Designing a Use Case for Supply Chain Resilience Based on Process Mining

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ABSTRACT
Amidst global disruptions, the significance of Supply Chain Resilience (SCR) has surged in scholarly and practical discourse. This paper endeavors to craft an industry-neutral conceptual dashboard, tailored for in-house consultants, to measure and oversee SCR. Drawing from the SCOR model's resilience metrics, Key Resilience Areas (KRAs), and Accenture's SCR application, this study presents a practical use case for deploying such a dashboard. Expert evaluation by process mining and supply chain specialists highlighted potential enhancements for the dashboard.

INTRODUCTION

In recent times, a series of events took place that have captivated economies worldwide and triggered major global repercussions. These events, which range from political conflicts to natural disasters, have caused substantial disruptions in global supply chains (SCs), affecting everything from raw materials, movement of people to finished goods and SC operations (Sheng et al., 2020). Such events prove relentlessly that "we live and operate in an ever-changing and turbulent environment" (Neubauer, 2018).

As a consequence of the growing frequency and size of SC disruptions, companies are facing significant challenges due to continuous changes in consumer behaviors, markets, and SCs, leading to an imbalance in their operations. Consequently, the concept of Supply Chain Resilience Management (SCRM) has garnered considerable attention in recent times. Global SCs have been made public by events like the COVID-19 pandemic, emphasizing the urgent need for enterprises to proactively manage SC risks (Bret et al, 2021). These destabilizing effects have highlighted how crucial it is to establish robust supply networks that can take shocks, quickly adapt to changing conditions, and recover effectively. The speed and magnitude of these changes necessitate swift responses from leaders who must embrace agile methodologies and accelerate the transformation of their chains. Enhancing the resilience of processes involves applying new insights and abilities while adopting alternative measurements for process-focused performance (Schätter et al, 2022). Additionally, robust data and analytics capabilities are crucial for comprehending complications, anticipating potential disruptions, and rapidly formulating effective strategies in response (Accenture, 2023). Resilience is both defined as a capacity that is developed in response to a shock or disruption and as being more pro-active in helping the company get ready for a disruption (Melnyk et al, 2014). The capability to learn from past disruptions to be able to predict and overcome future disruptions, by reducing the level of risk and being aware of the SC's vulnerabilities (Aman & Seuring, 2021). Therefore, being aware of SC vulnerabilities and possible risks can increase the effectiveness of the response to future disruption, mitigate its damage and restore the state of the SC.

On the other hand, over the past two decades process mining (PM) has emerged as a particularly promising contender and as a relatively new field of study that falls somewhere between process modeling and analysis, computatational intelligence, and data mining (van der Aalst et al., 2012). PM aims to identify, monitor, and improve business processes by extracting data from the event logs that are easily accessible in today's information systems. Event data has drastically increased in the past decades, and subsequently many PM techniques have also advanced significantly. Thus, PM has become highly important in management trends that are concerned with process improvement (van der Aalst, 2012; van der Aalst, 2016).

The foundation of PM is an event log, which contains events that relate to a specific process instance aka *a case* and refers to a clearly defined step in a process aka *an activity*. In other words, a case is a specific identifier, similar to an item from a purchase order, an invoice, or an order number, while an activity is a description of what took place, such as when a purchase order was created or when goods were received. It is necessary to chronologically order and consider all of the events that were connected to one case as "one run" of a process. Nevertheless, event logs can hold further information related to the events, such as *a timestamp* that indicates when an event has occurred, details about the resource i.e., device or person that is initiating or performing the activity, or *data elements* recorded along with the event (van der Aalst, 2012).

The information gathered from event logs is usually presented on dashboards, so that the person responsible can quickly identify issues and take corrective actions to help the organization perform better (Rasmussen et al., 2009, p.3). Pauwels et al., (2009) defines a dashboard as a reasonably compact group of linked key performance indicators and fundamental performance drivers that represents both immediate and long-term objectives and can be viewed by all members of the organization. A dashboard is a visual representation of the most crucial data required to accomplish one or more goals, collected, and organized on a single screen for easy monitoring (Few, 2006, p.26). Managers frequently use dashboards to monitor a company's performance, and since the COVID-19 pandemic, their use has increased (Reibstein et al., 2023). Dashboards can be categorized based on their level of detail and timeframe into strategic, tactical, and operational tiers (Few, 2006, p.33).

This paper aims to design a conceptual industry-neutral SCRM dashboard for the Purchase-to-Pay (P2P) process based on the event log used in PM. Tailored for in-house consultants at the mid-level management, the mockup dashboard aims to address challenges in ensuring uninterrupted supplies during unforeseen disruptions from the side of inbound logistics. Consequently, the objective of the paper is to answer the following research questions:

1. *How can insights into the resilience of the supply chain through the P2P process be obtained using an SCRM dashboard conception, considering a specific use case?*

2. *Which opportunities and limitations does the dashboard offer for resilience management of the P2P process from a tactical or strategic point of view?*

This paper stands out because it consolidates various resilience-focused theoretical concepts, forming a robust foundation for crafting a mockup dashboard for SCRM. Notably, it stands as a pioneering work by relying on the newest version of the SCOR model, introducing a redefined resilience performance category. This category further breaks down into three distinct sections, encompassing a broader range of metrics across diverse supply chain processes.

Interestingly, there's a noticeable gap in existing literature where no prior papers have delved into the design of such a dashboard, let alone the creation of a mockup that could serve as a visual aid for practitioners. The objective was to illustrate how an SCRM dashboard could be tailored to cater to users at both strategic and tactical levels, potentially leveraging the capabilities of process mining. While the dashboard includes certain design principles and heuristics, its primary aim was to offer a visual summary, essentially acting as an initial framework for an IT artifact. Furthermore, expert evaluation was conducted to gain deeper insights into the essential components that such SCR dashboards should encompass.

Throughout this entire process, our endeavor remained guided by the seven principles of Design Science Research (DSR), ensuring a systematic and methodical exploration of creating and evaluating this innovative IT artifact for SCRM (Hevner et al. 2004 ; Peffers et al., 2007). However, the structure of this paper doesn't strictly adhere to the predefined process activities of DSR. Instead, it incorporates and considers these principles when designing the mockup dashboard for SCRM, aligning with the advice of Hevner et al. (2004) who encourage flexible incorporation rather than strict adherence to predefined steps. Elaborating extensively on DSR principles might potentially divert attention from our main objective, which is to showcase the development and evaluation of this innovative IT artifact for SCRM.

PRACTICAL MEASURES OF SCR

In the ever-evolving landscape of global commerce, ensuring the resilience of a SC has become a paramount concern for organizations across industries. To address this challenge, a multitude of frameworks, solutions, and metrics have been developed and proposed in the academic and business literature. When designing a mockup dashboard for supply chain resilience management, it is essential to select the most effective and globally recognized tools. In this endeavor, we turned to the Supply Chain Operations Reference (SCOR) model, a framework widely adopted worldwide for SCM (ASCM, 2022). Additionally, we incorporated the Key Resilience Areas (KRAs) concept, a set of practical measures devised by Schätter et al. (2022), to help organizations pinpoint vulnerabilities within their SCs and evaluate their current state. This combined approach provides a comprehensive foundation for enhancing SCR and serves as the backbone for the subsequent sections that delve into the specifics of SCOR model resilience metrics and the utilization of KRAs in this context.

SCOR Resilience Metrics

The SCOR model is a comprehensive framework that provides organizations with a standardized approach for managing and improving their SC processes. Developed in 1996 by the Supply Chain Council, the SCOR model offers a common language and set of metrics to define, measure, and evaluate SC activities (Selitto et al., 2015). Its newest version, SCOR 14.0, outlines seven key SCM management processes: Orchestrate, Plan, Source, Transform, Return, Fulfill, and Order. These processes cover the end-to-end SC, from strategic planning and sourcing of materials to manufacturing, logistics, and customer service (ASCM, 2022). The SCOR model enables organizations to map and analyze their SC operations, identify areas for improvement, and optimize performance. By aligning with the SCOR model, businesses can enhance collaboration, increase efficiency, and achieve greater SC visibility and control. It serves as a valuable tool for organizations across industries seeking to optimize their SC operations and drive competitive advantage (Phadi & Das, 2021).

Within the SCOR model, the Performance section places emphasis on measuring and evaluating the results achieved through the execution of SC processes. This approach enables a thorough examination, evaluation, and diagnosis of SC performance. By considering these elements, organizations can successfully measure the effectiveness and efficiency of their SC operations and identify areas for improvement. Performance measurement is done by performance attributes which include various metrics. In fact, each attribute has three levels of metrics that function as diagnostic for the previous level. Therefore, Level-3 metrics act as diagnostic indicators for Level-2 metrics and so on. This provides valuable insights into the overall performance of the SC and enables organizations to identify areas for improvement or address performance gaps at various levels (ASCM, 2022).

SCOR 14.0 has redefined their performance attributes by categorizing them under Resilience, Sustainability, and Economic performance. The focus will be on resilience-only performances, for the purpose of this paper. The model provides three sub-attributes under "Resilience", this are Reliability (RL), Responsiveness (RS), and Agility (AG). Below you can find the description of each resilience attribute:

<u>Reliability (RL)</u>: Deals with the ability to execute tasks in accordance with established expectations. It concerns ensuring the predictability of process outcomes. Key metrics associated with Reliability encompass the timely delivery of products or services, meeting the prescribed quantity, and providing accurate documentation.

<u>Responsiveness (RS)</u>: Focuses on how quickly tasks related to customer orders are completed. It looks at how fast businesses can respond and satisfy customer needs.

<u>Agility (AG)</u>: Describes the ability to respond to unplanned external influences, disruptions and/or events.

Key Resilience Areas (KRAs)

The paper by Schätter et al (2022) "Supply Chain Resilience Management Using Process Mining" aims to identify relevant data needed for strategic monitoring of resilience status and provide a base for using PM in SCRM. The result is eight distinguished KRAs, which help to have an initial understanding of the state of the SC, and is easier to apply than more complicated analytical methods. Below you can find a short description for each of the KRAs:

- *KRA1 - Geographic Distribution*: Provides visibility into the locations and distribution of entities, for example assessing the risk of disruptions due to supplier concentration in one specific area or country.
- *KRA2 - Sourcing Strategy*: Evaluates the impact of supply disruptions by analyzing material sourcing strategies, with a focus on single-sourcing vs multi-sourcing approaches.
- *KRA3 - Warehouse Materials*: Enhances resilience through buffer stocks of critical materials in warehouses, ensuring SC continuity.
- *KRA4 - Average Storage Time*: Measures the average time materials are stored in warehouses to identify critical materials and assess buffer effectiveness.
- *KRA5 - Transport Delays*: Identifies critical transport relations by analyzing delivery durations and assessing delay-prone materials.
- *KRA6 - Consolidation of Deliveries*: Promotes cost-effective and resilient SC practices by consolidating (combining) material deliveries.
- *KRA7 - Transport Distance*: Analyzes transport distances and regional deliveries to reduce the risk of large-scale disruptions.
- *KRA8 - Intra-Logistics Processes*: Offers transparency into internal supply chain processes, assessing dependencies on critical materials and revealing potential weaknesses.

PM DASHBOARD FOR SCRM

Integration of resilience concepts

The theoretical foundation of the research is composed of three fundamental concepts that were discussed in the previous chapters. These concepts include SCR, the SCOR model along with its resilience attributes, and the KRAs. Notably, Accenture's SCR application significantly contributed to the conceptual development of the SCRM mockup dashboard. This application was developed in collaboration with Celonis, a leading process mining vendor, and aims to assist companies in enhancing their SCR by leveraging real-time data on disruptive events, conducting SC operational risk, assessment, and providing intelligent solutions to mitigate disruptions (Celonis, n.d.).

Throughout the course of the research, collaborative discussions were held with the Process Mining Capability Lead for Europe, who played an important role in clarifying the concept of SCR. Mr. Being directly involved in the development of Accenture's application, he provided valuable insights, and expertise that greatly influenced the design of the mockup dashboard.

The SCRM mockup dashboard drew inspiration from Accenture’s application and skilfully incorporated theoretical insights from the SCOR model, KRAs, and various other elements such as OLAP tables and visualizations that are often included in PM solutions. Although we were granted access to Accenture’s application, its functionality and elements served as an inspiring reference rather than a direct replication.

Due to the inherent complexity of covering the SC from end-to-end, it became necessary to narrow the scope of the research. Consequently, it was decided that the mockup dashboard would be industry neutral, offering greater flexibility and standardization, particularly in integrating the resilience metrics from the SCOR model. During the process of considering Accenture's application as a reference for the dashboard design, a thorough analysis of its functionalities revealed a primary focus on tracking external risks associated with suppliers, materials, and supplier's plants, predominantly covering the inbound logistics aspect of the SC. As a result, while narrowing the scope, the decision was made to concentrate on the inbound logistics, requiring the selection of a specific process within this domain. Additionally, Accenture's application was primarily designed to cater to users at the operational level, facilitating immediate action to prevent disruptions. However, for this conceptual dashboard the focus shifted to mid-level management, envisioning the end-users as in-house consultants. In this role, they would be responsible for investigating any anomalies and disruptions, and subsequently reporting their findings directly to the executives.

The final step in delimiting the scope was to select an appropriate process within the inbound logistics domain that would serve as the foundation for the envisioned dashboard’s construction. This selection would determine the specific resilience metrics and elements incorporated into the dashboard. The procedure of selecting the process is discussed in more detail within the following subchapters.

Selection of P2P process for the Use Case

The decision to focus on the P2P process for the use case and the dashboard design was carefully considered, driven by practicality and strategic intent. The P2P process, also known as procure-to-pay, is a fundamental and widely adopted component in SCs across various industries. It refers to the procurement activities of companies, and with the increasing digitalization, businesses have developed systems to track the P2P process from end to end, covering everything from requisitioning goods and services to payment to suppliers. These systems offer numerous benefits, including high-cost savings, increased efficiency, and enhanced procurement and financial visibility. In addition, their aim is to optimize the entire purchasing process and streamline operations (Barton, 2023).

Among the various solutions, Celonis offers to its clients, one focuses on procurement, specifically for the P2P process, and has accumulated numerous success stories. As part of its offerings, Celonis Academy provides a P2P demo, which effectively showcases how PM can be applied to enhance the P2P process. Within this demo, a simplified specified "to-be" P2P process model is included. Since the research did not center around a specific company, this process model served as an example for visualizing the activities within the P2P process. Additionally, when selecting resilience-related metrics from the SCOR model, this process model was taken into consideration. Taking into account Accenture’s SCR application and the domain of inbound logistics, the procure-to-pay (P2P) process seemed like a reasonable choice for the use case and the design of the mockup dashboard.

P2P and the SCOR Model

The SCOR model categorizes six major processes at Level - 0 and 1, namely Orchestrate, Plan, Order, Source, Transform, Fulfill and Return. Among these processes, the Source process emerged as the most suitable in the context of the research, specifically within the inbound logistics domain. The Source process encompasses a series of activities associated with procurement, order placement, order scheduling, handling deliveries, receipt of goods and services, and their subsequent transfer within the SC. It is further broken down into four sub-processes: S1 Strategic Procure, S2 Direct Procure, S3 Indirect Procure, and S4 Source Return (ASCM, 2022).

Nevertheless, the SCOR model does not directly and explicitly cover the P2P process, since the process itself falls within the activities listed under the Source process. In the attempt to find a process that closely resembled or effectively covered the P2P process, after careful consideration, the S2 Direct Procure was selected, which by the definition is the procurement process for acquiring products or services that are part of the final product. The S2 Direct Procure includes multiple activities organized in a hierarchy as follows: S2.1 Establish Order Signal, S2.2 Schedule Product Delivery, S2.3 Manage Inbound Transport, S2.4 Receive Product, S2.5 Inspect and Verify, S2.6 Transfer Product, and S2.7 Authorize Supplier Payment (ASCM, 2022). Subsequently, from the listed activities only the first five were considered as they matched the nature of the activities from the P2P process. Subsequently, S2.6. Transfer Product and S2.7 Authorize Supplier Payment were not considered when it came to the selection of the resilience metrics. Therefore, with the selection of the S2 Direct Procure process as a surrogate for the P2P process it was possible to identify resilience-related metrics.

After choosing the process S2 Direct Procure and the subsequent sub-processes that applied to the P2P process, the metrics related to the resilience performance attributes were selected. Later, these metrics were incorporated into the design of the mockup dashboard. Given the abundance of resilience metrics available, it was essential to narrow down the choices while ensuring an adequate representation of metrics falling under the resilience performance attributes. To achieve this, each metric’s description and formula provided by the SCOR model was considered, ensuring that the chosen metrics capture the essence of reliability, responsiveness, and agility within the process (Table 1).

Reliability	
Metric	**Description**
RL.3.13 Delivery Item Accuracy from the Supplier	The percentage of orders in which all items ordered from the supplier are the items actually provided and no extra items are provided.
RL.3.14 Delivery Quantity Accuracy from Supplier	The percentage of orders in which all quantities delivered by the supplier match the ordered quantities, within mutually agreed tolerances.
RL.3.15 Supplier Achievement to Original Organization Commit Date	The percentage of orders that are received by the organization's commit date.
RL.3.16 Delivery Organization Location Accuracy	The percentage of orders that are delivered to the correct organization location.
RL.3.46 Fill Rate	Fill rate, from the supplier's perspective, is a measure that quantifies the level of order fulfillment achieved within a specific timeframe, typically expressed as a percentage.
Responsiveness	
RS.3.37 Average Days per Schedule Change	Number of days each schedule change impacts the delivery date/Total number of changes.
RS.3.38 Average Release Cycle of Changes	Cycle time for implementing change notices/Total number of changes.
Agility	
AG.3.6 Additional Source Volumes Obtained in 30 days	Additional source volumes determined.
AG.3.12 Current Source Volume	Amount of each item purchased.

Table 1: Selected metrics from the SCOR model. Adapted from ASCM (2022)

In addition to the metrics selected from the S2 Direct Source, the mockup dashboard also incorporates higher-level metrics that enhance its comprehensiveness. Among these metrics is the Level 1 metric for reliability, denoted as RL.1.2 Perfect Supplier Order Fulfillment. This metric gauges the extent to which supplier orders fulfill delivery expectations, encompassing accurate documentation, complete deliveries, and absence of damage. In the context of the mockup dashboard, this metric portrays the collective effectiveness of all suppliers in meeting order fulfillment requirements. Furthermore, the dashboard integrated the Level 2 metric for reliability, RS.2.2 Source Cycle Time. This metric, which represents the average duration for completing Source processes, has been strategically adapted in the dashboard as the "Order Fulfillment Cycle." Through this translation, it signifies the average time suppliers take to fulfill orders (ASCM, 2022). The inclusion of these additional metrics underscores the dashboard's aim to provide a holistic view of supplier performance and order fulfillment dynamics.

P2P and KRAs

The last theoretical concept that was considered within the creation of the mockup dashboard were the KRAs, which were developed as a conceptual framework for evaluating the current state of SCR. The KRAs have been designed to identify and assess any vulnerabilities within the SC that could impact its operations during a disruptive event. Based on the nature of the P2P process, three specific KRAs were carefully selected and considered in the design phase of the mockup dashboard. Below you can find the selected KRAs for the P2P process along with the reasoning behind the choice:

KRA1 - Geographic Distribution of Entities is focused on gaining visibility into the locations and distribution of entities within the SC, such as factories, warehouses, suppliers, and customers. Understanding the geographic spread of these entities provides an initial indication of the SCR. For instance, identifying large concentrations of suppliers in specific 53 areas can highlight potential risks of significant disruptions if a risk affects an entire region (Schätter et al., 2022). Furthermore, KRA1 in the context of the P2P process, proves essential as it offers a comprehensive overview of all suppliers and their respective locations, including their density. For instance, if a company heavily relies on suppliers concentrated in a specific area or country, a disruptive event like an earthquake or a flood could pose significant risks. Such an event may damage not only the suppliers' warehouses but also disrupt the overall infrastructure of the affected country, consequently impacting the flow of materials within the SC. Additionally, it could present challenges in promptly finding alternative suppliers to ensure uninterrupted delivery of goods.

KRA2 - Sourcing Strategy of Materials is focused on assessing the impact of the sourcing strategy for materials within the SC. While a single-sourcing approach may offer some cost benefits, it also poses significant risks in managing supply disruptions. In such cases, there might be no redundancies for these materials, leaving the SC vulnerable to shortages in case of supplier failures (Schätter et al., 2022). Based on the description of KRA2, it is evident that it holds significant relevance for the assessment of the P2P process, given its direct involvement with sourcing strategies of materials. This aspect proves valuable in evaluating the resilience state, particularly when a manufacturer heavily relies on a single supplier for a critical material. If the sole supplier faces external or internal challenges and becomes unable to fulfill its obligations, it could potentially lead to severe disruptions for the manufacturer. To mitigate this risk, it becomes imperative to proactively minimize dependency on a single supplier by diversifying the sourcing strategy and identifying alternative suppliers in advance.

KRA5 - Transport Delay is focused on evaluating transport delays within the SC. If target data about delivery durations are compared with actual delivery durations, the delays within the SC can become evident. Nonetheless, based on this critical transport relations can then be identified (Schätter et al., 2022). Receiving purchase orders (POs) on time is of crucial importance for ensuring the seamless flow of operations for businesses. Consequently, KRA5 proposes a critical aspect that must be carefully considered within the P2P process, which involves analyzing the promised and actual delivery dates of suppliers. By relying on such data points, companies can make informed decisions about the reliability of suppliers in fulfilling their committed delivery dates. Such analysis empowers businesses to take appropriate actions, whether it involves continuing to work with dependable suppliers or reevaluating their partnerships with those who consistently miss their delivery commitments.

Mockup Dashboard

The mockup dashboard was designed to comprehensively address the three distinct aspects of resilience outlined in the SCOR model: reliability, responsiveness, and agility. Consequently, the dashboard structure comprises four distinct tabs, each dedicated to a specific facet of resilience. These tabs are identified as follows: Resilience Overview P2P, Reliability Deep Dive, Responsiveness Deep Dive, and Agility Deep Dive. Within the context of each tab, a prominent illustrative banner is positioned in the upper-left corner. This banner acts as a visual bridge, connecting cases derived from the event log to their corresponding appearances in the Celonis EMS dashboard analysis. Adjacent to this banner, an essential component facilitates the sharing and exporting of the content specific to each tab (as depicted in Figures 2 through 5).

Moreover, beneath these elements, another banner is situated. This banner is prominently displayed in each tab along with the name of the tab and with global indicators. It is important for items on a dashboard to have a consistent visual appearance; items that serve the same purpose or convey the same meaning should look the same. To prevent erroneous interpretations and preserve communication clarity, consistency in visual appearance and element selection is crucial (Few, 2006, p.143). Such repetitive patterns can work to simplify visual complexity through familiarity and predictability. The global indicators encompass critical metrics, including total count of POs, the total value of all POs, the average value of POs, and the count of POs exposed. The term "exposed POs" specifically refers to purchase orders that have been exposed to potential risks within the operational context. In the bottomleft corner, the dashboard features a conspicuous tab navigation bar. This navigational bar empowers users to effortlessly transition between different sections. This tab bar provides convenient access to the tabs, facilitating a userfriendly navigation experience (Figure 1 to 4).

The initial tab, labeled "Resilience Overview P2P," is divided into three distinct sections, each corresponding to a fundamental aspect of resilience. Here the gestalt principle of enclosure is incorporated, where fill colors and borders are established to group different informations together and set them apart from each other (Few, 2006, p. 76). Specifically, the "Reliability" section is structured with two distinct components, mirroring the arrangement found in the other two sections. The initial component is closely linked with the "Perfect Supplier Order" metric, as depicted within the SCOR model. Simultaneously, the second component is exclusively centered around the "Supplier at Risk" metric, which was taken as an idea from Accenture's SCR application. Within this section, the dashboard provides a comprehensive presentation of essential information for executives. Strategic dashboards are meant to give the decision maker a quick overview of key metrics and often include simple display mechanisms, and they simply present what is going on (Few, 2006, p.32). The previously mentioned section encompasses details such as the percentage of suppliers categorized as "at risk," the total count of suppliers in jeopardy, and a numerical breakdown of suppliers falling under the "at risk" classification. Collectively, this integrated section aims to underscore the overall reliability of suppliers.

The segments devoted to "Responsiveness" and "Agility" follow a similar structure. However, the "Responsiveness" section pertains to materials and the speed of their delivery, incorporating the SCOR metric known as the "Order Fulfillment Cycle Time." The corresponding element within this section mirrors the components featured in the "Suppliers at Risk" section but is tailored to materials. Lastly, the "Agility" section revolves around countries impacted by risks.

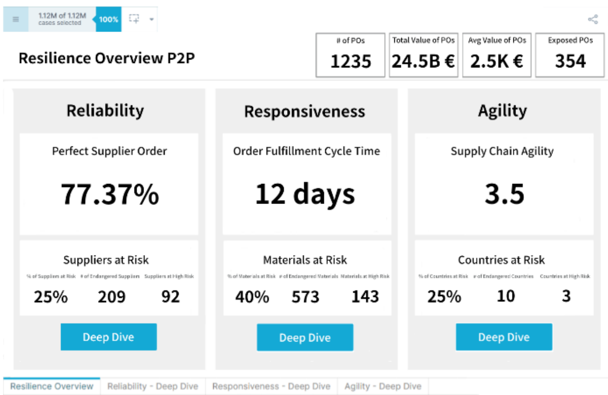

Figure 1: Resilience Overview P2P

Consequently, the KPI for "Supply Chain Agility" represents a conceptual measure designed to evaluate how effectively the SC can adapt to external influences, particularly within the context of inbound logistics. Additionally, this section provides information about countries that are at risk or have been affected by risks, akin to the content found in the "Suppliers at Risk" section. Each of these sections includes a "deep dive" button intended to guide the user to the corresponding resilience aspects within the tabs for in-depth exploration (see Figure 1). Dashboards designed for strategic purposes are not designed to be interactive and yield further analysis, because often strategic manegers are not directly responsible (Few, 2006, p. 32). Nevertheless, the "deep dive" buttons main purpose is to take the user to a dashboard with analytical purposes to further explore each aspect of the SC resilience.

Next, the second tab labeled "Reliability Deep Dive" (Fig 2), filters can be found beneath the banner featuring global indicators, which in this tab also includes the total number of suppliers. These filters enable users to narrow down the analysis by supplier, materials, country, risk, and date range (selectable by months). Below this section, you'll encounter the same metrics displayed in the initial dashboard tab. These metrics include the total number of suppliers at risk, the percentage of suppliers at risk, the number of endangered suppliers, and the total value of goods at risk. Directly beneath, an OLAP table can be found which includes the preselected SCOR Reliability metrics, along with the option that would allow users to search for specific suppliers. Tactical dashboards serve as powerful tools primarily intended for conducting in-depth analysis by consolidating and presenting comprehensive data. These dashboards empower users to gain deeper insights into performance metrics over time-and thereby foster impactful, data-driven decision-making across all tiers of the business (Rahman et al., 2017).

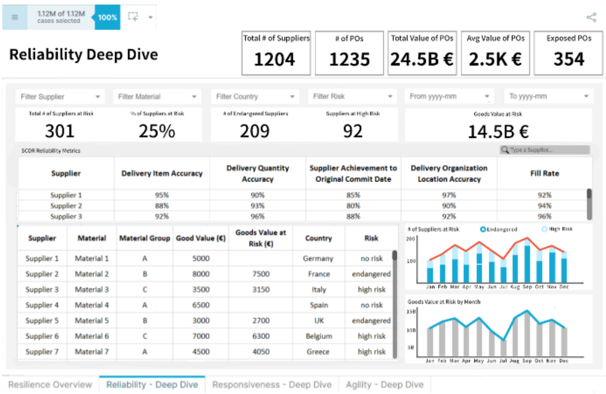

Figure 2: Reliability Deep Dive

Meanwhile, on the right-hand side of the dashboard, two bar charts come into view. The first chart depicts the number of suppliers at risk, divided into two categories: "endangered" and "high risk", plotted across months. The second visualization illustrates the value of goods at risk over months. In the left hand-side another OLAP table can be found that includes the following dimensions: Supplier, Material, Material Group (associated with the ABC analysis), Goods Value in Euros, Goods Value at Risk, Country, and Risk Type (no risk, endangered, and high risk). It's worth noting that the filters are meant to exclusively impact the second OLAP table and the accompanying visualizations, they do not extend their influence on the SCOR metrics presented in the initial OLAP table (see Figure 2). OLAP tables when accompanied with visualizations and through combination of interactive and navigational functions can reduce the recognition load and refine views on any particular area of interest in the data, while enhancing the user's understanding of the exploration (Techapichetvanich & Datta, 2005).

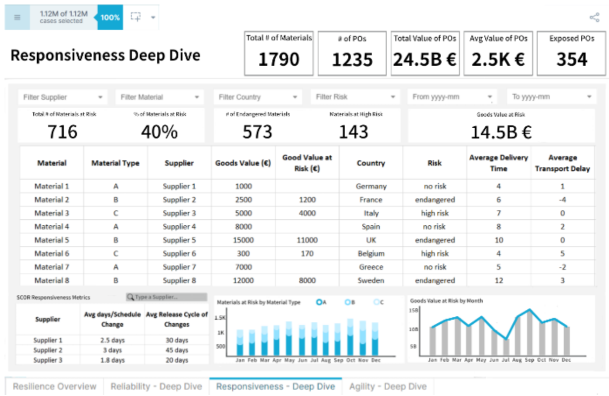

Figure 3: Responsiveness Deep Dive

In the corresponding "Responsiveness Deep Dive" tab, an additional numerical depiction of the total number of materials is provided within the top banner. This tab also features the same filters that were included in the previous section. Similarly, the OLAP table structure is maintained, incorporating several dimensions to facilitate comprehensive analysis. Furthermore, the OLAP table in this tab includes KPIs for both the average delivery time and the average transport delay. Adjacent to this, on the left-hand side of the dashboard, another OLAP table is positioned, encompassing the preselected SCOR responsiveness metrics. On the right-hand side of the dashboard, two visualizations are displayed. One of these visualizations was already introduced in the previous tab, while the second one is a bar chart that specifically illustrates the number of materials at risk categorized by materials type (ABC) across different months (Figure 3).

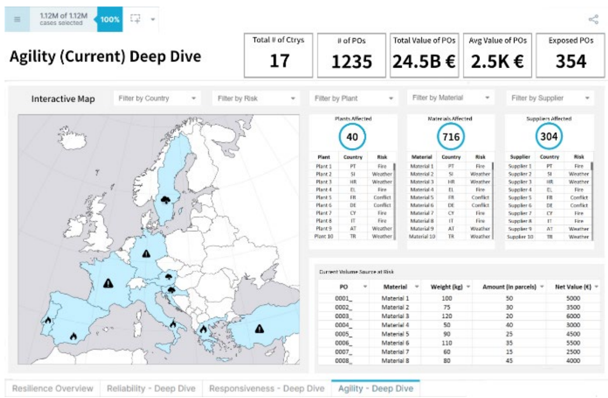

Figure 4: Agility Deep Dive

The final tab of the dashboard is labeled "Agility (Current) Deep Dive" (Figure 4). This tab is designed to be powered by real-time data, which justifies its name "current." Within this tab, users can access a range of filters including country, risk, plant, material, and supplier. The integration of real-time data is intended to provide up-to-the-minute insights into the company's agility. Prominently displayed within this tab is an interactive map that dynamically showcases countries affected by various risks. Geographic Information Systems capabilities, encompassing visualization, spatial analysis, optimization, and site research, significantly contribute to SCM decision-making. They provide crucial insights for supplier selection, facility location, supply chain network configuration, and asset management, facilitating more efficient SCM and logistics activities while offering valuable guidance for strategic decisions (Tsakiridi, 2021). The inspiration for the risk categories was drawn from Accenture's SCR application, resulting in three risk types: "fire" (indicated by a fire symbol) to denote instances of fires occurring in countries, "conflict" (depicted by a danger symbol) to highlight strikes, wars, or other conflicts at a national level, and "weather" (represented by a weather symbol) which encompasses floods, storms, and other supernational weather-related events. Positioned on the left-hand side are three tables, each presenting data on affected plants, materials, and suppliers. The tables furnish essential numerical indicators along with pertinent information, including the plant's name, the material and supplier impacted, the associated country, and the specific risk type (fire, weather, or conflict). Initially, the interactive map illustrates all countries affected by risks, with corresponding symbols indicating the risk type.

However, once filters are applied (as depicted in Figure 5), such as selecting a specific risk type like "fire," both the map and the corresponding tables undergo dynamic changes to reflect the filtered criteria. The culminating feature on this tab is an OLAP table, meticulously curated to include the chosen agility metrics derived from the SCOR model, specifically centered around "Current Volume Source." This table showcases comprehensive information, encompassing each PO at risk, the corresponding material ordered, its weight, quantity, and individual value.

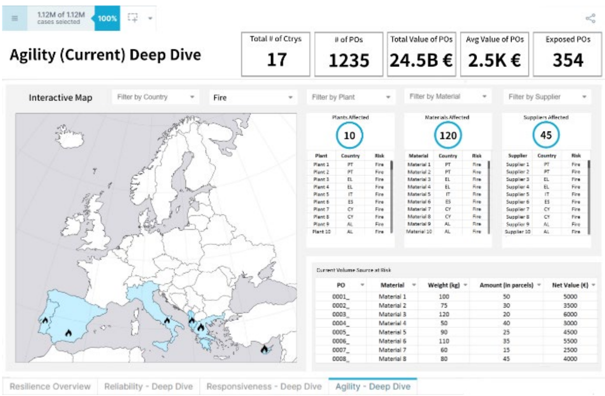

Figure 5: Agility Deep Dive with the Fire filter applied

P2P Use Case

The Use Case is essentially a demonstration walkthrough of the intended dashboard functionality, offering a comprehensive understanding of how the dashboard achieves its core goals. To enhance reader comprehension, additional figures (Figures 6 to 8) have been included. These figures offer visual cues that correspond to the steps a potential inhouse consultant would take while utilizing the dashboard.

As a hypothetical scenario, the in-house consultant initiates access to the dashboard within the Celonis EMS. Upon entry, their initial view is directed to the "Resilience Overview P2P" tab. Subsequently, they are provided the option to investigate a specific aspect, such as "Reliability," which encompasses two distinct sections. Within the first section, a vital metric—termed "Perfect Supplier Order"—is showcased. In this instance, the metric registers at 77.37%. This metric serves as a comprehensive indicator of collective supplier performance in fulfilling their orders. Notably, the maximum attainable value is 100%, signifying optimal efficiency in meeting the company's order delivery requirements. In the present case, the metric reveals certain suppliers demonstrating inefficiency in fulfilling orders. Transitioning to the second focal point, as depicted in Figure 7, the in-house consultant encounters three pivotal information metrics. These metrics unveil that a quarter (25%) of the suppliers are in a precarious state of risk. Of this subset, 209 suppliers are categorized as "endangered," while 92 are flagged as "high risk." The identification of such risk-laden suppliers raises a preliminary flag, indicating potential concerns warranting a more profound exploration. Consequently, the in-house consultant possesses the option to delve deeper by engaging the "Deep Dive" button—an action depicted as numeral 3 in Figure 6.

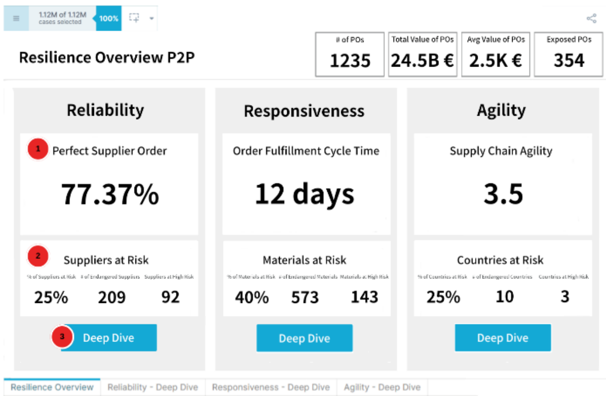

Figure 6: Resilience Overview P2P Demonstration

If the consultant opts to conduct a more in-depth exploration of the emerging issues, they can initiate this process by clicking the "Deep Dive" button, which leads them to the dedicated "Reliability Deep Dive" tab (Figure 7). Here, the in-house consultant gains the opportunity to observe the comprehensive list of suppliers, irrespective of their risk classification—indicated as point number 1 in Figure 7. To proceed, the consultant might choose to refine their focus by utilizing the filtering option to isolate suppliers categorized as "high risk." This action, illustrated as point number 2 in Figure 7, results in the display of exclusively those suppliers that have been identified as being exposed to elevated risk levels. Subsequently, the in-house consultant can elect to delve deeper into the performance of these specific high-risk suppliers based on the SCOR Reliability metrics. This entails leveraging the search functionality to scrutinize the historical performance of these suppliers. Should the consultant's concerns extend to comprehending the external factors influencing the heightened risk for these suppliers, they can navigate to the "Agility Deep Dive" section.

This option is accessible via the tab menu situated at the lower part of the page, as denoted by point number 4 in Figure 7.

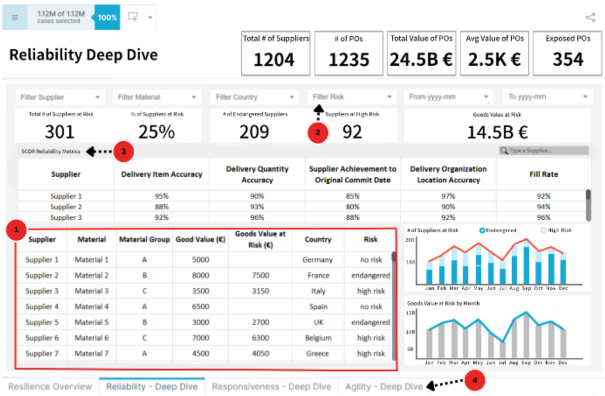

Figure 7: Reliability Deep Dive Demonstration

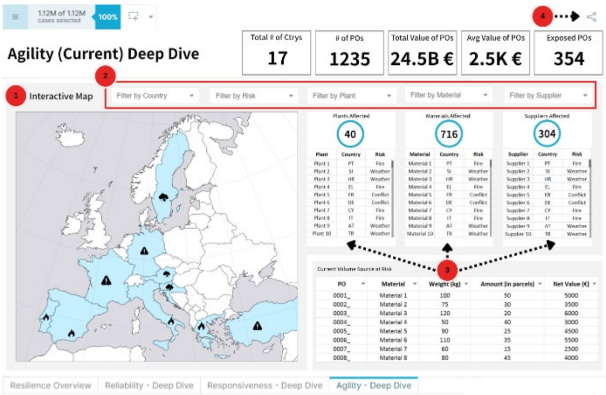

Figure 8: Agility Deep Dive Demonstration

Upon accessing the "Agility Deep Dive" tab, the in-house consultant is presented with an interactive map showcasing countries influenced by risks. This interactive map encompasses multiple functionalities, although in this mockup representation, it primarily serves as a visual depiction of countries impacted by risks—indicated as the primary function (point number 1 in Figure 8). To refine the analysis's scope, the consultant possesses the capability to implement various filters. These filters hold the potential to induce dynamic changes both within the interactive map and across the three associated tables (point number 3 in Figure 8). These tables correspond to plants, materials, and suppliers, and their content adapts according to the selected filters. Upon achieving a satisfactory level of insight, should the inhouse consultant consolidate their findings and share them with organizational executives, an option for data extraction is available. This functionality is readily accessible through a button situated in the top-right corner of the interface, which can be found also in all the tabs (point number 4 in Figure 8).

Moreover, the design of the mockup dashboard facilitates an exploration of the KRAs to evaluate SCR. Specifically, the previously mentioned KRAs—KRA1: Geographic Distribution of Entities, KRA2: Sourcing Strategy of Materials, and KRA5: Transport Delay—can be assessed using various components within the mockup dashboard. For instance, KRA1 can be hypothetically evaluated through interactive map functionality or by employing filtering options within the "Reliability Deep Dive" tab (Figure 2). These features would provide insights into the number of suppliers originating from specific countries. Likewise, the assessment of KRA2 can be accomplished using filters within the "Responsiveness Deep Dive" tab (Figure 3), shedding light on sourcing strategies for materials. Addressing KRA5, the mockup dashboard incorporates dedicated metrics to offer an overview of transport delay metrics, encompassing the time taken to procure particular materials and any associated delays (Figure 3).

EXPERT EVALUATION

The evaluation phase was a crucial step aiming to validate the design artifacts created during the development process. In this chapter, we present the results of the evaluation activity for the SCR mockup dashboard, which was conducted with two experts, referred to as Expert 1 and Expert 2, to maintain their anonymity. The evaluation process involved separate online meetings with each expert, during which the dashboard's design, functionality, and potential improvements were discussed. The meetings were conducted by presenting the use case from the previous chapter and the discussion afterwards was conducted openly. Subsequently, the discussions with both experts were recorded and transcribed. From these transcripts, themes within the discussions were identified for coding the expert's comments and organizing them into categories/themes of discussion.

Expert Profiles

- Expert 1 holds a background in finance and has transitioned into business analysis, with a primary focus on PM projects. This professional trajectory has equipped Expert 1 with a unique perspective on development of data-driven and process optimization solutions. In addition, they originally authored Accenture's SCR application and they were directly involved in its development.
- Expert 2 serves as a Senior Manager at Accenture within the field of SC and operations strategy. With over 15 years of consulting experience, Expert 2 specializes in guiding clients through strategic transformation endeavors, encompassing a holistic view of processes. They were not familiar with the SCR application that Accenture had developed.

Evaluation Process

The evaluation process commenced by introducing the use case for the SCR mockup dashboard to each expert separately. A presentation outlined the dashboard's functionalities, the use case it addresses, and its intended impact on SCR. Following the presentation, in-depth discussions ensued, delving into various aspects of the dashboard's design.

Themes of Discussion

I - Risk Assessment and Analytical Depth

Both experts provided valuable perspectives on risk assessment methodologies. Expert 1 discussed the SCOR model as an alternative approach to assess resilience, diverging from Accenture's SCR application, which followed an asset-driven approach. Expert 1 elaborated that the asset-driven method considers all company assets exposed to risks, such as materials, suppliers, and even supplier's plants. Despite supplier plants not being owned by the company, they house materials that may eventually belong to the company. In case of risks like fires, these plants directly affect material flow. Thus, Expert 1 suggested incorporating SCOR resilience aspects and asset-driven aspects in separate tabs on the dashboard. This insight underscores the importance of evaluating SC risks from various angles

Expert 2 delved into risk type classification, proposing a dynamic approach that reflects supplier behavior and commodity criticality. For instance, a consistently "at risk" supplier, producing a critical commodity, holds more significance for manufacturers than an "at risk" supplier dealing with a non-critical material. Expert 2 also highlighted the need to analyze historical risk trends by regions, countries, and the historical performance of suppliers impacted by external factors in more detail.

The feedback converged on the theme of analytical depth. Expert 1 found the initial "Resilience Overview P2P" tab suitable for executives but noted a lack of histograms for quick tracking of historical performance trends. Expert 1 also observed that deep-dive tabs for in-house consultants were overly simplistic and needed more metrics, visualizations, and elements. Moreover, Expert 2 agreed that the initial tab serves executives well, suggesting that with the ability to further drill down into specific metrics and elements, other tabs could provide an ideal level of detail for in-house consultants. Expert 2's proposal to explore specific event investigations addresses the growing demand for deeper insights into the dynamic SC nature. By integrating risk event data with PO information, the dashboard could offer a comprehensive view of SC performance, crucial for effective decision-making.

II - Key Performance Indicators and User Experience

The experts' insights converge on the significance of well-selected KPIs that align with user roles and requirements. Expert 1's endorsement of the SCOR reliability metrics as interesting and effective demonstrates the potential to capture critical supplier performance aspects. Expert 2's emphasis on categorizing order fulfillment cycles and understanding diverse lead times for different materials adds depth to the understanding of SC dynamics. For instance, he emphasized that certain commodities have an order fulfillment cycle of a few days, as opposed to packaging that has an order fulfillment cycle of several weeks. These observations collectively emphasize the need for more specific KPIs that cater to the diverse needs of different company settings.

The discussion with both experts also highlighted the central role of user experience in the dashboard's design. Overall, both experts suggested that incorporating colors into the dashboard's design is crucial. Expert 1 recommended refining the color and icon representation for risks in the interactive map, addressing it as an essential element of the user experience. On the other hand, Expert 2 introduced the concept of color-coding to visually indicate different risk levels, a technique that could improve the dashboard's usability and provide clear insights to the user. These recommendations highlight the potential of innovative visual representation techniques in effectively communicating complex data.

III - Process Mining

In terms of PM-specific elements, the experts provided insights from different angles. Expert 1 highlighted the logical inclusion of PM elements, sparking a discussion about developing a "Supply Chain Centric Data Model." However, Expert 1 acknowledged that developing such a model would be inherently intricate, demanding substantial effort from the designated team. The crux of the complexity, as pointed out, lies in sourcing the right data for the dashboard and experimenting with diverse services to monitor external risks like environmental disasters and weather data.

Likewise, Expert 2 expressed the feasibility of integrating PM elements, particularly if specific risk events are linked to specific POs. For a comprehensive deep dive, he suggested that the dashboard should incorporate facets commonly seen in regular PM solution dashboards for monitoring the P2P process. Examples include metrics such as on-time delivery, full delivery, and automation rate. If these elements were to be incorporated, they could enhance the dashboard's utility.

IV - Potential Improvements and Data Quality

Both experts provided valuable suggestions for enhancing the dashboard's effectiveness. Expert 1's primary recommendations for potential improvements revolved around incorporating a time perspective. This could involve integrating histograms to illustrate trends over time, implementing clearer scales for metrics, and enhancing visual clarity through the use of color-coded indicators. These enhancements would ensure that users have a comprehensive understanding of the data they are viewing and its significance. Nevertheless, Expert 2 pointed out potential extensions to the analysis that could further enrich the dashboard's insights. One such extension involves taking into account quality risks linked to materials. By considering these additional dimensions, the dashboard could offer a more comprehensive and nuanced view of the SC's performance and potential vulnerabilities.

In addition, Expert 2 strongly emphasized that the overall concept of the dashboard appears promising. However, he expressed a significant concern regarding data quality, underlining that many of his clients continue to grapple with this issue even today. According to him, the most substantial challenge would involve sourcing and upholding precise, dependable data inputs for the dashboard.

Both experts significantly contributed to the evaluation of the mockup dashboard, providing valuable insights regarding its usability and potential for conceptual enhancement. The feedback received from these experts has illuminated a spectrum of opportunities as well as areas necessitating improvement for the SCR mockup dashboard. Their observations centered around several prominent themes, including risk assessment, analytical depth, user experience, and resilience-related metrics.

DISCUSSION

With the groundwork established in the preceding chapters, the focus now turns to the core of this study: the investigation into the resilience of the SC through the innovative lens of a conceptual SCR dashboard. This discussion chapter engages with the research questions that have guided the exploration. Firstly, the focus is the demonstration of the intended functionality of the mockup that elucidate the synergy between the developed concept and the first research question at hand: *"How can insights into the resilience of the supply chain through the P2P process be obtained using an SCR dashboard conception, considering a specific use case?".* The walkthrough vividly illustrated the dashboard's ability to empower an in-house consultant to delve into the intricacies of SCR. While it is important to acknowledge that alternate use cases could have been explored, the example chosen for this research encapsulates the envisioned objectives the mockup dashboard aims to achieve. Specifically, it enables in-depth exploration and provides dual layers of analysis for assessing resilience. The "Resilience Overview P2P" section caters to the executive level, offering a consolidated perspective, while also allowing for further investigation for mid-level management by furnishing more detailed analyses across three distinct dimensions of resilience: reliability, responsiveness, and agility. Nevertheless, the conceptual dashboard included filtering options that would allow for drilling down and focusing on specific areas of interest, as well as various metric and elements that are of crucial importance for the SC.

In the assessment of the second research question *"Which opportunities and limitations does the dashboard offer for resilience management of the P2P process from a tactical or strategic point of view? "*, key insights emerged from the expert evaluation. These insights shed light on the potential advantages and constraints associated with the dashboard's effectiveness for resilience management. Notably, the experts acknowledged several positive aspects of the presented dashboard concept. The experts found the proposed dashboard concept intriguing, with one of them remarking that it introduced a fresh perspective on SCRM. Expert 2 observed that the initial tab included in the mockup provided an optimal level of analysis for executives. Conversely, the more detailed tabs, such as the deep dive sections, were deemed valuable for managers operating at the tactical level within organizations. In addition, Expert 2 underscored the concept's potential for further development, suggesting the incorporation of additional elements such as a quality perspective and diverse drill-down categorizations of risks and the entities they impact. Turning to the limitations, both experts stressed the significance of color usage within the dashboard, highlighting it as a notable drawback. Few (2006, p. 62) highlighted the importance of colors, warning the overusing colors can cause confusion, but that also the misusing colors can lead users to wrong conclusions when reading information from a dashboard. The mockup dashboard's absence of vibrant colors resulted in a lack of emphasis on crucial metrics or data, that would make it challenging for users to identify potential disruptions within the SC. Nevertheless, it is more effective to display alerts using color-coded indicators that signify varios levels of threats. These threats have predefined performance target thresholds and so-called zones e.g. a green zone representing the target area, a yellow zone indicating a warning level, and a red zone signifying a critical area of concern (Karami & Safdari, 2016).

Moreover, a significant constraint identified was the relatively limited availability of visualizations within the mockup, which hindered the capacity to compare current data with historical trends. Such a comparative analysis should be deemed essential for both tactical and strategic decision-making perspectives. However, an overflow of information can result not only in ignoring details but also in making inaccurate decisions (Yigitbasioglu & Velcu, 2012). Iselin (1988) discovered a relationship where the accuracy of decision-making and the amount of provided information follow an inverted U-shape. This relationship suggests that there exists an optimal level of accounting information within reports that leads to the most precise decisions. However, the experts' criticism suggests a deficiency in visualizations, particularly in time-related graphs. This highlights the potential need for increased visualization within SCRM, considering its inclusion of various perspectives and entities within a SC. Therefore, colors and color coding, as well as the time-related visualizations for tracking risks and entities across time were deemed important considering the complex data representation that is required to have an overview on the SCR.

While the DSR principles influenced the design and development of the mockup dashboard, it's essential to recognize the iterative nature of this methodology. The paper didn't explicitly delve into these principles, but it's crucial to note that DSR inherently involves multiple refinement cycles before reaching a "final product." Ideally, the feedback gathered from experts could have been utilized to improve and enhance the conceptual dashboard's design. Nevertheless, the input gathered from the expert evaluation not only contributes to forthcoming refinements of the dashboard but also provides a clearer path for design focus points and future development.

Considering a broader study, like a survey, might clarify which elements are crucial for inclusion in an SCRM mockup dashboard. This approach could distinguish between essential components, potential value additions, and those that might not be necessary. Additionally, previous research highlighted a comprehensive set of criteria applicable across various dashboard types. These criteria, covering aspects such as user customization, knowledge discovery, security, information delivery, alerting, visual design, and integration with system connectivity, offer a valuable framework for assessing the effectiveness of such dashboards (Karami et al., 2017).

The evaluation of the mockup dashboard, however, raised additional questions regarding the practical development process and the challenges associated with integrating the necessary data to operationalize the dashboard. Of particular interest was Expert 1's suggestion to create a "Supply Chain Centric Data Model," a concept not covered within this paper but holding potential for future exploration. Delving into this concept could unlock the true potential of PM in driving process optimization within companies, even for elements outside their immediate control. This could empower companies to take both reactive and proactive actions when addressing external influences on their SCs. Moreover, Expert 2 highlighted the persistent data-related issues as a fundamental challenge that would likely arise in bringing such a concept to fruition. This challenge, as well could serve as a valuable avenue for future research.

In addition, a thorough examination of the SCOR model and its specific breakdown of resilience facets in SCs opens the door to carefully selecting metrics when tailoring solutions for individual enterprises. Given that the SCOR model serves as a versatile framework applicable across diverse industries and company types, it offers a plethora of available metrics falling under the "Resilience" performance category (ACSM, 2022). Additionally, it accommodates various process types. Practitioners can leverage mockup dashboards as exemplars to streamline data organization, ensuring its alignment with both executive and tactical levels within an organization. Nonetheless, it is crucial to recognize that these discrete sub-dimensions of resilience play a pivotal role in conceptualizing and comprehending SCR within varying contexts and across diverse types of companies. This understanding becomes particularly paramount in the context of inventing solutions aimed at mitigating challenges posed by unforeseen external factors that frequently impact SCs.

The development of the SCRM mockup dashboard stands as a significant milestone, offering a visual representation that provides stakeholders with a sneak peek into the envisioned dashboard's interface, data visualizations, and interaction designs tailored for enhancing and overseeing SCRs. Creating this preview and subjecting it to expert evaluation has revealed a profound understanding of the complex challenges inherent in SCR. While established design principles, color schemes, and visualization techniques have been acknowledged in the development of other types of dashboards, identifying the most crucial elements specifically for SCRM requires further exploration, as pertinent literature on this subject remains scarce. Conducting a broader study focused on gathering insights and data from experts across various SC processes in this field would be imperative for identifying these essential elements and metrics, and creating a checklist that could serve dashboard developers as a guide when deciding how and what they should consider when designing such innovative solutions for SCRM.

Despite its static nature the mockup significantly contributes to theoretical advancement, thus deepening the understanding of how information based on the SCOR model resilience aspects could empower resilient decision-making. Furthermore, the mockup provides a conduit for knowledge dissemination. This paper could serve as a means of communication for the academic community, simultaneously directing future research endeavors and enhancement of the SCRM conceptual dashboard, and potentially developing a functional prototype.

CONCLUSION

The primary goal of this paper was to create an industry-neutral conceptual dashboard for the P2P process. This dashboard was designed based on the event log of PM and intended to cater to in-house consultants at the mid-management level. Furthermore, the paper was crafted with the intention of addressing the research questions that steer the course of the research.

The initial research question, "How can a conceptual SCR dashboard provide insights into supply chain resilience within the P2P process, focusing on a specific use case?" was addressed through the creation and presentation of a mockup dashboard. This mockup effectively illustrated how the dashboard could potentially offer insights into SCR. It showcased the dashboard's intended functionality, highlighting its capability to assist consultants in investigating issues that impact the P2P process, with a focus on various important entities and aspects.

Answering the second research question, "What opportunities and limitations does the dashboard present for enhancing resilience management of the P2P process from tactical and strategic standpoints?" involved soliciting insights and feedback from experts in the fields of SCM and PM. The feedback emphasized the well-considered integration of metrics from the SCOR model and elements from Accenture’s SCR application. However, the experts identified the absence of time-related visualizations and color-coded information as crucial additions that would aid in easier tracking of disruptions and issues within the dashboard. These additions were seen as particularly valuable for mid-level managers and executives.

Nevertheless, the conceptual dashboard proposed in this paper could serve as a steppingstone for further research that could potentially lead to the development of a prototype using the Celonis EMS. In addition, the proposed dashboard could offer a visual foundation for understanding the three distinct resilience dimensions, along with organizing key metrics and elements thar are crucial for addressing disruptions that impact the SCR within the context of the P2P process.

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