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Situation Awareness Monitor And Liquidity Assessment For Enterprise Resilience Management

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Abstract

Currently, companies are becoming increasingly vulnerable towards unforeseen disruptive events. One example of such an event is the COVID-19 pandemic, in which many companies are facing existential difficulties. The sudden loss of suppliers and customers as well as frequent changes in regulations at short notice present companies with considerable challenges. Potential uncertainties and complexity complicate the planning and the implementation of measures. A fast and effective overview and the benefit of measures is usually missing. Situation awareness monitors have long provided orientation for first responders and rescue operators within the field of crisis management and can be just as relevant for companies.

Identifying, gathering, interpreting and visualizing external information from the corporate environment in relation to relevant disruptions remains an unsolved problem. In addition to the decision to implement effective measures before, during and after a crisis, an approach for the simulation of the disruptive impact and the effect of resilience measures on the company's performance as well as liquidity is required.

In this paper, a Situation Awareness Monitor (SAM) for resilience management is presented to address the aforementioned issues. First, the model-based IT architecture for the monitor is depicted. The enterprise model is coupled with an approach to assess critical processes of small and medium enterprises. Statistical models are applied to draw up the balance between single components, like input, output, supplier, storage and production. The result shows a continuous performance-based liquidity assessment to evaluate the resilience against disruptive events. Finally, single enhancement measures in alignment to the resilience phases – prepare, prevent, protect, respond and recover – can be analyzed.

Keywords

Business Resilience; Situation Awareness; Simulation; Crisis Management; Performance Monitoring

1. Introduction

Uncertain disruptive events and the changes of framework conditions are challenges especially for small and medium enterprises. Simultaneous disruptions to which a company is exposed or the potential adaptions before, during and after the crisis increase the complexity. This variety of information can lead to an overload of information management in companies. A fast provision of external and internal information before, during and after uncertain situations helps to derive effective and reliable solution strategies and decision-making aids. A Situation Awareness Monitor (SAM), taking significant resilience characteristics as well as liquidity simulation into account, enables an effective analysis and visualization.

The example of the COVID-19 pandemic shows that many companies have encountered existential difficulties due to the sudden loss of suppliers and customers as well as frequent short-term changes in regulations. The frequent increase of infections has exacerbated the uncertainty and made planning security and implementation of measures more difficult. By applying resilience management, the disrupting event can be conceived, analyzed and evaluated in advance at any moment.

The SAM for resilience management is able to combine incoming information and simulate the effects of disruptive events on a company's liquidity. This means that all changes can be displayed in a detailed overview of the current company situation, taking into account the time and the corresponding recalculation.

2. State of the art

2.1 Situation awareness

Since CLAUSEWITZ [1], the creation and use of SAMs have been of particular importance to emergency personnel of the military, police and health services for the success of networked action in crises. The starting and end point of the military command and control process as well as the police planning and decision-making process is always the situation picture, since it forms the foundation of the entire operation [2]. The relevant data must be identified, captured, structured and correlated. The second step is a structured analysis of the information obtained. The result leads to at least one, ideally to several decision options, within which the respective advantages and disadvantages are pointed out and weighed. On the basis of the decision taken, the implementation planning – which can be seen as a constantly recurring control loop – pursues the goal of a continuous actual-target comparison and makes it possible to react promptly to the changing situation. The goal of networked operations is to link the information, command and control systems from the infantryman's helmet camera to a military satellite as well as across all military organizations and units in order to aggregate as much relevant information as possible into a common situation picture. The information is then made available to the organizational units on a user-specific basis – for example, via an integrated display system in the infantryman's helmet. This enables individual decentralized systems and organizational units to work in a coordinated manner and within a shorter time. As flight control systems gradually became more automated and pilots started losing track of flight operations and aircraft status, concepts for situation awareness were further developed for the aviation industry [3]. One of the dominating definitions and theories was given by ENDSLEY: The three-level model approach describes the three steps for information processing, starting from "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future*" [4].

What manufacturing companies have in common with these sectors is the bias between a decision-maker's understandings of the system status – the company and its environment – versus the actual system status. This is mainly driven by the complexity of environmental influences, like natural disasters, climate change, geostrategic as well as economic policy influences, for example. In order to create a basis for further investigations and decisions for action, a large amount of information from a wide variety of sources must be collected and evaluated within a short time. This information must then be compared with existing findings, correlated with each other and communicated with responsible parties.

Hence, it is essential for companies to monitor the execution of their business in real time and to consistently have an overview of the current state of the company's liquidity and its facilities [5] [6]. Therefore, many companies today make use of so-called information systems, which are often summarized under the term management cockpit. However, the information processing is largely shaped by the hierarchical system of the automation pyramid [7]. This enables companies to provide operational data from process execution in production, to assign it to the corresponding order data and production specifications and to visualize it within the scope of performance analysis. Nevertheless, these instruments are just focusing on the impact of disruptions and are only partially suitable for the early planning of crisis containment measures and the assessment of their effects. They need extensions with regard to environmental influences as well as liquidity assessment.

2.2 Life cycle oriented resilience assessment

The reduction of potential risks is a central strategic challenge for small and medium enterprises. Classical crisis management calculates and estimates a possible disruption in advance, but does not make any specific adjustments in the further course of the disruption. SCHUMACHER shows that measures of a current crisis management are not suitable for small and medium enterprises [8]. Especially the COVID-19 pandemic showed that not many risk management systems were able to control risks within the supply chain or the maintenance of the business [9].

In contrast, a resilience analysis provides a holistic view of the situation. By continuously re-analyzing a disruption, the resilient approach provides, at any point in time (i.e. before, during and after a disruption), a reliable statement about the state and the effect of the disruption on the company as well as possible countermeasures and their positive effects on the company. With the help of resilience management, a specific assessment of the company's situation is carried out depending on the progress of the disruption.

While resilience describes the ability to react to a disturbance and to return to the desired initial state through suitable measures, the resilience cycle [10] deals explicitly with the evaluation of the disturbed system at any point in time. Therefore, the resilience cycle can be broken down into five interconnected phases: prepare, prevent, protect, respond and recover. The prepare-phase evaluates the system before the disruption occurs. Prevent, protect and respond are resilience phases that evaluate the system during the disruption, and recover initiates the time slot after the disruption including a new prepare-phase to continue the analysis into a cycle and preparing the system more robustly for a new occurrence by analyzing known events.

In addition, the Fraunhofer Resilience Evaluator (FReE) [11] was developed to support companies and systems to increase their resilience. For this purpose, a disruptive event is systematically analyzed and, with the subsequent evaluation, a company is enabled to successfully cope with a crisis [12]. The FReE tool gives a fast overview, but only a qualitative assessment concerning resilience.

2.3 Requirements and objectives for Situation Awareness Monitoring for resilience management

In order to create a SAM for resilience management and liquidity assessment for supporting tactical and strategic management decisions, it is of great importance to consider the previously mentioned open issues. In particular, the capability of monitoring the actual situation of the system in real time, collecting and evaluating the large amount of information from a wide variety of sources within a short time, correlating this information with existing findings and also communicating the results with responsible parties should be noted. Furthermore, the SAM for resilience management is characterized by its resilient, interactive, and interoperable performance. Specifically, resilience ensures situation awareness before, during and after a disruption. Interaction focuses on the communication between heterogeneous systems, and interoperability describes the clear visualization of relevant, reliable and up-to-date information, presented in a common situation picture. Thus, the functions to be supported by the system are:

1. Perform a continuous situation assessment and environment analysis to detect every change in status and obtain an early warning system. Furthermore, the simulation of the situation assessment monitor includes the impact of disruptions and of countermeasures, focusing on liquidity and performance.
2. Detect disruptions early and estimate potential effects through continuous analysis of trends, threats and deviations (e.g. delays in production).

3. Derive countermeasures and plan implementation support to obtain predictions of impacts of decisions and reliable predictions of environmental trends.
4. Implement the most appropriate countermeasures into the system.
5. Evaluate the changes and provide recovery.

These five steps correspond chronologically to the five phases of the resilience cycle (prepare, prevent, protect, respond, recover), ensuring a holistic resilient approach.

3. Situation Awareness Monitoring for resilience management

3.1 Target model

As explained above, the resilience cycle [10] serves the evaluation of the disturbed system throughout all five interconnected phases of a disruption. In Figure 1, the interdependencies between the activities and required resources in the resilience phases are described systematically with integrated enterprise modelling [13], supported by the modelling tool MO²GO [14].

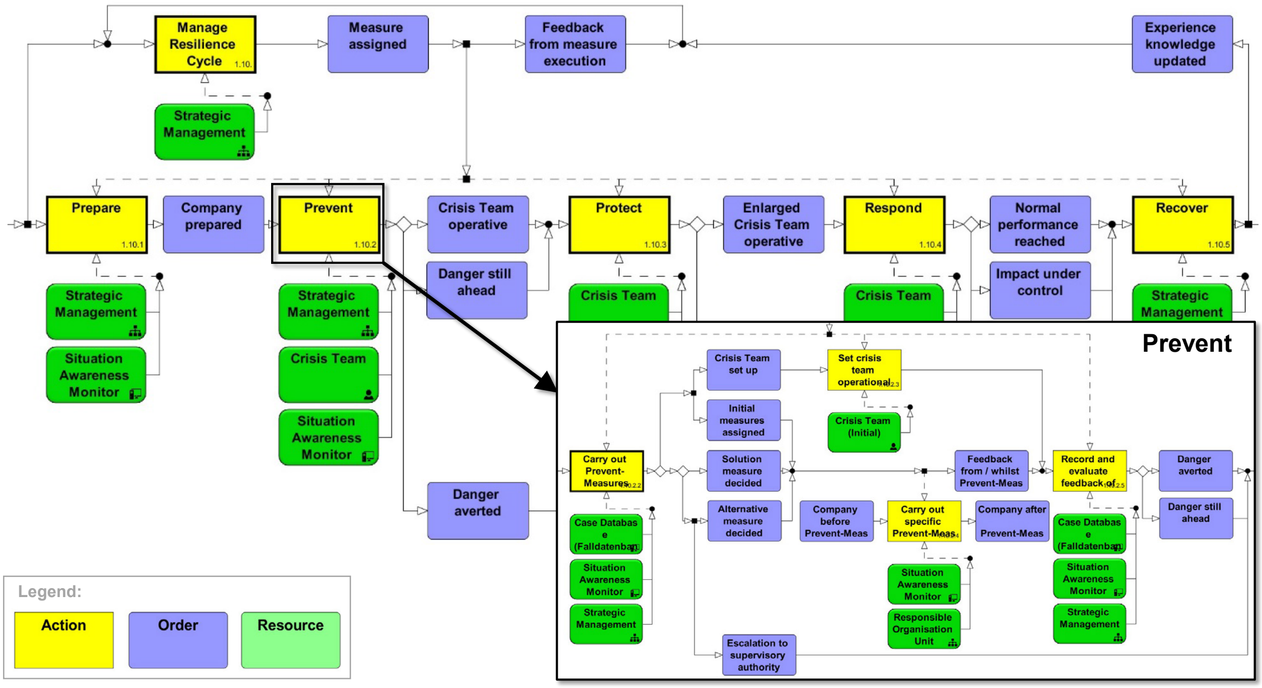

Figure 1: Process model excerpt from a reference model for holistic resilience management

The process "*Manage Resilience Cycle*" – which is depicted in the upper left corner of Figure 1 – triggers and controls the activities of the resilience cycle. It is an early warning system in the way that influences such as trends, external threats and internal deviations (e.g. delays in production) are continuously analyzed and their effect on critical performance parameters are evaluated based on simulated scenarios. If a potentially hazardous influence is identified, appropriate resilience measures are derived and assigned as controlling orders. In contrast to the other phases, activities in the prepare phase – such as ensuring the required redundancy by conducting employee trainings for multiple-qualification of employees – are carried out according to the continuous resilience assessment and are not only triggered by specific potentially hazardous influences. Based on the preparations of the company, prevent measures are carried out when a crisis becomes apparent and the previously defined crisis team is set operational. If the danger associated with the crisis could not be averted, protect measures must be carried out and the crisis team needs to be enlarged. In case the normal performance of the company could not be achieved, a rapid and well-organized response is necessary before the system enters the recover-phase in which the focus lies on stabilization and deriving lessons learned for improving the resilience cycle for future disruptions. Each phase includes a continuous evaluation of the measures being taken, which represents a feedback of the resilience cycle to the previously mentioned control process.

3.2 Model-based architecture

The reference model for holistic resilience management is an integrated part of the integrated enterprise model. As shown in Figure 2, the integrated enterprise model and the SAM for resilience management are the central components of the model-based architecture.

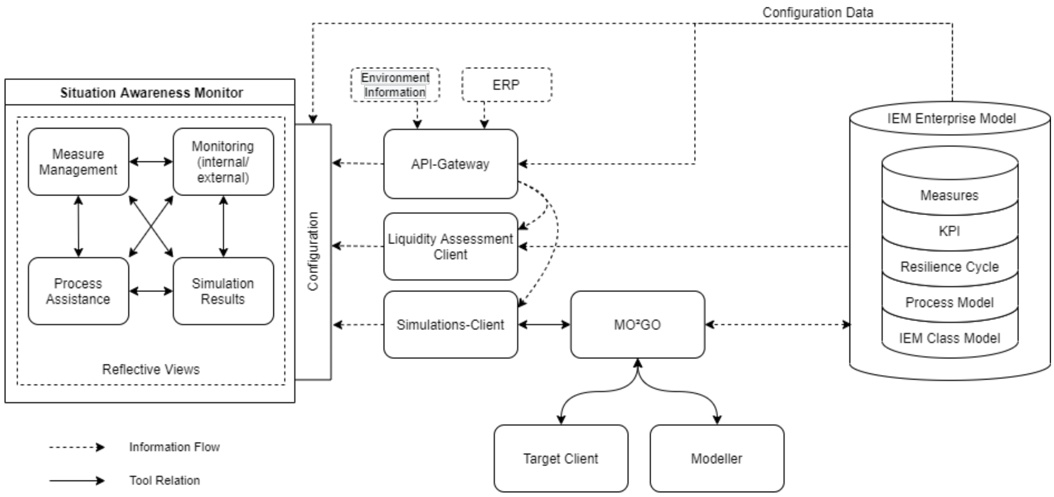

Figure 2: Model-based architecture for Situation Awareness Monitoring for resilience management

From the structural perspective, the integrated enterprise model combines the objects of an enterprise and its relationships with their behavioral aspects in processes [13]. Behavioral aspects can be, for instance, the definition of the key performance indicators (KPIs) in relationship to the enterprise objects and processes (e.g. duration, overall equipment effectiveness (OEE)). These model parts are used for the configuration of the SAM. In addition, the integrated enterprise model contains operational data as well (e.g. duration of a single process): KPI values and measures in all phases of the resilience cycle. The resilience measures are connected to the process definition in the model. Additional data from the corporate environment and internal IT systems (e.g. data from the enterprise resource planning system) are gathered by the application programming interface (API)-Gateway, which is configured by the integrated enterprise model as well. In the SAM, the information is displayed using four reflective view types: Measure Management, Monitoring of internal and external status of processes and resources (KPI-based), Process Assistance and Simulation Results. These view types can be instantiated by configuration. The API-Gateway is providing data for simulation and liquidity assessment. For the design of the integrated enterprise model, clients of the MO^{2}GO software [14] are used (e.g. modeler).

3.3 Resilience-based liquidity assessment

The model-based architecture helps to generate an abstracted overview of small and medium sized companies (SMEs) and to identify critical processes which give essential contributions to the liquidity of an SME. This section introduces an approach to assess the performance and the liquidity as basis for a resilience assessment. The left picture of Figure 3 shows a generic critical process of a manufacturing company including several components and their dependencies. The production depends on the number of orders, realized within the order management. The production further needs several components provided by the storage. An external dependence exists due to the component provision from appropriate suppliers. After the quality assurance, finished products contribute to the business volume, presented by the delivery process in the left picture of Figure 3.

For each component of the generalized model in the left picture of Figure 3, decisive parameters and their dependencies are developed and implemented into a tool for assessment. The result is a multi-dimensional model to describe the liquidity and the performance of a critical process. Single parts of the model are reserved with uncertainties. Examples are:

- supply risks concerning quality, quantity and delay,
- changing input based on a change of the market or the demand and
- changes within the production, based on the capacity or the performance.

In this approach, the theory of production logistics [15] is used to specify the resilience assessment with regard to the system to result in quantitative measures. The key figures of logistics are combined with probabilistic models to integrate potential risks, like failure rates or supply risks in combination with discrete event simulations, oriented to LANDTSHEER ET AL. [16] and CUBE ET AL. [17]. Insights of the reliability analysis of systems [18] are also considered. The combination of the different approaches allows a quantitative assessment of resilience. Performance and liquidity are derived as basic quantities.

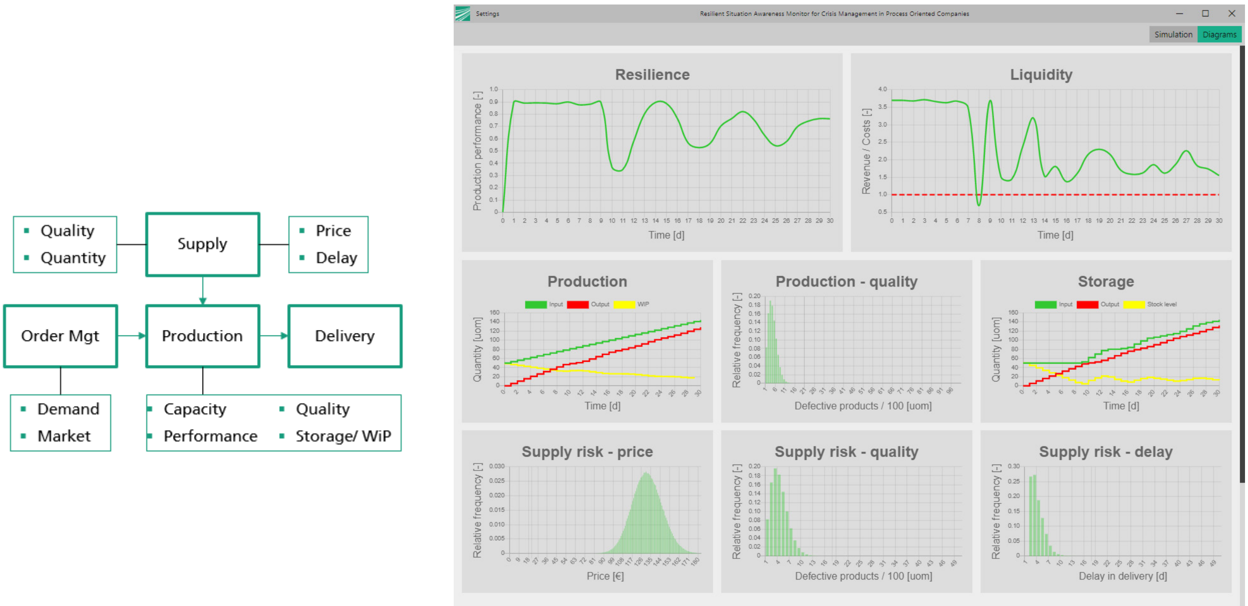

Figure 3: Left: Generic model to represent a critical process of an SME according to VDI 4499 [19]. Right: Overview of the graphical user interface to assess the resilience, the liquidity and further performance functions of a critical process.

The result of the multi-dimensional assessment is shown in the right picture of Figure 3. The user can simulate the resilience and the liquidity for an arbitrary number of shop calendar days. The impact and interdependence of certain parameters can be easily evaluated. The liquidity is expressed by the relation of revenue, based on finished goods, and the costs for employees, resources and the supplier. The performance target for the resilience quantification (upper left diagram) is based on the relation of maximum and current capacity of the production. The overall assessment scheme allows a quick overview concerning the consequences of disruptive events. Furthermore, the effectiveness of certain resilience phases, like preparation, protection, response and recovery can be evaluated.

4. Application in use cases

4.1 Application of the Situation Awareness Monitor for resilience management

The SAM for resilience management serves as an assistance tool for tactical and strategic decisions as well as the implementation of derived measures in the event of disruption and in daily operations. A prototype with a view generated for a company in the prepare phase, for example, is illustrated in Figure 4.

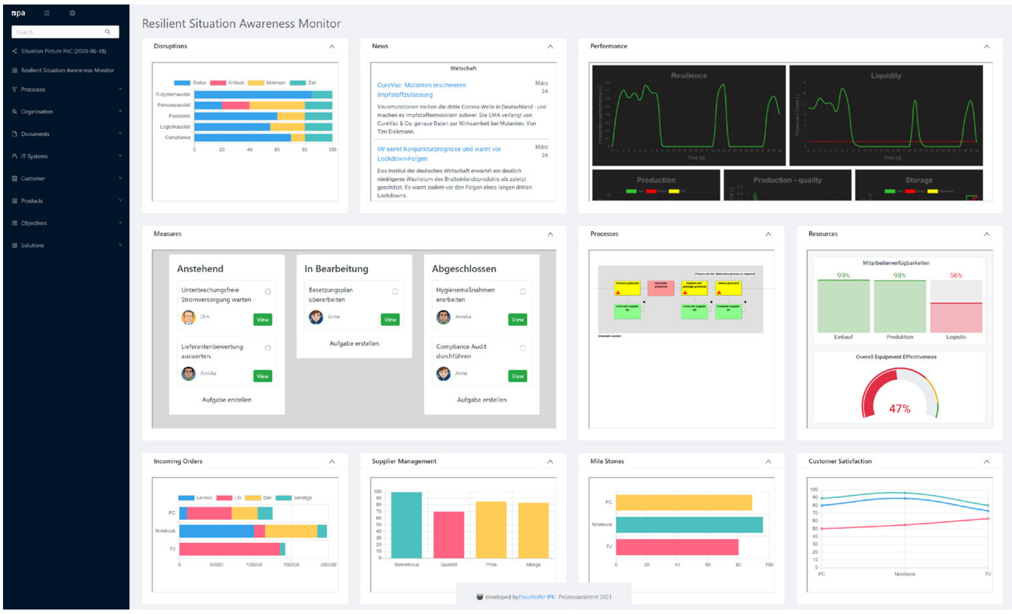

Figure 4: Prototype of the Situation Awareness Monitor for resilience management

Following the approach shown in Figure 1, recent news are continuously displayed in the upper left side of the prototype and form the basis for the corporate environment analysis, which represents the core element of the resilience cycle management process. In the widget left of the news ticker, the preparation status of the company concerning relevant disruptions is displayed. The associated resilience measures are managed in the Kanban board below. In the later phases of the resilience cycle, the Kanban board facilitates the implementation of measures – including setting the crisis team operational – and thus enables networked action. In preparation for a pandemic, the exemplary company illustrated in Figure 4 has developed a hygiene concept, which had previously been defined as the minimum preparation level that must be reached in order to be above the critical limit. In order to reach the target preparation level with regard to a pandemic, the staffing plan needs to be revised and updated. The corresponding resilience level as well as the liquidity level can be monitored and simulated in the multi-dimensional resilience-based liquidity assessment that is integrated into the upper right side of the prototype. Processes that are potentially affected by specific disruptions as well as the company's resources (e.g. staff availability and OEE) can be monitored on the center right side, which allows for a fast and targeted reallocation of resources in case of a disruption. In the lower section of the prototype, data of heterogeneous information systems (e.g. order management system, supply chain management system, manufacturing execution system, customer relation management system) is displayed for a comprehensive evaluation of the company's situation. This enables the management board to assess the feasibility of customer orders in case of a pandemic as well as to search and implement process alternatives.

4.2 SME liquidity during a disruptive event

The introduced assessment tool (as shown in Figure 3) generates a quick overview concerning the dynamic interaction of certain parameters of a critical process within an SME. Within the consideration of a disruptive event, the effects on the liquidity are analyzed. Taking the COVID-19 pandemic as an example, the effects are first seen in the suppliers and the customers. While many suppliers cannot provide reliable statements about the delivery status, the first impact on customers can be seen in the lockdown-induced retail closures. The action and information restrictions of these two elementary components of a critical process lead to massive limitations in the production of a manufacturing company. The affected parameters are primarily a drop in the economic indicator and order quantity, as well as an increase in storage time, storage space, and supplier pricing and delay calculation. Figure 5 shows the resulting liquidity in the left diagram, where a decreasing demand is considered. Furthermore, an increasing supply risk is realized by a larger uncertainty concerning the price and delay in delivery. After a few days, the liquidity decreases rapidly and losses are expected.

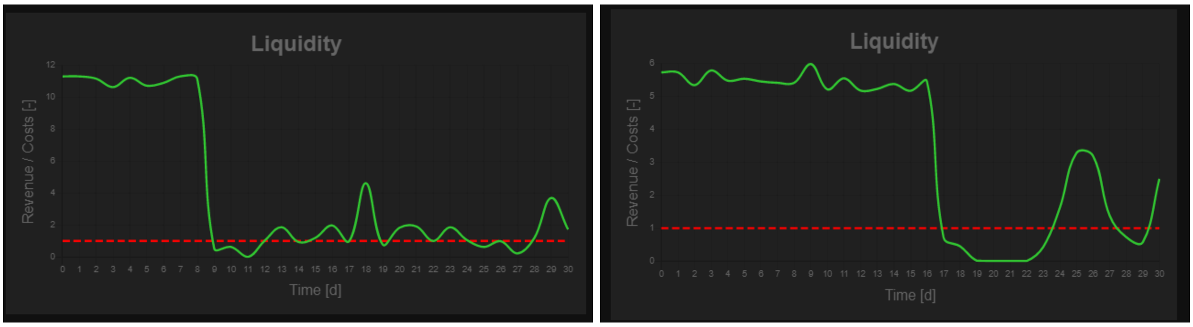

Figure 5: Left: time-dependent liquidity of an SME during a crisis situation (decreasing demand, increasing supply risk). Right: Similar disruption with consideration of short-time work as enhancement measure. For both simulations, random data is used for visualization.

Based on these impacts, suitable protective measures can be specifically derived. These are applied according to the category of the impact parameters in order to mitigate the disruption as far as possible at the point of origin. The right diagram of Figure 5 shows the result with the same disruption but the consideration of short-time work as countermeasure. The positive liquidity is reduced by a factor of two but extended on a longer time span. The decrease is induced to a delay in delivery by the supplier, but a fast recovery follows, based on the consideration of the enhancement measure.

5. Summary and Outlook

This paper provides an approach and a solution for an SAM for resilience management with an integrated resilience-based liquidity assessment. Due to its model-based architecture, the SAM and its reflective view types are generated by an integrated enterprise model, which enables a fast configuration of the SAM for various disruptions as well as daily operations and along the resilience phases. Furthermore, data from the corporate environment and internal IT systems is gathered and processed, which supports continuous performance and liquidity assessment. Moreover, the consequences of possible disruptive events as well as the effectiveness of resilience measures can be evaluated. Hence, the functions derived in Chapter 2.3 are supported by the SAM presented in this paper. The application example shows that the derived model considers the essential parameters to characterize the complex behavior of a small and medium enterprise. Further steps will focus on the validation of single elements, which is currently missing.

However, currently there are opportunities for improvement. So in the future, the views have to be adaptable directly in the SAM. When implementing the appropriate countermeasures, for example, adjustments need to be made in the integrated enterprise model, which then generates the SAM views. Therefore, further research is needed on the technical level in order to agilely enable the user to make adjustments in the SAM, which are reflected in the integrated enterprise model and vice versa. Concerning the methodological approach, further research should be conducted on improving the accuracy of the SAM in order to assess the completeness and the consistency plausibility. Likewise, it is to be evaluated under which circumstances the parameter-based liquidity assessment is preferred to the event-discrete simulation.

Another aspect to be taken into account is the relationship between the introduced model-based resilience monitoring and the performance management using electronic performance boards on the production shop floor. On the one hand, a number of artefacts are addressed on both systems, e.g. output rate, sickness level, measure definition and monitoring. On the other hand, some elements are currently suitable in one of the systems only (e.g. external information, events in the SAM). In order to avoid complexity and redundant systems, further research has to be performed for synchronization and contextualization. So for instance, advanced performance boards can be enabled to integrate necessary views and functions as required along the resilience phases (e.g. communication channels to crisis management board).

References

[1] Clausewitz, C. von, 2019. Clausewitz - Vom Kriege: Militärische Führung und Strategie, 1st ed. epubli, Berlin.

[2] Schaub, H., 2016. Vernetzte Operationsführung zur Unterstützung militärischer Stäbe, in: Hofinger, G., Heimann, R. (Eds.), Handbuch Stabsarbeit. Führungs- und Krisenstäbe in Einsatzorganisationen, Behörden und Unternehmen. Springer, Berlin, Heidelberg, pp. 291–295.

[3] Stanton, N., Chambers, P., Piggott, J., 2001. Situational awareness and safety. Safety Science 39 (3), 189–204.

[4] Endsley, M.R., 1995. Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors 37 (1), 32–64.

[5] Kung, P., Hagen, C., Rodel, M., Seifert, S., 2005. Business Process Monitoring & Measurement in a Large Bank: Challenges and Selected Approaches, in: Proceedings of the 16th International Workshop on Database and Expert Systems Applications (DEXA'05), Copenhagen. IEEE, pp. 955–961.

[6] Harmon, P., Wolf, C., 2014. The State of Business Process Management 2014. Business Process Trends. http://www.bptrends.com/bpt/wp-content/uploads/BPTrends-State-of-BPM-Survey-Report.pdf. Accessed 10 March 2021.

[7] Heinrich, B., Linke, P., Glöckler, M., 2017. Grundlagen Automatisierung: Sensorik, Regelung, Steuerung, 2nd ed. Springer Vieweg, Wiesbaden.

[8] Schumacher, J., 2020. Coronavirus-Krise: Die langfristigen Folgen für KMU. https://unternehmer.de/management-people-skills/250243-coronavirus-krise-folgen-fur-kmu. Accessed 31 March 2021.

[9] KPMG, 2020. Unternehmensüberwachung – Welche Entwicklungen jetzt im Fokus stehen. CGP Das Governance Magazin 9.

[10] Thoma, K. (Ed.), 2014. Resilien-Tech: "Resilience-by-Design": Strategie für die technologischen Zukunftsthemen. Utz, München.

[11] Hiller, D., Finger, J., 2021. Fraunhofer Resilience Evaluator. Fraunhofer Ernst-Mach-Institut. https://www.resilienz.leute.server.de/free/. Accessed 10 March 2021.

[12] Fraunhofer Ernst-Mach-Institut, 2021. Resilienz als Schlüssel, um Krisen erfolgreich zu bewältigen. Fraunhofer Ernst-Mach-Institut. https://www.emi.fraunhofer.de/de/geschaeftsfelder/sicherheit/forschung/Fraunhofer-Resilience-Evaluator-FReE.html. Accessed 10 March 2021.

[13] Spur, G., Mertins, K., Jochem, R., 1993. Integrierte Unternehmensmodellierung, 1st ed. Beuth, Berlin.

[14] Fraunhofer Institute for Production Systems and Design Technology IPK. MO²GO: Enterprise Modelling, Analysis and Optimisation. https://moogo.ipk.fraunhofer.de/. Accessed 16 March 2021.

[15] Nyhuis, P., Wiendahl, H.-P., 2009. Fundamentals of production logistics: Theory, tools and applications. Springer, Berlin, Heidelberg, XIX, 312 S.

[16] Landtsheer, R. de, Ospina, G., Massonet, P., Ponsard, C., Printz, S., Härtel, L., Cube, J.P. von, 2016. A Discrete Event Simulation Approach for Quantifying Risks in Manufacturing Processes, in: ICORES. Proceedings of 5th the International Conference on Operations Research and Enterprise Systems, Rome. SCITEPRESS - Science and Technolohy Publications Lda, Setúbal, pp. 313–322.

[17] Cube, P. von, Härtel, L., Schmitt, R., Ponsard, C., Massonet, P., Landtsheer, R. de, Ospina, G., Printz, S., Jeschke, S., 2016. Monetary Quantification of Supply Risks of Manufacturing Enterprises - Discrete Event Simulation Based Approach, in: Editorial 49th CIRP International Conference on Manufacturing Systems (CIRP CMS), Stuttgart. Elsevier, Amsterdam, pp. 164–170.

[18] Straub, D., 2018. Lecture Notes in Engineering Risk Analysis. TU München, München.

[19] Verein Deutscher Ingenieure e. V., 2008. VDI 4499 Part 1: Digital factory. Accessed 31 March 2021.

Biography

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