



Manufacturing
Technology Centre

The background of the cover is a dynamic, abstract graphic. It features a large, semi-transparent white triangle pointing upwards from the bottom left. Inside this triangle, there is a complex network of glowing blue and red lines and dots, resembling a digital or molecular structure. Below the triangle, there are images of industrial machinery, including a robotic arm and a circuit board, all in shades of blue and white.

SUPPLY CHAIN READINESS LEVELS

WHITE PAPER

October 2021

SUPPLY CHAIN READINESS LEVELS

Enhancing the Industrial
Readiness and Resilience
of Global Value Chains

A White Paper

Authors

Prof Paul Maropoulos
Dr Thorsten Kampmann
Mr Cy Keogh
Mr Michael Cunliffe

EXECUTIVE SUMMARY

Manufacturing industry is undergoing a transformational change globally, brought upon it by an unprecedented combination of geopolitical events, technology advances, societal trends and health emergencies. The challenges are multiple, as are the commercial opportunities for those who will develop the correct strategic responses.

An overriding industrial requirement is to rapidly develop and successfully deploy innovative technologies, from digitalization and automation to new green and sustainable technologies, whilst at the same time enhancing the effectiveness and resilience of global and regional value chains. The key antithesis here is that rapid innovation adoption by industry can increase industrialisation risks and reduce deployment readiness. In this context, the ability of corporations to rapidly and successfully industrialise innovations is frequently limited by the readiness or maturity of their global value chains. And whilst measurement systems exist for the measurement of the maturity of a particular technology, or a manufacturing process, they do not exist for measuring the maturity of supply chains; this creates a significant global challenge and a strategic opportunity to unlock major operational and competitiveness benefits in global value chains.

Following on from the original, academic definition of system-level risk mitigation and maturity approaches, an industrially oriented ‘Supply Chain Readiness Levels’ [SCRL] methodology and associated digital toolkit were developed from a practical, industrial implementation perspective. The methodology is assessing the maturity of nine key measurable technology and business capabilities called ‘threads’ using four maturity attainment Levels from ‘awareness’

and ‘understanding’ to ‘advanced’ and ‘expert’. In essence, SCRL assesses the supply chain’s readiness to industrialise Innovation and operate at world class standards. In order to enhance the ability of businesses to deal with major and frequent disruptions in their business environment, it is mission critical to understand how key business capabilities contribute towards building business resilience. The SCRL methodology has been especially adjusted and extended to provide a measure of resilience, by identifying specific combinations of capabilities that contribute towards it and measuring their combined effect, thus resulting in the ‘SCRL-Resilience’ methodology and toolkit. To the knowledge of the authors, this is the first readiness and resilience focused methodology and toolkit to be made available for deployment within industry sectors and supply chains, addressing a major global industrial requirement.

The SCRL-Resilience methodology has been applied to two UK supply chains, one supplying the railway sector and one supplying the digital and automation sector, with very good results. In each cohort, the overall readiness and resilience of each company were measured and benchmarked against the cohort’s overall attainment. Interesting trends were identified regarding how specific sets of capabilities were clustered together at the same level in high performing companies. Perhaps more importantly, capability maturity gaps were identified within each company and within the overall supply chain via subsequent cohort data analysis. The findings allowed the clustering of low readiness and resilience capabilities that characterised the low maturity attainment companies.

The industrial deployment of SCRL Resilience provided unique perspectives and a ‘landscape view’ into the capability and readiness of two UK supply chains to industrialise innovation or deal with major disturbances. Following the deployment in the railway supply chain, a structured supply chain development programme was defined, aiming to get companies to improve their individual readiness from Level 2 [understanding] to Level 3 [advanced] in the first instance. The programme also aims to codify the interventions and actions needed in order to define a ‘how to do it’, standard performance improvement process. For the digital and automation supply chain the analysis of results underpinned a regional supply chain strategy that is focused on developing the supply chain’s capabilities, retaining best performing businesses, and attracting new competitive companies in the region.

A key readiness finding from the overall attainment, across the two supply chains, was that two out of three companies had their overall readiness measured at the two lowest maturity levels. This represents a strategic risk and provides an opportunity for targeted supply chain capability development to allow businesses to thrive in an increasingly competitive and volatile global market. In terms of specific business capabilities, good attainments of readiness were measured for ‘Contract Management, Risk Management and Security’, ‘Synchronisation of Supply’, and ‘Innovation and Technical Mastery’ as for each one of these capabilities more than 40% of companies were assessed as having advanced or expert readiness. At the other end of the spectrum, almost three out of four supply chain companies had their ‘Digital Competence’ measured at the two lowest readiness levels. This indicates a significant challenge with the digital transformation of the supply chains assessed and represents a business and technology risk that needs to be addressed.

The overall assessment of resilience resulted in an interesting set of results with the headline finding being that 72% of companies had achieved expert or advanced levels reflecting mature business practice in strategy and innovation. This is a highly significant outcome that indicates the priority UK businesses give to enhancing their ability to deal with major market disturbances. In terms of specific capabilities, ‘Strategy’ is a well performing capability with 28% of companies being assessed at the top resilience quartile, whilst ‘Agility’ and ‘Sustainability’ were identified as key foci of companies for enhancing their resilience, with both having 34% of companies assessed in the two lower resilience quartiles.

The use of SCRL is strategic and front-end, to assess readiness during new value chain configuration. This makes the methodology especially well placed to support the efficient industrialisation of new and innovative products from all sectors of the economy, including products of the ‘green industrial revolution’ from electrification of transport, to hydrogen applications. SCRL can also be applied during the reconfiguration of legacy value chains and this is especially pertinent during the period of global industrial recovery post Covid-19 when companies are seeking to rebalance and enhance the resilience of their value chains, re-purpose capabilities to access different markets or re-shore critical products. Apart from using SCRL commercially, the methodology can be deployed by Trade Associations and Government Agencies to gauge a value chain’s maturity roadmaps and then plan appropriate capability interventions to bridge the identified gaps or fund research and innovation programmes to enhance national capabilities.

Currently, the SCRL methodology is being deployed to more sectors of the UK’s economy, the industrial clients have benefited from its deployment and commissioned strategic supply chain capability enhancement projects and work will continue to expand its deployment and further enhance its impact.

65%

65% of the companies assessed had their overall Readiness measured at the two lowest maturity levels. These businesses have an increasing understanding of the main capabilities required by high performing supply chains, but they have not, as yet, progressed the development and significant deployment of such methods. This represents a strategic risk and an opportunity for targeted supply chain capability development to allow businesses to thrive in an increasingly competitive and volatile global market.



Rapid innovation adoption by industry can increase industrialisation risks and reduce deployment readiness.



Whilst measurement systems exist for the measurement of the maturity of a particular technology, or a manufacturing process, they do not exist for measuring the maturity of supply chains; this creates a significant global challenge and a strategic opportunity to unlock major operational and competitiveness benefits in global value chains.

43%

43% of companies have advanced level maturity attainment for 'Contract Management, Risk Management and Security', reflecting good business strengths in life-cycle contract management, risk management, use of standards and data security.

41%

41% of companies have advanced readiness for 'Synchronisation of Supply' showcasing strong ability to react to changes in demand and ability to cope with uncertainty in forecasting, resulting in on time delivery.

41%

41% of companies have advanced readiness for 'Innovation and Technical Mastery', incorporating innovation in products and processes with an active focus on building technology collaborations.

72%

72% of the supply chain companies assessed had their 'Digital Competence' measured at the two lowest readiness levels. This indicates a significant challenge with the digital transformation of the supply chains and represents a business and technology risk that needs to be addressed.



The Supply Chain Readiness Levels [SCRL] methodology is used to assess the supply chain's readiness to successfully industrialise Innovation and operate at world class standards

72%

72% of the supply chain companies assessed had their overall resilience measured as expert or advanced, reflecting the strategic focus UK businesses have given to enhancing their ability to deal with volatile market conditions and the adoption of best practice standards. Whilst this is positive, the concern is that the remaining 28% of the companies assessed are ill prepared to deal with major disruptions to production and this increases their business risk and threatens the sustainability of the supply chains.



In order to enhance the ability of businesses to deal with major and frequent changes in their business environment, it is mission critical to understand how key business capabilities contribute towards building business resilience.

34%

34% of companies were placed in the two lower resilience quartiles for 'Agility' and 'Sustainability'; these areas emerge as key foci of supply chain companies in the process of enhancing their resilience.



The intention is to accelerate and widen the industrial deployment of the SCRL-Resilience toolkit to deliver the maximum possible benefit to the competitiveness and sustainability of supply chains.

28%

28% of companies reached expert level for 'Strategy' when assessing resilience; this is the top attainment level for any capability that contributes to resilience and reflects good leadership, technology forecasting and market awareness within the supply chains.



To the knowledge of the authors, this is the first resilience focused methodology and toolkit to be made available for deployment within industry sectors and supply chains, addressing a major global industrial requirement.

THE AUTHORS



Prof Paul Maropoulos PhD, CEng, FIMechE, FCIRP is the Director of Technology and Strategy Consulting Ltd and an Honorary Fellow of the MTC in recognition of his contribution to UK's manufacturing. He is Professor of Advanced Manufacturing at Queen's University Belfast, Director of the Advanced Manufacturing Innovation Centre and Editor-In-Chief of the Journal of Engineering Manufacture.



Dr. Thorsten Kampmann PhD, LLM-IP, MSc-HE, MSc-BT, is leading the MTC product and service offering for supply chain improvement. Thorsten has worked in consulting for the last decade in sectors including healthcare, manufacturing, automotive, aerospace, energy, technology and automotive.



Cy Keogh BSc [Hons] MBA [MBS], a supply chain development specialist with 30 years' experience focusing on developing supply chains as a competitive asset through the design of value-driven development programmes. He took a lead in developing the MTC's Supply Chain Readiness Assessment tool. He has published work on Entrepreneurship in the Journal of Innovation and Technology.



Michael Cunliffe PGDip CQP MCQI, working within the MTC's Transformation Team, developing UK supply chain capability introducing innovation to products and processes. Has over 30 years of experience in manufacturing operation management in high value manufacturing sectors, with further experience in managing and mentoring for UK Aerospace grant programmes.

1.0

INTRODUCTION AND BACKGROUND

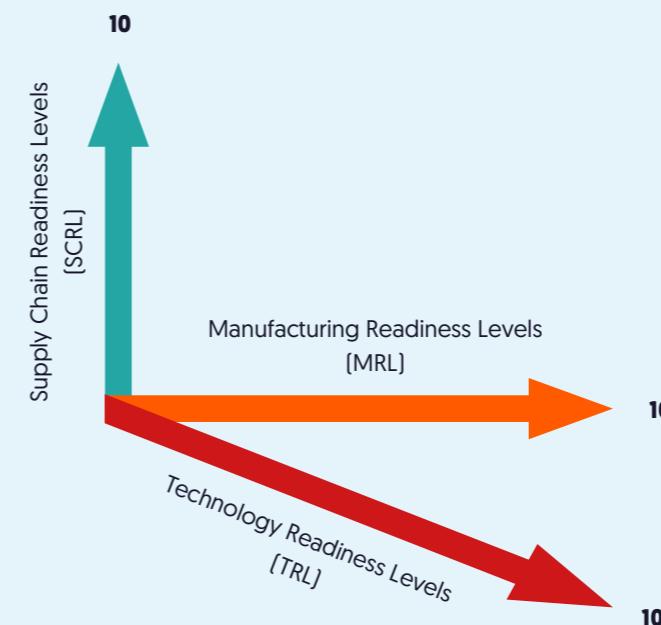
Manufacturing industry is undergoing a transformational change globally, brought upon it by an unprecedented combination of geopolitical events, technology advances, societal trends and health emergencies. The challenges are multiple, as are the opportunities for those who will develop the correct strategic responses. An overriding industrial requirement is to rapidly develop and successfully deploy innovative technologies, from digitalization and automation to new green and sustainable technologies, whilst at the same time enhancing the readiness and resilience of global and regional value chains. In this context, the ability of corporations to successfully industrialise innovations is frequently limited by the readiness or maturity of their global value chains. Readiness of value chains is the ability to industrialise new product innovation and respond to market demands in a timely, effective and productive manner, satisfying customer expectations in terms of the required performance metrics.

The need for resilience has come into sharp focus during the Covid-19 pandemic, with sectors of the economy experiencing unplanned shocks and major changes in demand and supply. McKinsey¹ reports that 'shocks that affect global production are growing more frequent and more severe' and that 'disruptions lasting a month or longer now occur every 3.7 years on average'. This signifies the need to develop resilience as a corporate capability and an attribute of value chains in the longer term. Resilience is the capacity of value chains to recover quickly from major shocks and disturbances and, in a manner similar to readiness, it is a 'complex, cumulative capability' that depends on the coordinated deployment of a wide range of interrelated business functions and technologies.

Rapid innovation development and adoption by industry increases industrialisation risks and reduces deployment readiness. And whilst measurement systems exist for the measurement of the maturity of a particular technology, or a manufacturing process, they do not exist for measuring the maturity of supply chains; this creates a significant global challenge and a strategic opportunity to unlock major operational and competitiveness benefits in global value chains.

Following on from the introduction of Technology Readiness Levels [TRL] by NASA² and Manufacturing Capability Readiness Levels [MCRL] by M. Ward et al.³, there are now various readiness assessment concepts and tools covering technology and manufacturing processes. The development of such concepts allowed for the development of 'systems level' risk mitigation concepts. Fig.1 visualises the relationships between the readiness of technology, process and supply chain axes. The relationships between variations along the three axes are not orthogonal or linear. A downgrade in the readiness of manufacturing processes, will have an impact on supply chain output, cost and quality, thus reducing the supply chain readiness.

Fig. 1. Technology, Process and Supply Readiness



The term Supply Chain Readiness Levels [SCRL] was used by J. Tucker⁴ and had five levels of maturity designed for human space operations and also involved risk and cost. A different version of the SCRL methodology was developed by Matopoulos et al⁵. to address the perceived industrial need to successfully and rapidly industrialise innovative products and processes; this SCRL method had ten levels of attainment/maturity that were clustered within the life-cycle stages of 'concept and R&D', 'development' and 'production' for a supply chain.

Assessing Readiness - Realizing Opportunities from Innovation & Rapid Market Response with Mitigating Business and Technology Risks

In early 2019, the MTC, with expert input from Professor Maropoulos, started work on SCRL from the perspective of developing an industrially oriented SCRL methodology, and an associated digital toolkit, that would be flexibly structured to ensure its generic applicability to various manufacturing sectors. A key priority was to focus on developing SCRL, from an industrial implementation perspective. Following a successful pilot testing phase, the SCRL methodology was further refined and suitably extended to cover supply chain resilience considerations. This has been done by identifying business and technology capabilities that contribute towards resilience and then defining an aggregate process of measuring resilience attainment. Initial testing with supply chain companies from the railway sector and the digital and automation sector has resulted in very encouraging results. The version of SCRL that is now available and can be deployed to measure readiness and resilience in supply chains is referred to as 'SCRL-Resilience'.

1. McKinsey Global Institute, August 2020, Risk Resilience and rebalancing in global value chains.

2. Mankins, J. C. 1995. "Technology readiness levels". Houston, TX: NASA (National Aeronautics and Space Administration)

3. M J Ward, S T Halliday, and J Foden. 2011. A readiness level approach to manufacturing technology development in the aerospace sector: an industrial approach. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, vol. 226, 3: pp. 547-552.

4. Tucker, B. and Paxton, J. 2010. SCRL-model for Human Space Flight Operations enterprise supply chain, 2010 IEEE Aerospace Conference, DOI: 10.1109/AERO.2010.5446850

5. Matopoulos, A., Kalaitzi, D., Sweeney, E., and Maropoulos, P.G., 2017, From Technology and Manufacturing Readiness Levels to the need for Supply Chain Readiness Levels, 24th Conference of European Operations Management Association, 3-5 July 2017, Edinburgh, UK.

2.0

HOW DOES THE SUPPLY CHAIN READINESS METHODOLOGY WORK?

SCRL is a methodology designed to assess and improve the business and technology readiness of supply chains to produce new, innovative products, incorporate state of the art manufacturing processes and systems and respond to major demand or supply disruptions and shocks.

The key objectives of SCRL are as follows:

1. Understand the businesses capabilities required for optimum performance in a supply chain.
2. Provide a high-level measure of these capabilities across 9 business themes.
3. Provide an indication of the resilience (strategic) and robustness (tactical & operational) of a company as measured by the 9 business themes.
4. Identify areas where a company might focus its limited and precious resources on improving both robustness and resilience.
5. Provide a framework for defining improvement activities to address capability shortfalls, and a method by which improvement can be monitored.
6. Stimulate engagement in areas of business activity that will strengthen the commercial position, competitiveness, and sustainability of the organisation involved.

The SCRL methodology has been productised by developing the 'SRCL tool'. This is a 'capability landscape' tool that enables a company to assess its own supply chain capabilities as well as those of its suppliers. It also provides a high-level measure of resilience. It is a sector agnostic, 'guided' assessment tool in which representative(s) of the business are 'walked through' the assessment by a qualified assessor. The tool can be used by a company to assist in the development of a plan to enhance readiness in terms of commercialising innovative products and services and build robustness and resilience within the company and its supply chain network.

The SCRL tool includes an 'Assessment Matrix', a 2D decision making space, in which nine (9) key business themes called 'Threads', are assessed against four (4) levels of 'Attainment' or 'Maturity'. The Threads are areas of combined capability of direct relevance to a supply chain network, which can impact business performance.

The SCRL Threads:

1. Innovation and Technical Mastery,
2. New Product Introduction,
3. Supplier-Customer Relationship,
4. Contract Management, Risk Management and Security,
5. Sustainability of Supply,
6. Synchronisation of Supply (Physical),
7. Supply Chain Organisation and Governance,
8. Agility and Transformation, and
9. Digital Competence.

For each Thread there are five (5) specific capabilities / competencies, called 'Sub-Threads'. This gives a total of $9 \times 5 = 45$ relevant capabilities that are evaluated during the process. Each sub-thread capability is then assessed against 4 levels of Attainment, namely; 'Awareness', 'Understanding', 'Advanced' and 'Expert'. A numerical score is assigned to each level of Attainment to help analysis and results evaluation. This gives a rich evaluation space consisting of $45 \times 4 = 180$ company capability maturity assessments. The summary output of the SCRL Assessment Matrix includes a radar chart, defining the readiness profile of a company along each one of the 9 SCRL Threads, plus contextual and numerical feedback based on the assessments of each Thread.

3.0 EVALUATING SUPPLY CHAIN RESILIENCE

The impact of Covid-19 has put into sharp focus the need for regional and global value chains to recover quickly from major shocks and disturbances. Resilience is a ‘complex, cumulative capability’ that depends on a wide range of interrelated business functions and technologies. The generic flexibility of the SCRL methodology and the richness of the information and data gathering process became apparent when the SCRL assessment matrix was utilised to generate a measure of ‘Resilience’ of a supply chain.

The first consideration was to identify the business and technology capabilities that contribute towards resilience and the subsequent task was to find a way of measuring their impact and arriving at an overall measurement of resilience for a company within a supply chain; the individual resilience assessments are then used to provide a measure of the overall supply chain resilience. The above became feasible by viewing and analysing the rich set of data and contextual statements of the SCRL decision-making space through a different, resilience-focused perspective.

Six ‘Resilience Threads’ or ‘Resilience Attributes’ were identified by clustering appropriate capabilities of the SCRL tool. The process of selecting the attributes was informed by previous research by J Fiksel et al⁶. Selected capabilities of the SCRL Assessment Matrix were mildly redefined and grouped within the following six resilience attributes or threads to provide a combined measure of resilience.

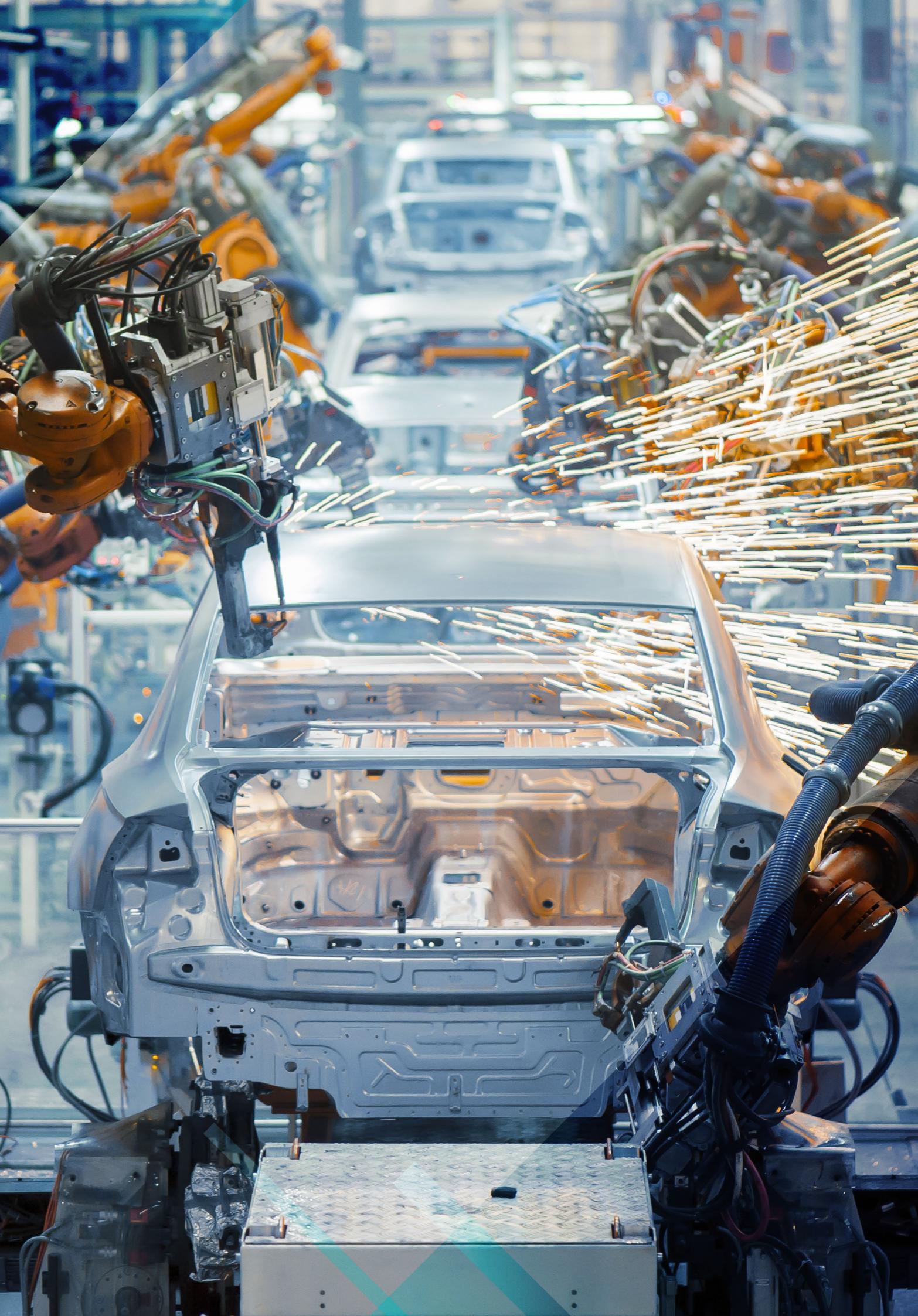
The Resilience Threads:

1. Digital Competence and Innovation;
2. Strategy;
3. Supplier Intimacy;
4. Sustainability;
5. Agility and Systems;
6. Standards and Processes.

Each Resilience Thread comprises a number of capabilities called sub-threads, selected to provide a coherent measure of business resilience. The deployment and measurement process involves assessing each sub-thread for a company and assigning a numerical score with a value that reflects its level of attainment. Performance outputs for each Resilience Thread and the Overall Resilience are aggregated and reported using Quartiles, with Quartiles 1 and 2 representing low attainment levels, corresponding broadly to the SCRL Levels of ‘Awareness’ and ‘Understanding’; Quartile 3 represents ‘Advanced Practice’ and Quartile 4 corresponds to ‘Expert Practice’ for Resilience.

When the SCRL tool is used to assess the resilience attributes and provide a measure of resilience, is referred to as SCRL-Resilience. Testing of this tool as part of the railway sector and digital and automation supply chains has provided key new insights. The MTC is currently developing, with active industrial input, appropriate interventions arising from the assessment results generated by applying SCRL-Resilience to these sectors and the supply chain partners.

6. Joseph Fiksel, Mikaela Polyviou, Keely L. Croxton, Timothy J. Pettit. From Risk to Resilience: Learning to Deal With Disruption, MIT Sloan Management Review, Vol. 56, No. 2, 2015





The ability of corporations to rapidly, and successfully, industrialise innovations is frequently limited by the readiness or maturity of their global value chains. And whilst measurement systems exist for assessing the maturity of a particular technology, or a manufacturing process, they do not exist for measuring the readiness of supply chains. The newly developed, Supply Chain Readiness Level methodology, bridges this gap by assessing a supply chain's readiness to industrialise Innovation and operate at world class standards. The industrial adoption and implementation of this methodology offers a strategic opportunity to unlock major operational, sustainability and competitiveness benefits in global value chains.

4.0

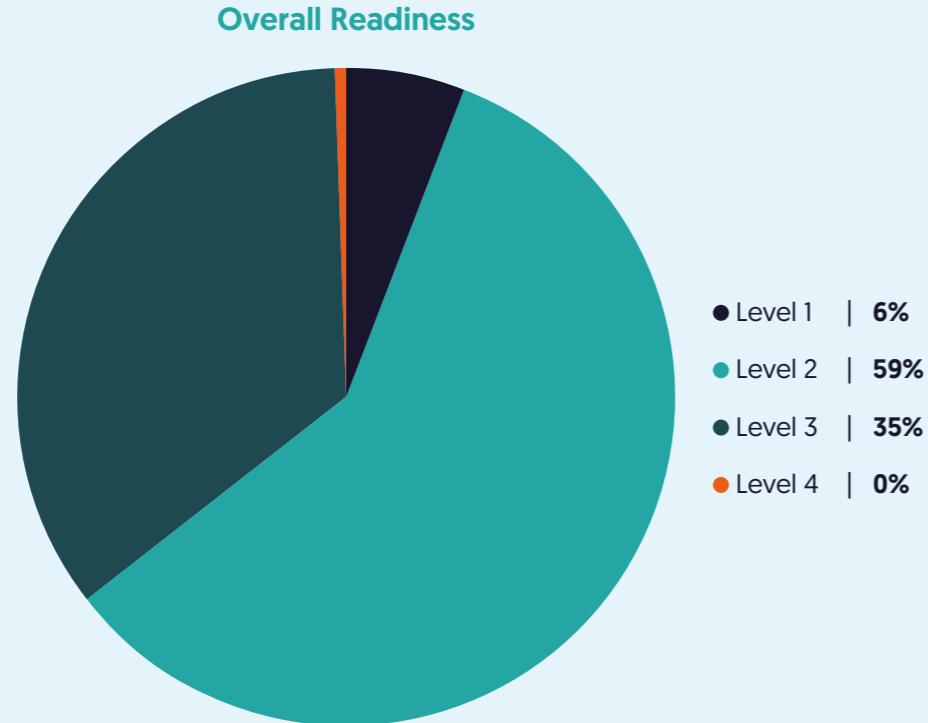
RESULTS AND CONTEXTUAL FINDINGS FROM THE INDUSTRIAL DEPLOYMENT OF SCRL

The SCRL methodology was applied to 46 companies of two UK supply chains, a railway supply chain and a digital and automation supply chain, under a pilot testing and evaluation phase. The learnings from the industrial deployment helped to verify the contextual relevance of the numerical results received per company and validated the methodology by analysing the assessment results generated during the industrial deployment of SCRL and the subsequent working with the companies involved.

4.1 Overall Readiness Attainment

Fig. 2 shows the overall maturity measurement for the cohort and 35% of the companies assessed were found as having met and exceeded Level 3, that is the Advanced Readiness Level. This level characterises companies that have above average business capabilities across the board and they can leverage their capabilities and relationships with customers for mutual advantage, including being prepared to commit to joining new product development and enter new commercial arrangements.

Fig. 2. Overall Readiness Levels of All Companies.



Notwithstanding that there were some very well performing companies at the top of Level 3, there were no companies in this sample that reached readiness Level 4 that represents the Expert level.

The overall readiness rating of 59% of the companies assessed was measured as having met and exceeded Level 2 that is the Understanding Level but not yet reached Level 3, the Advanced Level. Clearly, this represents the large majority group and typically includes companies that have a wide range of capabilities under development from Innovation, to Agility and Supply Organisation, with some capabilities maturing but the overall status can be described as 'work-in-progress'. Finally, 6% of the companies were assessed as having overall readiness at Level 1, that represents Awareness. It is this sub-group that is mostly at risk by either significant production disturbances or the introduction of significant rates of product and process innovation.

A key finding from the industrial deployment of SCRL is that 65% of companies had their overall Readiness measured at the low maturity Levels 1 and 2. This indicates that the majority of businesses assessed are engaged with the main competencies required by contemporary supply chains, but as yet they have not progressed the adoption and deployment of such methods. This represents a strategic opportunity for targeted supply chain capability development to enhance the ability of these businesses to win work in an increasingly competitive global market.

65%

65% of companies had their overall Readiness assessed at Level 1 [Awareness] or Level 2 [Understanding]. In terms of potential for future performance enhancement and risk mitigation, this group of companies represents the prime target for follow on work to accelerate the adoption of best practice for agility and supply synchronisation and embed state of the art processes for new product introduction and the implementation of Industry 4.0.

4.2 Overall Attainment Across Business Themes – Selected Threads

The 'Contract & Risk Management and Security' is the Business Thread with the best overall attainment of the cohort of companies assessed, as 41% of companies were measured at Level 3 and 2% at Level 4. This strong performance is mainly due to the existence of comprehensive contract management life cycle capabilities, mature risk management processes, a wide range of process certifications and good conformance with standards. There is also good attainment in managing confidential information and in data security. Finally, the 'Synchronisation of Supply' Thread also performed well with 41% of companies assessed as Level 3; this performance indicates strong ability to react to changes in demand and cope with uncertainty in forecast, resulting in on time delivery. Adoption of capacity planning systems and advances in forecasting and logistics contribute to this good maturity level.

17%

17% more companies were measured at Level 3 [Advanced] Readiness for 'Contract and Risk Management and Security' and 'Synchronisation of Supply' than the companies that reached Level 3 for overall Readiness

3/4

Almost 3 out of 4 supply chain companies had their 'Digital Competence' measured at readiness levels below Advanced. This indicates a significant challenge with the digital transformation of the supply chains and represents a business and technology risk that needs to be addressed.

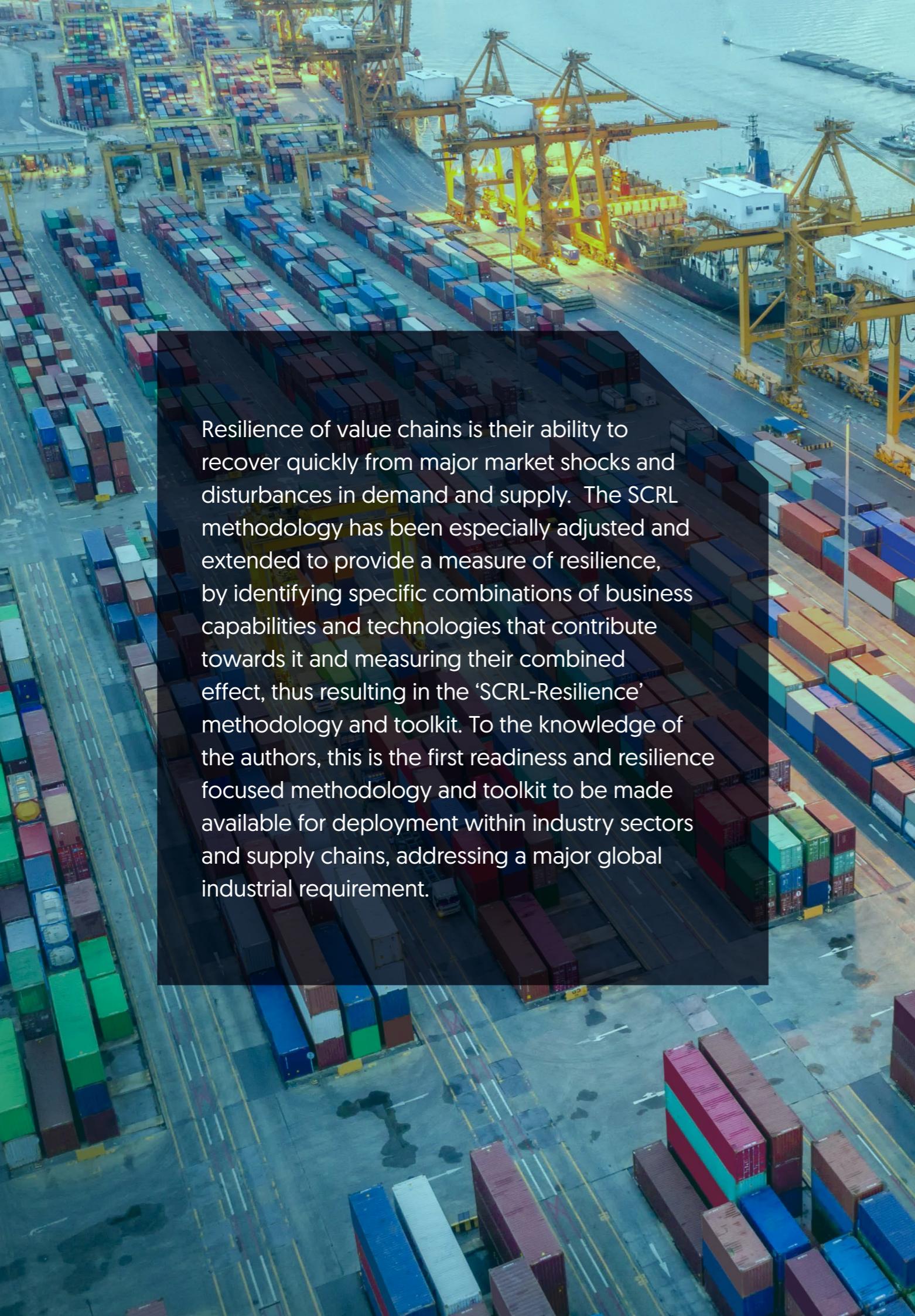
For the 'Digital Competence' thread, 72% of companies assessed had maturity measured at Levels 1 or 2 and this is the highest combined percentage of all business threads reflecting low overall readiness. This indicates that the digital transformation of the supply chain companies is on-going and there is a considerable amount of work still to be done as almost 3 out of 4 companies have not reached an advanced state of digital readiness. Companies with digital readiness at Levels 1 or 2 will most likely not be in a position to successfully deploy advanced digital technologies to gain competitive advantage. This finding is especially significant as it indicates a substantial capability gap in the maturity of digital technologies within the supply chain companies considered, at a time when the digital transformation of manufacturing industry is gathering pace globally and becomes a key ingredient of business competitiveness.



The overall readiness profile of supply chain companies for the 'Innovation and Technical Mastery' thread was also especially strong with 37% at Level 3 and 4% at Level 4; this strong showing of innovation maturity within 41% of companies of the supply chain is significant, as it will allow for the rapid and successful industrialisation of new products. However, for the same Thread 13% of companies were assessed at Level 1 and 46% at Level 2. The 13% of companies measured at Level 1 (Awareness) is the highest percentage recorded for any Thread and is 2.17 times higher than the number of companies with overall readiness at Level 1 that was 6%. This finding represents an important capability gap, as a significant number of companies assessed are lacking the technology understanding that will allow them to make effective use of new technologies to develop innovative products or processes and make effective use of data for business competitiveness.

41%

The measurement of readiness for 'Innovation and Technical Mastery' showed an apparent polarisation of attainment, with 41% of companies excelling whilst 13% having the lowest readiness to industrialise innovation, and the remaining 46% of companies have the potential to develop their capabilities. This readiness gap could be bridged by disseminating best practice via peer-learning together with targeted innovation R&D programmes.



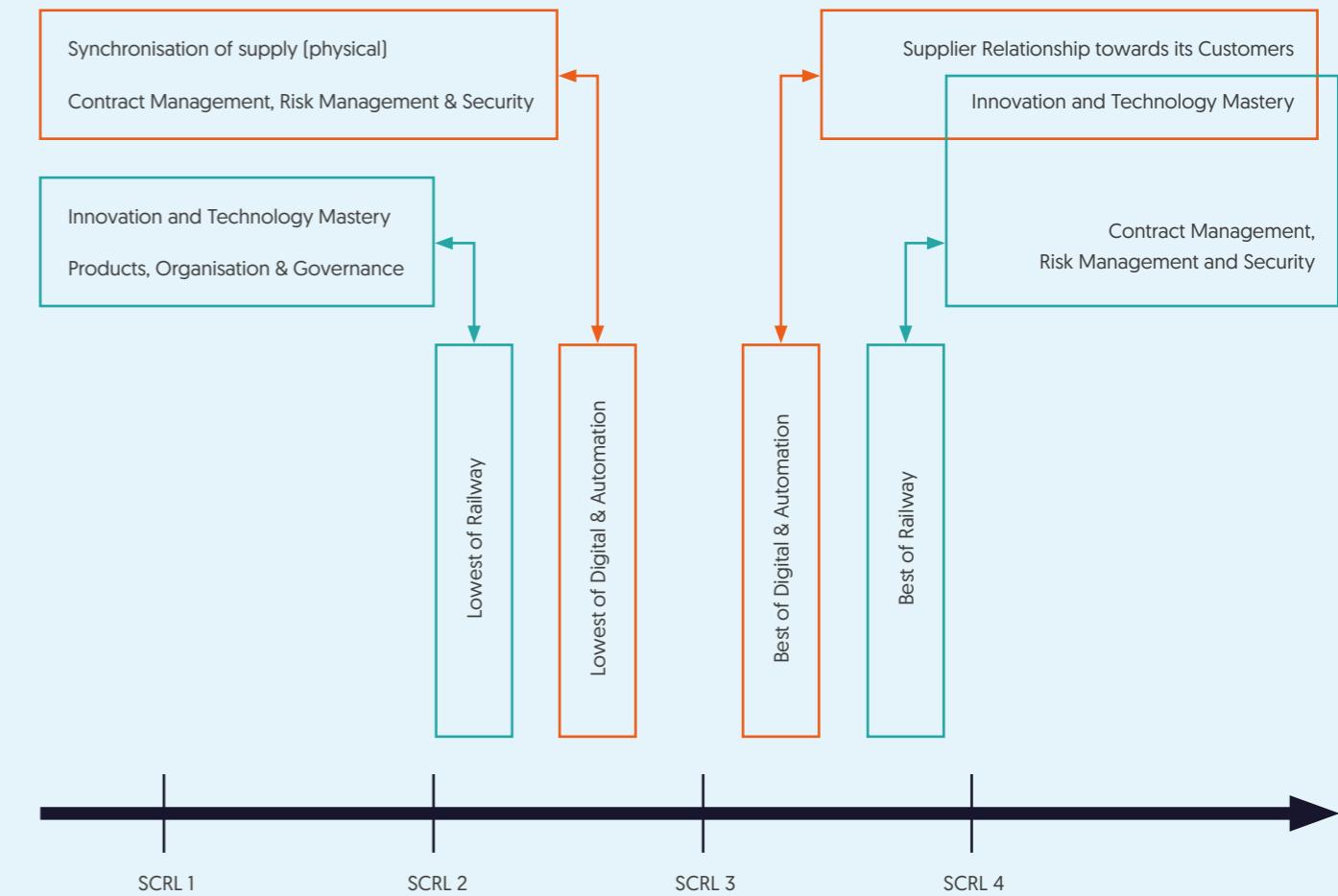
Resilience of value chains is their ability to recover quickly from major market shocks and disturbances in demand and supply. The SCRL methodology has been especially adjusted and extended to provide a measure of resilience, by identifying specific combinations of business capabilities and technologies that contribute towards it and measuring their combined effect, thus resulting in the 'SCRL-Resilience' methodology and toolkit. To the knowledge of the authors, this is the first readiness and resilience focused methodology and toolkit to be made available for deployment within industry sectors and supply chains, addressing a major global industrial requirement.

4.3 Heads and Tails

The analysis of the Railway supply chain assessments demonstrated a significant attainment gap between the best performing (top quartile) and worst performing (bottom quartile) groups of companies, that is wider than that of the Digital and Automation supply chain, as shown in Fig. 3. The best performing Railway companies were assessed as having higher overall readiness than the best group from Digital and Automation. This is significant as it demonstrates that businesses from the 'traditional engineering' sectors can excel in supply chain readiness by having a strategy for the adoption of advanced technologies and the development of advanced practice in key business functions.

Fig. 3 also shows the Threads contributing to high or low readiness attainment, i.e., the Threads with the highest readiness for the high attainment groups and the lowest readiness Threads for the low maturity company groups. The high performers from both supply chains have Innovation and Technical Mastery as common high attainment Thread and this indicates that good performance in this thread is a strong indicator of good overall readiness. The other observation from Fig. 3 is that the Innovation and Technical Mastery and Contract Management, Risk Management and Security appear in both the top and bottom quartiles, indicating their influence to the overall readiness.

Fig. 3. Heads and Tails of Railway and Digital and Automation Supply Chains and Contributing Threads.

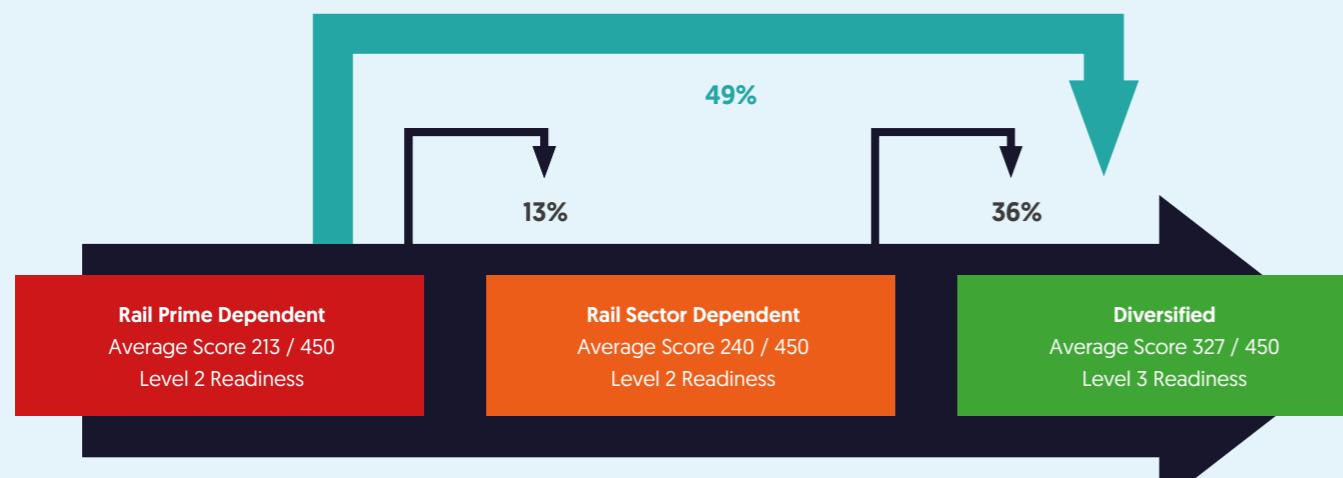


4.4 Contextual Analysis of Findings

The Impact of Diversification of Engineering Supply Chains.

The resilience and readiness assessments were considered within the contextual evaluation of the particular circumstances of the companies assessed. For the railway sector supply chain, the companies can be grouped into three categories, 'Rail Prime Dependent', 'Rail Sector Dependent' and 'Diversified', depending on the rate of their diversification within this rather traditional engineering industry.

Fig. 4. Overall Readiness Levels and Scores of the Three sub-Groups of the Railway Supply Chain.



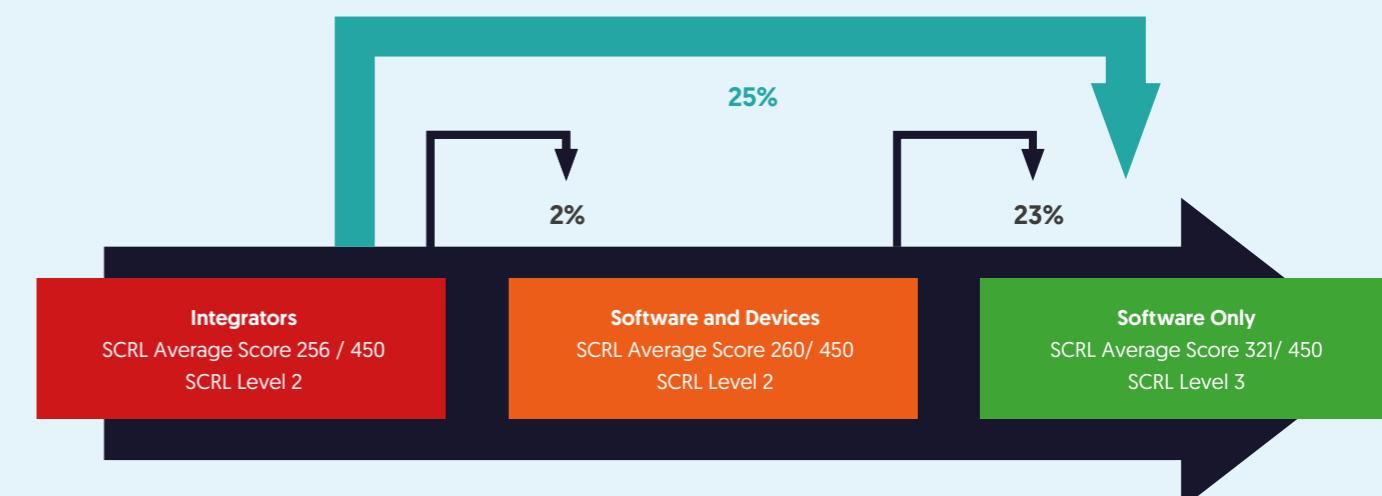
As shown in Fig. 4, the Diversified sub-group of companies achieved an overall SCRL Level 3, and the average SCRL score for this group is 49% higher than the Rail Prime Dependent group that consists of the least diversified companies. Indeed, the Diversified sub-group of the railway supply chain comprises a few high performing companies that top the readiness assessment across both supply chains. The results from the deployment of SCRL have provided evidence that well managed, diversified supply chain companies from the traditional engineering sectors can achieve impressive readiness to adopt new production and

distribution technologies and join new value chains. The partly diversified, 'Rail Sector Dependent' sub-group achieves an intermediate SCRL score, and shares Level 2 readiness with the Rail Prime Dependent group. The fact that there is a positive correlation between increasing business diversification and SCRL score and SCRL readiness levels, serves to validate the SCRL methodology.

Digital Supply Chain and the Impact of Assets

The Digital and Automation supply chain comprised three distinct sub-groups, namely 'Software Only', 'Software and Devices' and 'Integrators' as shown in Fig. 5. The sub-group of Software Only supply chain companies had the highest readiness, reaching an average of Level 3 [Advanced]. The impact of additional complexity as a consequence of dealing with physical assets was clearly demonstrated by the fact that the Software and Devices sub-group had an average overall readiness at Level 2 and a 23% reduction in numerical score readiness when compared to Software Only. The Integrators sub-group had an almost identical to the Software and Devices sub-group average readiness, as shown in Fig. 5 below, as both have to deal with the management and distribution of physical assets. In particular, the high customisation content of Integrators puts additional pressure on the effectiveness of New Product Development and the Sustainability of supply in terms of managing the dependencies on the supply of critical items.

Fig. 5. Overall Readiness Levels and Scores of the Three Sub-Groups of the Digital and Automation Supply Chain



Readiness Gaps Arising from the Analysis of Low Readiness Performance

The analysis of results from the industrial deployment of SCRL identified a number of low attainment areas (represented by SCRL ratings of Levels 1 and 2) that indicate technology and business readiness gaps for the supply chains assessed. For the Railway supply chain, a key finding was that 65% of companies had low levels of maturity in operating a lean supply chain with obvious operational efficiency and productivity implications. The digital integration from production to logistics also had a low maturity attainment level by 65% of companies. Perhaps the most significant finding concerning a readiness gap of the Railway supply chain was that 91% of companies were assessed with low readiness for the implementation of Industry 4.0 technologies.

For the Digital and Automation supply chain, 56% of companies did not have mature and formal product introduction frameworks to assist with the management of product and process development reducing the readiness level of 'New Product Introduction'. For this supply chain, 52% of companies had low maturity ratings for the deployment of continuous improvement and a similar percentage was assessed as having low attainment levels over their control of the supply of critical parts. These low maturity ratings are partly a reflection of the fact that this supply chain is relatively newly established, and the relationships and experience have not developed yet to the point required for agile and sustainable operations and effective product introduction work.

91%

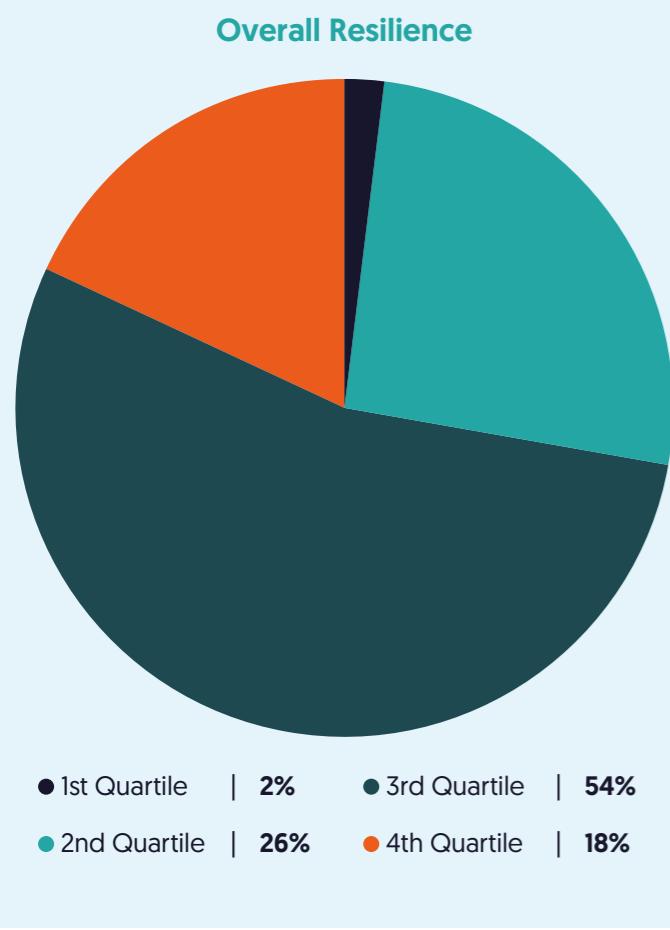
91% of Railway supply chain companies had low Industry 4.0 readiness, indicating the significant effort required to enhance the digitalisation capabilities of these companies to competitive levels.



4.5 The Resilience Assessments

The assessment of resilience resulted in an interesting set of results and perspectives, per company and overall, and enabled the identification of business capabilities in which there were gaps as well as areas of good performance. Fig. 6 shows the overall Resilience assessment for the cohort of companies assessed. 18% of companies reviewed were placed in Quartile 4 (Expert Practice) for resilience, reflecting mature business practice in strategy, innovation and sustainability. 54% of companies were placed in Quartile 3 (Advanced Practice) for resilience, reflecting its growing significance within the UK's business community with good areas of performance including business strategy and the adoption of standards and best practice within the supply chains.

Fig. 6. Overall Resilience Assessment of Supply Chains



1 in 4

More than one in four of companies assessed have their resilience measured in the two lowest quartiles. This increases their business risk and threatens the sustainability of the supply chain.

For the remaining companies, the level of business resilience can best be described as work-in-progress, with 26% of companies classified in Quartile 2 (Building an Understanding) and 2% in Quartile 1 (Generating Awareness). It is reassuring to see the low percentage of companies in Quartile 1, clearly showing that the need for building corporate resilience is now well understood by UK businesses. All these companies have a growing understanding of the importance of resilience for their future survival and growth, but at present they have not developed their relevant corporate capabilities and metrics at the levels required to shield them from volatility in markets and major unexpected events. This leaves them vulnerable and increases their business risk and the overall sustainability of the supply chains.

The analysis of company performance and cohort attainment in the six 'Resilience Threads' helps to identify the resilience attributes in which there is good supply chain performance and also areas in which significant business effort must be directed to bridge shortcomings. 'Strategy' is the business area in which 28% of companies reached 'Expert Practice' level and this is the Resilience Thread with the largest percentage of companies in the top Quartile 4. This strong performance is indicative of the good level of maturity of the strategic capabilities of the companies assessed that can be utilised in the context of enhancing their business resilience.

The Resilience Threads, 'Agility' and 'Sustainability' have been identified as key foci of companies for enhancing their resilience, with 33% and 30% of companies respectively assessed in Quartile 2. In terms of 'Agility', priorities include to shorten product development times and strengthen the operation of the 'learning organisation' by focusing on skills development and providing the training to employees to expand knowledge in required fields. Priority areas for enhancing 'Sustainability' include improving the financial performance of businesses, by using assets efficiently and maintaining a healthy profit margin on sales as well as introducing supply continuity management processes. 'Supplier Intimacy' was also identified as an area for development with 35% of companies assessed in the lowest two quartiles. Business feedback from subsequent work with companies provided more context regarding the importance of being close to the strategic priorities of the key customers and gaining market intelligence. Finally, 'Innovation and Digital Competence' has 8% of companies in the lowest maturity Quartile 1 (Awareness) and this is the highest percentage of all Resilience Threads for Quartile 1. This represents a significant risk to the companies concerned and the supply chain as a whole, and is a consequence of not having started the digital transformation journey and of lacking systematic approaches to the introduction of new technology.

4.6 Industrial Impact and Learnings from the Deployment of SCRL Resilience

The industrial deployment of SCRL Resilience provided unique perspectives into the readiness of two UK supply chains to industrialise innovation or deal with major disturbances. It also gave individual companies a wealth of vital measurements regarding the maturity of their key business capabilities. In the Railway supply chain, a structured development programme was introduced following the SCRL deployment, aiming to get companies to improve their individual readiness from Level 2 to Level 3 in the first instance. The programme also aims to codify the interventions and actions followed for such an improvement in order for this to become a 'how to do it', standard performance improvement process across the Railway supply chain. There has also been an additional cluster of activities focused on the needs of five companies that shared low attainment levels for a common set of sub-threads including logistics and ability to upscale production, digital order processing and introduction of robotic automation. This effort is also progressing, providing individual solutions and also sharing best practice and learnings across the companies involved.

35%

35% of companies were assessed in the two lowest performing resilience quartiles for 'Supplier Intimacy' and this is an area of future development due to the significance of creating and maintaining close, strategic relationships with their key customers and gaining market intelligence.

The Digital and Automation supply chain's strategic objective is to create a regional supply chain that is competitive, nationally and internationally. The deployment of the SCRL Resilience methodology and tool has provided a landscape view of the levels of maturity of key supply chain capabilities, across all companies. Shared strengths were identified that can be built upon to underpin enhanced competitiveness. For instance, for the Software subgroup of companies, four capabilities were identified in which over 60% of companies were assessed at the top, Level 4 readiness; these capabilities were, Industry 4.0 Readiness, Digital Connectivity, Product Lifecycle Management and Understanding and Influencing their Markets. At the other end of the spectrum, a range of common weaknesses were identified across the supply chain. 70% of the Digital and Automation supply chain companies had low readiness assessments in the following capabilities; Agility, Framework for New Product Introduction, Lean and Continuous Improvement. These results underpinned a regional supply chain strategy that is focused on developing the cluster's capabilities, retaining best performing businesses, and attracting new competitive companies to join the supply chain.

5.0

CONCLUSIONS AND KEY POINTS

The SCRL methodology is a strategic tool used for the assessment of the readiness of individual companies within a supply chain and provides an overall, landscape view assessment of the readiness of the whole supply chain. In essence, SCRL assesses the supply chain's readiness to industrialise Innovation and operate at world class standards. The methodology has been specifically adjusted to provide a measure of resilience of individual companies of a supply chain and also provide the overall resilience assessment of the supply chain. The approach is based on capturing key capabilities and attributes that are relevant for a systems-level evaluation of readiness and resilience. SCRL can be deployed as a front-end tool during the design of new supply chains or the re-engineering and performance enhancement of legacy supply chains.

The SCRL methodology allows for the early identification of potential gaps in the capability and capacity of supply chains to deliver innovative products at the required quality and volumes, align with the requirements of new sectors and markets and deal with major market disturbances and shocks. For instance, SCRL is particularly well suited to investigate and mitigate the impact of disruptive changes to supply chains, due to electrification in transport or the repurposing of knowhow and production capabilities post Covid-19. The supply chain owner and/or individual companies can then drive technological improvement & innovation in a structured and collaborative way, to address the identified gaps and reduce business and technology risks.

The SCRL-Resilience methodology and toolkit were deployed for the purpose of industrial testing and evaluation of two supply chains and the results have proven the validity of the approach, with the follow-on work with the companies involved verifying the key findings. This is highly significant as this is the first ever industrially deployable methodology that assesses readiness and resilience within supply chains. The MTC has an active supply chain development programme working with key manufacturing sectors of the UK and the SCRL methodology is an integral part of this programme. The intention is to accelerate and widen the industrial deployment of the SCRL-Resilience methodology in order to deliver the maximum possible benefit to the competitiveness and sustainability of our industrial sectors.

Acknowledgements and Contributions

The authors received support and advice from a number of MTC colleagues in the preparation of this paper and the related work. In particular, contributions from the following colleagues are gratefully acknowledged; Steve Smith, Chris Owen, Nigel Haigh and Kit Lee.

