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The manufacturing resilience dashboard – compass and radar navigation through uncertainty

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ABSTRACT

Global manufacturing value chains are exposed to various risks making them vulnerable and requiring them to strengthen their resilience. However, manufacturing companies are not equipped with the right tools to navigate uncertainties and assess their resilience capabilities. This paper builds on a previously developed IDEF0 resilience model and provides a holistic resilience measurement tool called the 'resilience dashboard' comprising a compass and a radar. This navigational tool assists manufacturing companies in assessing their current and desired future resilience states, enabling them to develop and deploy resilience capabilities across three temporal stages of anticipation, coping, and adaptation. By preparing for and mitigating risks of varying frequency, severity, and sources, the tool can enhance manufacturing resilience in dynamically changing environments.

1. Introduction

The EU's Green Deal [1] aims to achieve a carbon neutral Europe by 2050 and is a strategy to implement UN's 2030 Agenda [2]. Specifically within the EU's strategic foresight agenda [3] lies the concept of resilience, which has been highly prioritised as a means to strengthen EU's response to vulnerabilities due to climate change, post-Covid, demographic challenges, etc. whilst achieving green and digital dual transitions. Monitoring resilience progress and developing resilience capabilities may be the only way to address emerging risks and contribute positively to growing sustainability needs.

This paper provides a holistic measurement tool called the resilience dashboard that comprises a compass for developing resilience capabilities [4] and a radar to deploy resilience capabilities to mitigate risks. The resilience dashboard can be utilized by manufacturing companies to navigate uncertainties, develop resilience strategies tailored to time-dependent stages of resilience, i.e., depending on when disruptions occur, and visualise which capabilities need to be prioritised when disruptive risks occur. This proactive approach can give manufacturing companies a competitive advantage by enabling them to stay ahead of their rivals.

2. Related work

A search in the SOTA shows that several resilience assessment tools [5–8] and frameworks [9] for resilient manufacturing exist, but these do not take into account a comprehensive view of the capabilities required at various temporal stages nor when these capabilities should be deployed in response to uncertain risks, and cannot easily be visualised and applied especially in manufacturing organisational contexts (development and deployment of resilience capabilities). And although a resilience dashboard [10] and compass [11] exist at the policy level, they do not provide a holistic view of current and future resilience capability levels (a sense of direction) that encompass temporal stages of resilience. In addition, these measurement instruments do not specifically address manufacturing needs and how the capabilities relate to mitigation of risks.

3. Methodology: the resilience dashboard design and application

The resilience dashboard comprises a compass and a radar (Fig. 1). The compass [4]—based on a previously developed IDEF0 resilience model [12]—is a resilience assessment tool that can provide manufacturing companies with a sense of direction on their current and desired future resilience capability implementation levels, much like a compass is used as a navigational aid. The compass encompasses three temporal resilience stages (anticipation,

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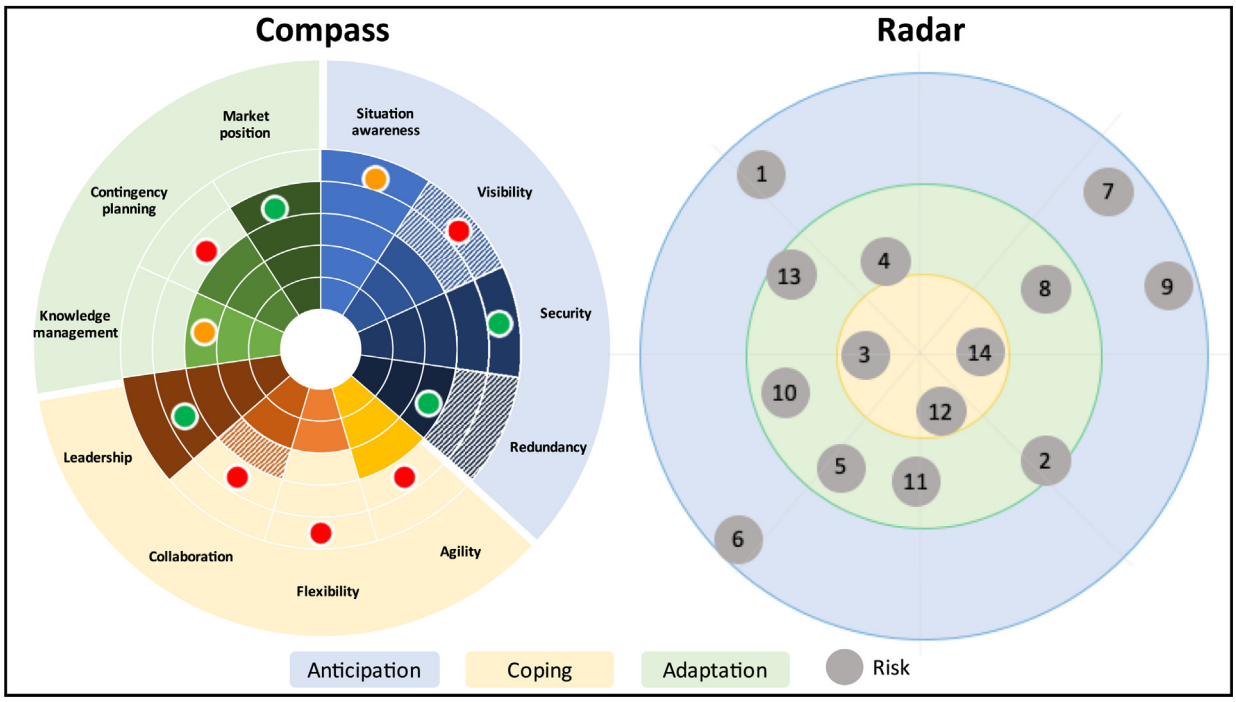

Fig. 1. The resilience dashboard applied in the automotive company (left: compass, right:radar).

coping and adaptation), 11 dynamic capabilities and 54 practices for manufacturing resilience. Anticipation capabilities can help build 'resilience potential' [13] which are foundational capabilities. Four capabilities were identified in the anticipation stage: situation awareness, visibility, security and redundancy. Coping capabilities can help organisations deal with disruptions in real-time (as they occur) and four were identified in this stage: agility, flexibility, collaboration and leadership. Adaptation capabilities can help organisations learn, adjust to critical conditions and transform, and three were identified in this stage: knowledge management, contingency planning and market position.

To assess resilience capability levels in current and desired future states using the compass, companies rate practices from 0 (not ready for implementation) to 5 (always implemented). The dark bands represent the average current scores, while dashed bands indicate the maximum score (5). Capability scores are averaged from individual practice ratings. Dots highlight gaps between current and future states, with thresholds visualized as green (<0.5 difference, no additional investment needed), orange (<1, improvement possible but not urgent), and red (>1, requiring resource allocation to enhance resilience capabilities). Additional details can be found in [4].

The resilience radar helps companies detect risks and deploy dynamic capabilities (assessed via the resilience compass) to mitigate them. It complements risk assessment methods like HIRARC (Hazard Identification, Risk Assessment, Risk Control), FMEA (Failure Mode Effect Analysis), and FTA (Fault Tree Analysis), which analyze risk likelihood and impact. Positioned at the radar's center, a company faces various risks: those in the anticipation phase can be mitigated proactively, while adaptation-phase risks require operational transformation based on past experiences. Risks in the coping phase demand reactive responses, limiting learning opportunities. However, low-priority or infrequent risks may remain in the coping phase without major disruption. The goal is to transition from coping to adaptation and ultimately anticipation, especially for high-severity risks.

4. Value of using the resilience dashboard

The resilience dashboard was implemented in two phases across six discrete manufacturing companies in four EU manufacturing domains—aerospace, machine tools, e-mobility, and automotive—under the RE4DY project [14]. This paper focuses on an assessment at an automotive assembly plant aiming to enhance logistics quality and cost by improving supply chain visibility and resilience.

In the first phase, the resilience compass (left of Fig. 1) assessed current and desired resilience capability levels. The compass shows the company's priority to enhance agility and collaboration (marked in red), while flexibility scored lower but was deemed less relevant in their context. A full score of 5 was not necessary for resilience at a given stage, indicating satisfaction with existing capability levels and no immediate investment plans.

The second phase applied the resilience radar (right of Fig. 1), identifying and mapping 14 organizational risks (Table 1) based on frequency, severity, category (organizational, industrial SC, environmental SC), type (operational, system, demand, policy, etc.), and impact level [15]. For instance, the company leveraged situational awareness capabilities to anticipate R#1 by monitoring technological developments. R#2 was addressed through adaptation capabilities like knowledge management and contingency planning. R#3, a high-frequency, medium-severity risk affecting the supply chain, led to production disruptions due to material shortages, managed primarily through redundancy strategies.

The dashboard facilitated capability-risk connections, prompting considerations for Industry 4.0 technologies to enhance anticipatory analysis and production system redesign via simulation-driven insights. These improvements support adaptive logistics, optimizing production responses to disruptions. The company recognized the dashboard's value in strengthening resilience, fostering innovation, digitalization, and adaptability in a VUCA environment. Beyond logistics, the findings were relevant at the board level, with applications across business functions. At the

Table 1
Risks identified in the automotive case company of the RE4DY project.

No	Risk	Frequency	Severity	Risk Category	Risk Type	Impact Level
1	Technological advancements in core automotive technologies	Low	High	Industrial (Within SC)	Demand	Factory
2	Damage (supplier or plant premises) to infrastructure and/or material triggered by natural causes (supplier or plant premises)	Low	High	Environmental (Outside SC)	Disruption	Factory, supply chain
3	Delivery issues caused by delays on external supply chain, or damages to parts/containers, specifically with regards to incoming material moving by any means of transportation, earth, sea or air	High	Medium	Environmental (Outside SC)	Disruption	Supply Chain
4	Suboptimal logistics configurations	Low	Medium	Industrial (Within SC)	Operational	Worker
5	Accident in logistics equipment within plant premises	Low	High	Organisational (Within firm)	Operational	Machine
6	Suboptimal engineering configurations when releasing parts for production such as technical configurations	Low	High	Organisational (Within firm)	System	Worker
7	Misinterpretation of line feeding or sequencing tasks caused by logistics service provider	Low	Low	Organisational (Within firm)	Operational	Supply Chain
8	IT issues (locally)	Low	Medium	Organisational (Within firm)	Cybersecurity and safety	Factory
9	Malfunction of automation devices	Low	Medium	Industrial (Within SC)	Operational	Machine
10	Accidents caused by human errors	Low	High	Environmental (Outside SC)	Disruption	Factory
11	Raw material shortage	Low	High	Industrial (Within SC)	Demand	Supply Chain
12	Geopolitical issues between neighbouring countries or internal political policies	Medium	High	Environmental (Outside SC)	Policy/Regulation	Supply Chain
13	Issues with parts quality invalidating bulk or big batches of parts	Medium	Medium	Industrial (Within SC)	Operational	Supply Chain
14	IT issues (headquarters)	Low	High	Organisational (Within firm)	Cybersecurity and safety	Factory

material supply level, the dashboard improved visibility into geopolitical volatilities, reinforcing the company's risk management strategies.

Dashboard assessments across the other manufacturing domains identified key risks and technological solutions but lack direct comparability due to differences in domain characteristics, company size, and location. Details of the differences in resilience capability levels across the domains can be found in [4]. In the e-mobility firm, supply chain dependencies posed major risks, with delayed assembly parts disrupting production; digital twins were explored to anticipate disruptions. The machine tool company prioritized anticipatory risks from EU classification of key raw materials as carcinogenic, necessitating a full production overhaul—less amenable to technological mitigation. In aerospace, expertise loss from workforce turnover was critical, prompting AI-powered training to enhance adaptive or learning capabilities. Predictive expertise from these efforts could support supply chain modeling and ERP/MES integration. Overall, the companies prioritized investments in anticipation capabilities and related technologies to mitigate risks before they could disrupt their organizations. However, transformative or adaptation capabilities were also considered essential for managing certain known risks.

5. Discussion and conclusions

This paper provides a resilience dashboard that can support manufacturing companies to navigate uncertainties, develop dynamic capabilities and deploy them for risk mitigation. The resilience dashboard is designed to be holistic in nature – resilience practices and capabilities have dependencies and interrelatedness, and these are categorised under three temporal stages. Such a categorisation can help begin resilience capability implementations in manufacturing companies [4]. However, the capabilities can be categorised under more than one stage based on the type of practice performed. For instance, flexibility was originally categorised under coping, but it could also be an anticipation capability when production systems are designed to accommodate multiple products, real-time changes [16] and so on. The dashboard, designed for discrete manufacturing, allows adaptability by modifying resilience practices. Companies can suggest additional practices, enabling customization for the process industry. Ongoing work aims to extend its applicability to general organizational contexts. The dashboard enables domain-specific benchmarking, helping companies identify frontrunners and laggards for targeted improvements.

The resilience dashboard, when integrated into digital platforms [12] can provide real-time data access not only to manufacturing companies but also to their supply chain stakeholders, enhancing decision-making in dynamic environments. This will be tested in future work. Additionally, aggregate indicators that quantitatively measure resilience can complement the holistic value of resilience-building offered by the dashboard.

CRediT authorship contribution statement

Arpita Chari: Writing – original draft, Validation, Investigation, Conceptualization, Writing – review & editing, Visualization, Methodology, Formal analysis. **Johan Stahre:** Writing – review & editing, Resources, Methodology, Conceptualization, Supervision, Project administration, Funding acquisition. **Mélanie Despeisse:** Visualization, Writing – review & editing, Supervision. **Björn Johansson:** Writing – review & editing, Funding acquisition, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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