019). Therefore, there is a need for comprehensive performance measures for agile-only, resilient-only, and agile-resilient practices along the lines we have taken in this paper.
5. *Moving to supply chains as the unit of observation*: Finally, there is the question of the unit of observation – plant, company or supply chain – and Askariazad and Wanous (2009) argue for a value-chain perspective comprising supply, manufacturing, logistics, marketing & sales, and

support activities. Our research used *the company* as the unit of analysis, but researchers may expand the unit to the supply chain, including those parts that a company cannot orchestrate.

Underlying our research is the practice-based view consistent with the operations domain where practitioners recommend 'best practices.' We hope this paper provides further impetus into not just theory-building but helping create a shared understanding amongst researchers of agility, resilience, and the higher-level concept of resilient agility.

Appendix 1: Survey for the study

***please indicate the extent to which your organization has been successful implementing the following practices across the supply chain (including the plant(s), customers, suppliers) in comparison with similar tier 1 suppliers (*1-very low/not at all, 4- average, 7-very high/best-in-class)**

	Practice	**Not Applicable**	**1=Very low/Not at all 4=Average 7=Very high/Best-in-class**						
1	Computer-based technologies to manage manufacturing processes		1	2	3	4	5	6	7
2	Customizing the final product for individual end-customers		1	2	3	4	5	6	7
3	Responding quickly to rapidly changing situations somewhere in the supply chain		1	2	3	4	5	6	7
4	Integrating different functions in the company		1	2	3	4	5	6	7
5	Just in time (JIT)		1	2	3	4	5	6	7
6	Concurrent engineering for overlapping activities in product design to achieve simultaneous development		1	2	3	4	5	6	7
7	Knowledge management		1	2	3	4	5	6	7
8	Total quality management (TQM)		1	2	3	4	5	6	7
9	Implementing new technologies		1	2	3	4	5	6	7
10	Reducing process downtime between product changeovers		1	2	3	4	5	6	7
11	Alternative modes of transportation		1	2	3	4	5	6	7
12	Business continuity teams		1	2	3	4	5	6	7
13	Contingency plans made		1	2	3	4	5	6	7
14	Detection systems in place to detect any supply chain disruption		1	2	3	4	5	6	7
15	Decentralization of physical assets in multiple locations of assets		1	2	3	4	5	6	7
16	Security against deliberate intrusion		1	2	3	4	5	6	7

17	Establishing communication lines in case of a disruption in the supply chain		1	2	3	4	5	6	7
18	Redundant supplier for the same part with these suppliers being capable to substitute each other		1	2	3	4	5	6	7
19	Flexible manufacturing equipment to produce different products with the same facilities		1	2	3	4	5	6	7
20	Excess capacity in the supply chain to absorb sudden increases in demand		1	2	3	4	5	6	7
21	Visibility		1	2	3	4	5	6	7
22	Cross-functional workforce		1	2	3	4	5	6	7
23	Collaboration…with customers		1	2	3	4	5	6	7
24	Collaboration…with suppliers		1	2	3	4	5	6	7

***Part 3: Please rate your company's performance on the following performance measures across your supply chain (including the plant(s) customers, suppliers) in comparison with similar tier 1 suppliers (*1- very poor, 4-average, 7= best-in-class)**

	Performance measures	**1= very poor 4-average 7= best-in-class in the peer group)**						
1	Distribution cost per unit: transportation and handling costs to customer location	1	2	3	4	5	6	7
2	Manufacturing cost per unit: labor, maintenance and Re-work costs	1	2	3	4	5	6	7
3	Inventory cost per unit: work-in-process + finished goods inventories+ raw material	1	2	3	4	5	6	7
4	Time to detect undesirable risk event in the plant or supply side in a timely manner	1	2	3	4	5	6	7
5	Time to design a solution when an undesirable event occurs in the supply chain	1	2	3	4	5	6	7
6	Time to deploy a solution when an undesirable event occurred in the plant or supply side in a timely manner	1	2	3	4	5	6	7
7	Time to recover from risk incidents or disruptions and to return to normal operational state rapidly.	1	2	3	4	5	6	7
8	*Orders delivered* at the right time as a percentage of total orders: On-time delivery (percentage of orders delivered on or before the due date)	1	2	3	4	5	6	7
9	*Fill rate*: The proportion of orders that can be filled immediately	1	2	3	4	5	6	7
10	*Order cycle time of customer*: Customer response time: the amount of time between an order and its corresponding delivery. It includes the reaction time, manufacturing time, and transportation time.	1	2	3	4	5	6	7
11	*Orders with the right quantity* as a percentage of total orders: Delivery dependability (meeting quoted or anticipated delivery quantities on a consistent basis)	1	2	3	4	5	6	7
12	*Volume flexibility*: Percentage change possible in demand volume of specific products without incurring high incremental costs: demand volume may change, and organizations need to	1	2	3	4	5	6	7

	respond quickly and efficiently to either increases or decreases in aggregate demand levels							
13	*Mix flexibility*: Number of products from this supply chain without incurring high costs: the number and variety of products which can be produced without incurring high costs or large changes in performance outcomes	1	2	3	4	5	6	7
14	*Number of new products introduced* in response to customer demand without incurring high incremental costs	1	2	3	4	5	6	7
15	*Delivery flexibility*: Percentage change possible in customer lead time in response to changes in the delivery schedule without incurring high incremental costs; the ability to move planned delivery dates forward to accommodate rush orders or special orders.	1	2	3	4	5	6	7
16	*Customer service level:* Post-transaction customer service	1	2	3	4	5	6	7

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