Workplace safety know-how: enhancing workplace safety through the capability driven solution

Rūta Pirta-Dreimane [1] and Ralfs Matisons [1]

[1]Riga Technical University, 6A Kipsalas Street, Riga LV-1658, Latvia

Abstract
The Covid-19 pandemic has induced significant changes in workplace practices, prompting a paramount emphasis on creating a safe work environment. This transformation coincides with the emergence of Industry 5.0, where advanced technologies are fused with human-centric approaches to foster a more adaptable and interconnected ecosystem. The paper demonstrates an experience of Safe work environment modelling in a research and development project, jointly with an industry partner. The paper presents capability-driven solution modelling and design. The study combines Enterprise Architecture and Capability Driven Development to conceptualize safe work environment capabilities and design value-driven information system.

Keywords
Safe workplace, Business capabilities, Capability Driven Development, Enterprise Architecture

1. Introduction

The Covid-19 pandemics has transformed the workplace with a shift of the ways of working and greater emphasis on the importance of a safe work environment for on-site work [1]. Simultaneously, the Industry 5.0 has been rapidly developing. This new paradigm combines advanced technologies with the human factors to create a more interconnected and adaptable ecosystem [2]. The well-being of the workforce is prioritized as a central element of production processes [3]. The workplace conditions, such as optimal CO2 level, humidity, are essential factor to ensure the safety and well-being of employees. Wile, perspective technologies, such as Artificial Intelligence (AI), Internet of Things (IoT) can enable the workplace safety management [4].

Technology-enhanced safe work environment provision has been investigated in several studies [5]–[7]. Emerging technologies, such as IoT and AI has been applied in healthcare monitoring [8]–[10] and building and facilities management [11], [12]. However, existing solutions primarily cover dedicated risk factors (such as air quality monitoring) and cannot be supplemented with new diffusion models. Early warning signals are not monitored, and solutions don't consider the topology of an enterprise. Hence, the knowledge gap exists, along with opportunities for innovation.

Capability design is not a novel concept, it has been applied to both business architecting and information systems (IS) modelling. Enterprise architecture (EA) is widely used approach for description of enterprise views and states [13]. Capability driven development (CDD) enable the design of value-adding IS [14]. Both, EA and CDD helps to improve alignment between information technology (IT) and business. Therefore, in our study both approaches are combined

BIR-WS 2023: BIR 2023 Workshops and Doctoral Consortium, 22nd International Conference on Perspectives in Business Informatics Research (BIR 2023), September 13-15, 2023, Ascoli Piceno, Italy
ruta.pirta-dreimane@rtu.lv (R.Pirta-Dreimane); ralfs.matisons@rtu.lv (R. Matisons)
0000-0001-8568-0276 (R.Pirta-Dreimane); 0000-0002-3057-4959 (R. Matisons)

to conceptualize safe work environment capabilities and to define requirements for supporting IS. EA helps to identify the decomposition of the business capabilities from an enterprise viewpoint. While CDD, is applied to explore lower-level capabilities and their related concepts to be provided as IS services.

The paper demonstrates an experience of Safe work environment modelling in a research and development project, jointly with an industry partner. The paper presents capability-driven solution modelling and design. The solution realizes business continuity and risk management capabilities that are conceptualized as knowledge patterns. The contributions of this paper are multi-fold. Firstly, it describes EA and CDD application in value driven IS design an serves as an experience report. Secondly, it proposes knowledge patterns for a safe workplace management. Additionally, it provides DROVIDS solution design and demonstration.

The rest of the paper is organized as follows. Section 2 presents the research overview, presenting methodology and key artefacts. Section 3 describes the workplace safety knowledge model. The model implementation is elaborated in Section 4. Section 5 concludes.

2. Research Overview

The Action Design Research (ADR) method [15] is used as the main method of the research project. The ADR method emphasis on cultivating both practical and theoretical relevance in the research. It considers the iterative development process and combine different research methods. The essence of the method is the cyclical development of project artefacts by conducting the main phases of the research (Figure 1). All phases are primarily focused on the development of a new artefact, the DROVIDS platform.

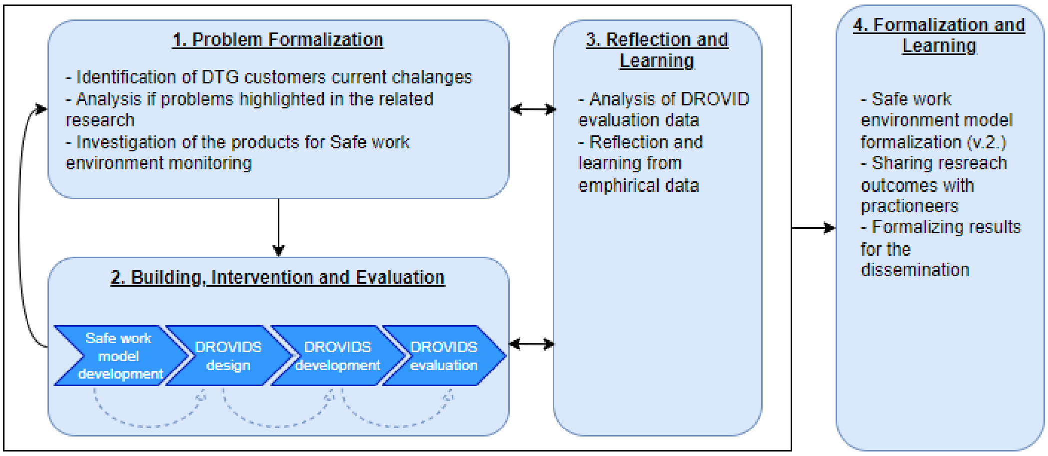

Figure 1: Research Methodology (adapted from [15])

This paper describes the second phase of the research with focus on safe work model development, DROVIDS design and piloting. The safe work environment model is the foundation of the platform, and it consists of three main building blocks: business continuity and risk assessment model [16], sensor model [17] and enterprise topology model [18]. The enterprise architecture framework TOGAF [19] and CDD method [20] are used in the development and conceptualization of the artefacts of the model. The EA framework is used to describe high-level architecture in the form of a reference model of business continuity [21]. While CDD is used in the later project phases for the description of lower-level architectural artefacts, such as knowledge patterns. The knowledge patterns encapsulate the best practices from related research studies, experts and competent institutions [16]. The design of the platform follows the C4 model, representing Context, Containers, Components, and Code of the platform [22]. The model allows a gradual decomposition of the system and provides a way to visualize the different layers and components of a software system, from high-level contexts down to the code level. The evaluation of the platform is done in real operating conditions in the industrial partner office.

Multi-set of methods are used for the platform evaluation: experiments, interviews, and survey. The validation is performed gradually, starting with the collection of data and progressing through their analysis and the formulation of recommendations.

3. Workplace Safety Knowledge Model

"Business capability" and "capability" concepts are widely used, meanwhile, there are still lack of consensus regarding the fundamental characteristics of capability [23], [24]. The concept is presented in different frameworks, such as TOGAF, Beimborn, VDML [25]. This study has opted to apply two frameworks - TOGAF and CDD. TOGAF business capabilities guide [27] is used to conceptualize business capabilities required for a business continuity (3.1. section). While CDD [26] is applied to investigate requirements for the DROVIDS platform (3.2. section).

3.1. Business Capabilities

Business Capability is perceived an abstraction of a business function, capturing what an organization does, rather than specifying the details of how, why, or where it is accomplished. The Open Group [19] define Business capability as "particular ability that a business may possess or exchange to achieve a specific purpose". Business capability is realized through four main components [27]:

- People /roles - individual actors, stakeholders, business units, or partners involved in delivering a business capability.
- Business processes - processes, that enables or delivers business capability.
- Information – representation of business data, knowledge and insights.
- Resources – tools, materials and assets required for execution of business capability.

Business capabilities typically encompass four to five hierarchical levels. Leveling involves breaking down each top-level business capability into lower levels to convey more detailed information at a suitable level for the intended audience or stakeholder group [27].

The reference architecture for business continuity [21] defines ten Level 1 (L1) business capabilities that is suggested for a resilient enterprise: Strategy management, Policy management, Business continuity management, Risk and compliance management, Facility management, IT management, People and culture management, Public relationship and communication management, Third party management and Safety, health and environmental management.

Safe work environment management is directly related to two L1 capabilities: (1) Safety, health and environmental management and (2) Facility and equipment management. Safety, health, and environmental management is responsible about workplace accidents reduce and work environment safety increase what aims to increase enterprise resilience and sustainability [28], [29]. Meanwhile, facility and equipment management deals with facilities related assets management, as buildings, physical workplaces and others. Facility monitoring activities are applied to detect distributive events and damages. Facility management enables workplace transformation by implementing remote and hybrid workplaces required in crisis situations [30].

The selected L1 capabilities have been decomposed in the lower-level capabilities (Figure 2). The following L4 level capabilities are defined: Epidemic guidelines monitoring, National level infections monitoring, Local level infections monitoring, Hospital occupancy monitoring, Personal hygiene monitoring, Use of personal protective equipment monitoring, Air quality monitoring, Safety precautions monitoring. In the project context primary the monitoring capabilities are investigated, what will be associated with recommendations and adjustments to enable planning capabilities.

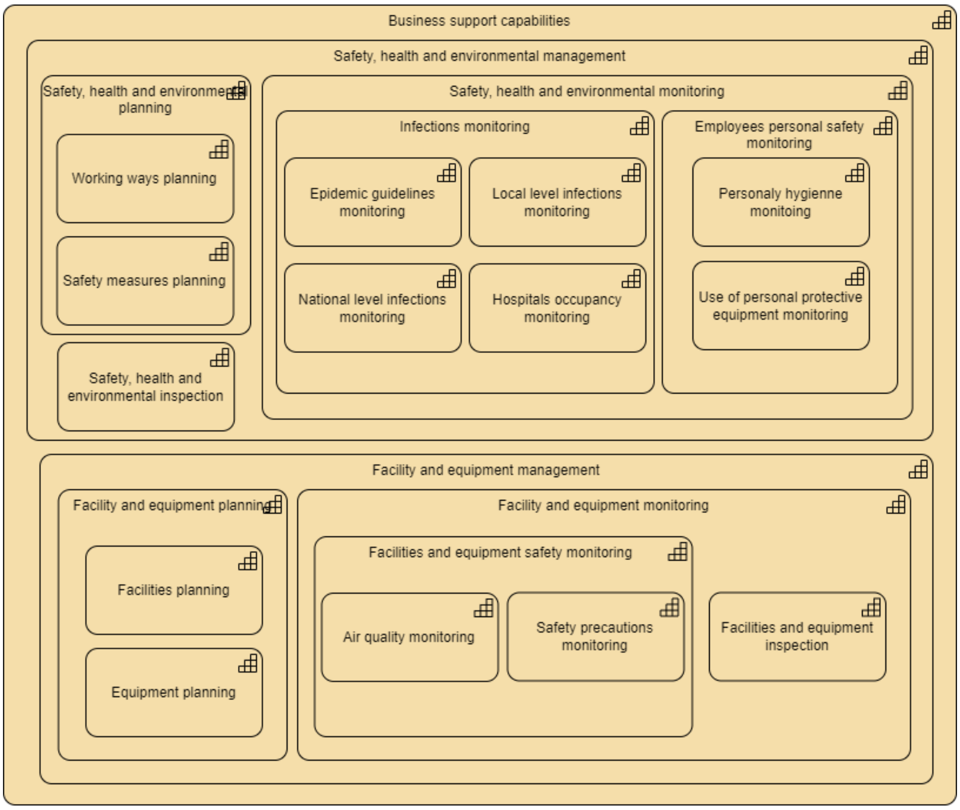

Figure 2: Safe work environment capabilities map (a fragment)

3.2. Knowledge Patterns

The lower-level business capabilities (L4) have been used as basis for the knowledge patterns that are published in a pattern repository. The patterns repository incorporates the best practices and recommendations in particular domain formalized in the form of patterns. The pattern includes such main attributes [26]:

- Capability - ability and capacity to achieve organization's objectives in variable contextual situations.
- Goal - a desired state of affairs that needs to be attained.
- KPI - measures achievement of the goals.
- Context Element - represents information characterizing situation of an entity, i.e., service.
- Adjustment - an algorithmic recommendation to adapt capability delivery according to the context situation.

The patterns are structured and reusable knowledge that support solve a problem in a specific context by offering the most suitable solution or solution alternatives. Selected examples of the safe work environment knowledge patterns are included in the next sub-sections.

3.2.1. Air quality monitoring

The air quality monitoring pattern encompasses the best practice that the employers should apply to ensure qualitative air (Figure 3). The goal of the capability is to provide good air quality to avoid of viruses spread among the employees. The goal can be measured by: (1) infection cases minimization trend (yearly, quarterly); (2) employees satisfaction level about air quality. The capability is associated with the context element – air quality, what can be measured by air humidity level (%) and CO_2 level (ppm). To achieve the goal following adjustments in work environment can be performed: (1) window opening and switching on the air humidifier. The goal can be supported by new platform services provision: (1) air quality monitoring and (2) Building management system (BMS) signaling.

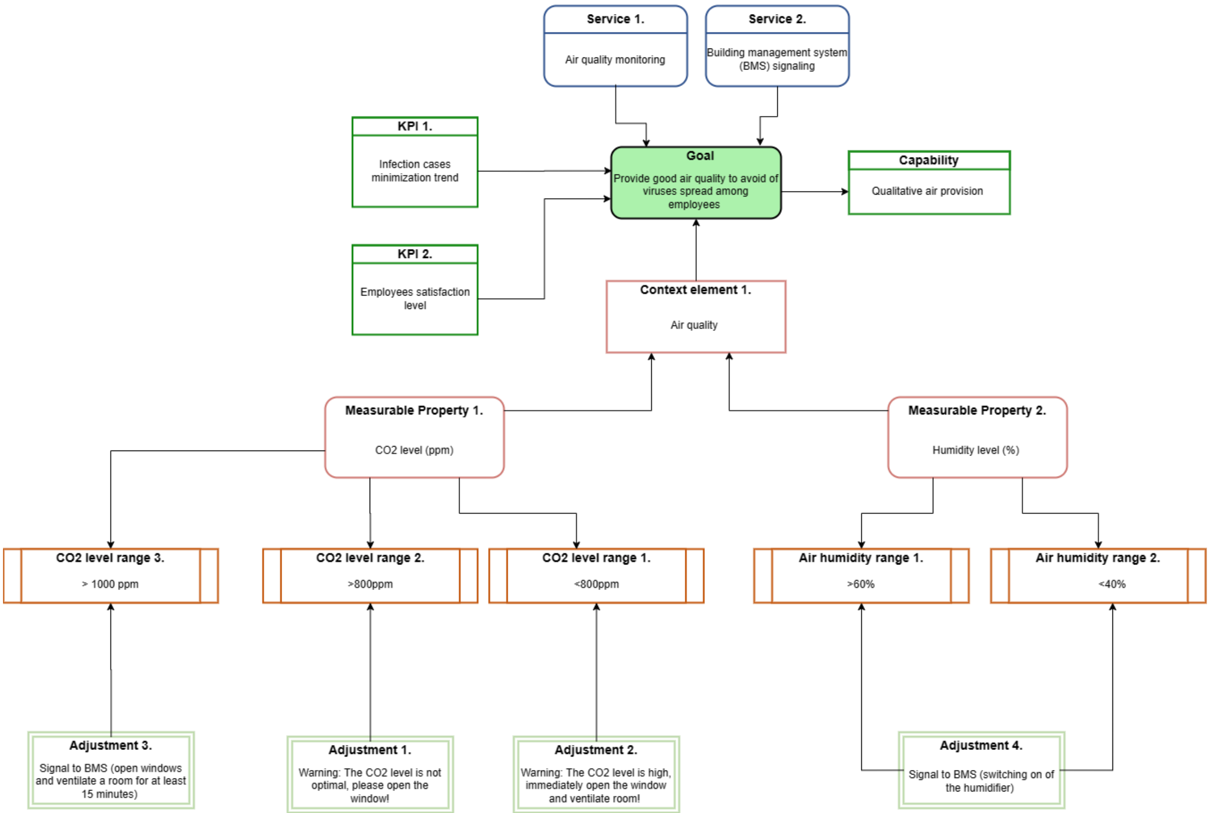

Figure 3: Air quality monitoring pattern

3.2.2. Local level infections monitoring

The local level infections monitoring pattern suggests infection early waring detection and monitoring approach using infection spread monitoring in the wastewaters of the office premises (Figure 4). The goal of the capability is to detect infected employees as early as possible. The goal can be measured by: (1) infection cases from co-workers' minimization trend (yearly, quarterly) and (2) early detected infected employees' number.

The capability is associated with a context element - local level virus concentration in the wastewaters. The local level virus concentration can be measured by RND gene copies amount per employees in the office.

To achieve the goal following adjustments in work organization can be performed: (1) off-line work introduction in case of high infection risk; (2) hybrid work with teams split introduction in case of the medium infection risk; (3) prohibition of face-to-face meetings in case of low infection risk. The goal can be supported by a new platform service provision: wastewater monitoring service.

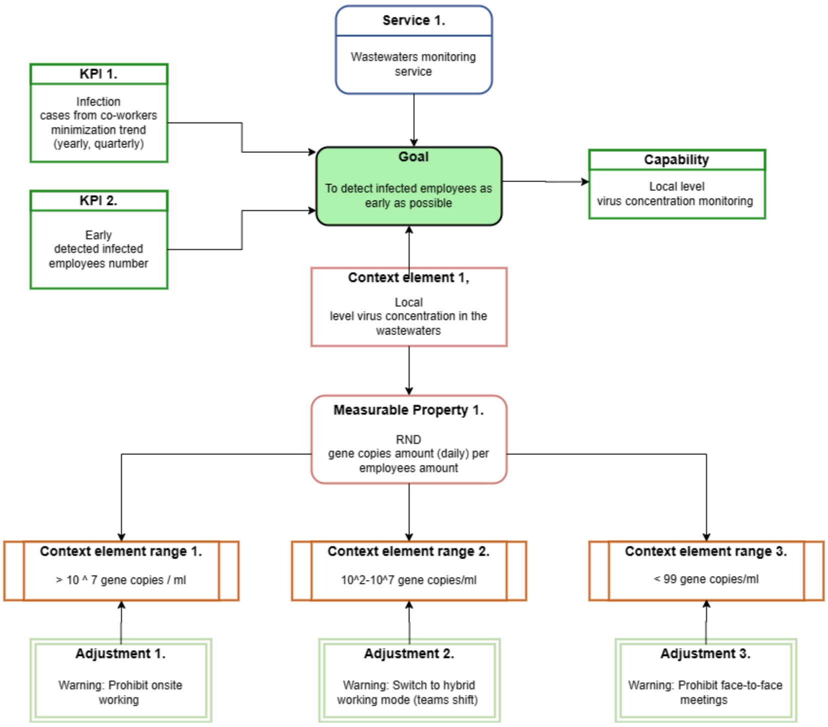

Figure 4: Local level infection monitoring pattern

4. Model Implementation

The workplace safety knowledge model has been implemented in the DROVIDS platform. The primary purpose of the platform is to combine interoperable and reusable services to ensure business continuity and reduce the risks of Covid-19 spread at the company's premises. Initially it has been designed, considering the Covid-19 virus spread, however the solution can be applied to a wide range of infectious diseases. The platform takes measurements of the office environment, providing a better understanding of the office ecosystem. By having a constant flow of data, the platform gains a much more superior insight of the office environment, thus minimizing the risk of infection spread among employees. Having a constant platform which monitors the ecosystem notifies the employees when any of the guidelines are being broken. The platform keeps an optimal CO2 level, humidity level, people count and people density in the office premises, thus ensuring the wellbeing of employees are met and the risk of infection spread is minimized.

4.1. Technical Solution Overview

The DROVIDS platform interacts with external systems, actuators, sensors, messaging services, users and the laboratory. The platform exchange data between its components and with several external components, such as, Knowledge management repository (ARTSS), Ticketing system (RedMine), Wastewater sampler, National Wastewater Management monitoring solution and Google Trends (Figure 5).

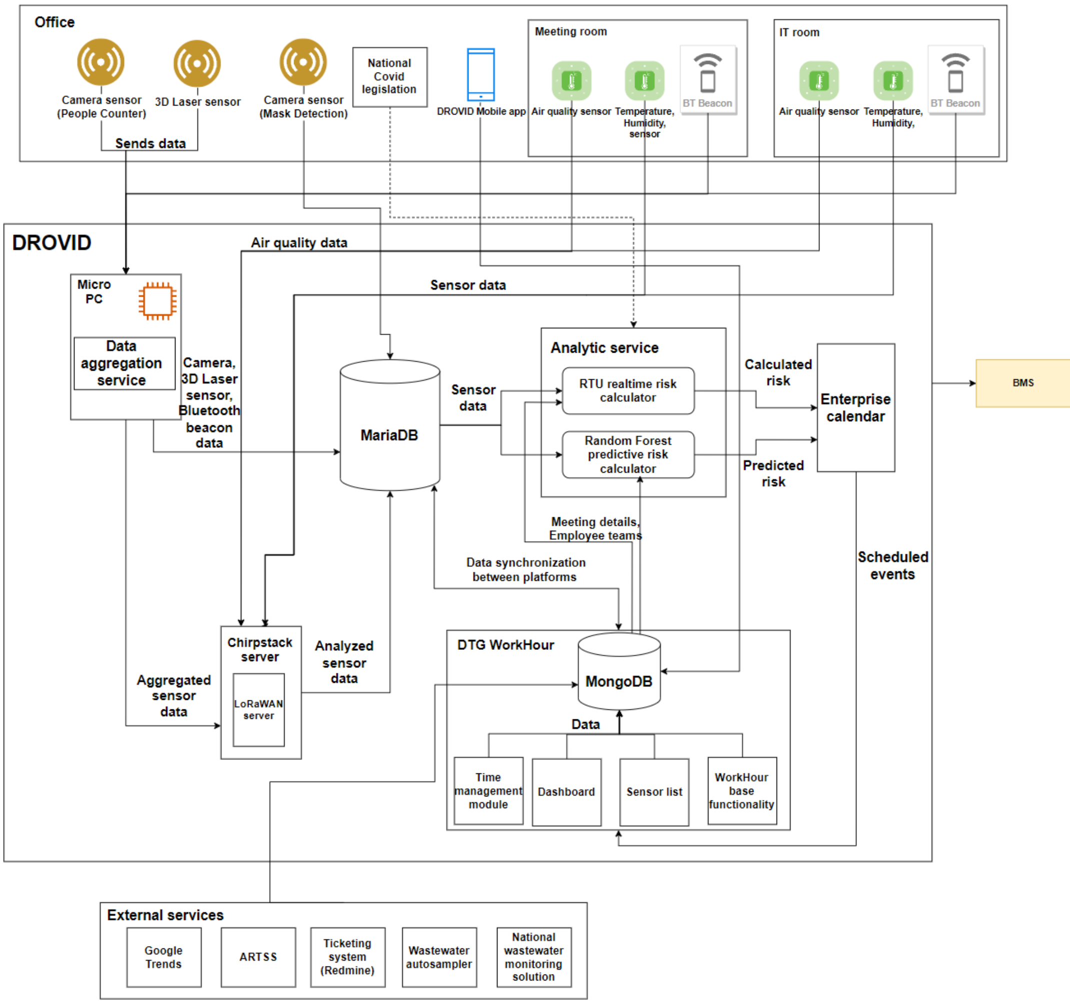

Figure 5: The data pipeline of the DROVIDS platform

The DTG WorkHour component allows the platform to access data about the employees, sensor list, time management module, and the dashboards, which are a collection of the analysed data of the platform. The ChirpStack server collects data from IoT devices and aggregates them before storing in a database, which is accessed by the platform. The analytical service calculates the risk of the office space. The risk is further shown on the dashboard so that the employees can immediately understand whether the office space is in a safe condition or not. There are different classifications for the risks [16].When the risk of the office space is calculated, necessary mitigations to decrease the risk rating must be taken into consideration.

Covid-19 prevention and response rules and rules derived through data analysis are stored in the Knowledge management repository [31]. The repository allows to transform graphical knowledge patterns to JSON files. The repository functionality allows storing the rules in machine-readable form and retrieving them in JSON format. This allows to easily update the platform and keep it up to date with relatively low effort.

The wastewater sampler is a crucial part of the platform, since it gives an early insight of the employee state in the office, whether they are already becoming ill or not, thus giving an early warning for other employees to be more careful and cautious. By implementing Google Trends in the dashboard, the employees have an early warning of a disease. If the people search for keywords such as, covid, covid19, etc, it appears in a graph on the dashboard. The higher the search results in the town might correlate with the disease spreading across the town and to be cautious.

The analytical model is a central part of the DROVIDS platform, it calculates risk rating of the room. The system uses real-time IoT data to calculate the risk and also gives back the calculated risk in near real-time. Even though it requires IoT data, the system can function and calculate the risk even when there are not all of the required data. By combining Apache Spark Streaming and Apache Spark Machine Learning, it is possible to enrich the missing data. A Random Forest model is used in Apache Spark Streaming to predict in near real-time fashion the missing data. It has given a great accuracy predicting people count, co2, humidity, temperature, pressure.

4.2. Recommendations and Adjustments

DROVIDS calculates the risk level and triggers adjustments (Figure 6). Adjustments change working conditions to reduce the risk level. The adjustments are defined according to the best practices and may include advanced computational models to decide on the required actions. Alerts and warnings are used to alert about high risk working conditions. They can be consumed by both humans and machines. The adjustment is invoked if the predicted or actual risk level is high. The adjustment action is determined as specified in the patterns stored in the pattern repository. The relevant pattern is determined by matching the current risk rating with the context defined in the pattern.

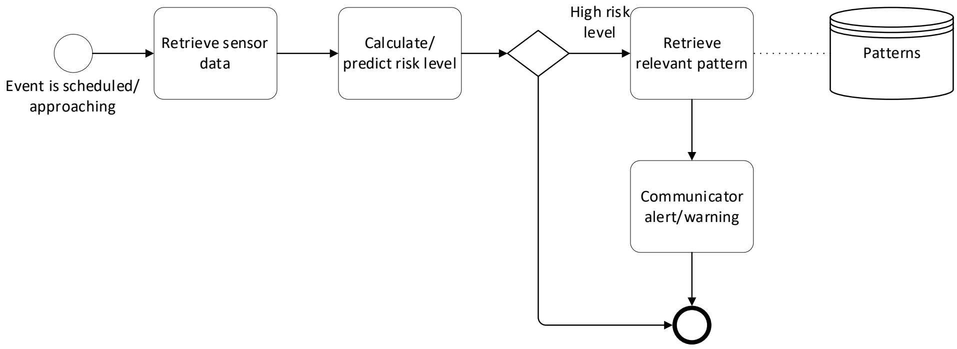

Figure 6: Recommendations and adjustments triggering process

The primary place of displaying the alerts is the DROVIDS dashboard (Figure 7). A dashboard presents all necessary information in one place. The presented data include but is not limited to people density by room, air quality state, all sensor data, etc. A notification panel is also displayed that is reserved for alerts coming from sections of the system. Alerts consist of critical measurement brackets that are breached, and any other values that have stepped out of the safe levels. The purpose of the dashboard is to be displayed in a central location at the works pace, as well as to be easily accessed by the person assigned responsible for the safety of the workspace.

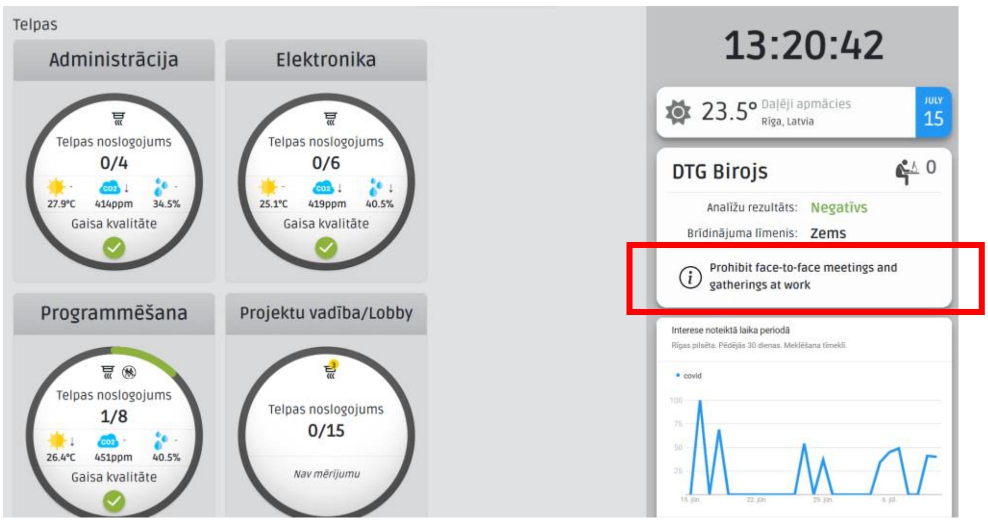

Figure 7: DROVIDS dashboard (a fragment)

5. Conclusion

This paper presents an experience on modelling a capability-driven solution, the DROVIDS platform, to enhance workplace safety. The study demonstrates the leverage of EA and CDD methods to conceptualize safe work environment capabilities and design value-driven information system. The safe work environment knowledge management process is presented, starting from business capabilities definition till knowledge model implementation in the DROVIDS platform. The case demonstrates how patterns for workplace safety could serve as a configuration model of the technical platform.

Business capabilities can be used as central elements for the management of reusable knowledge. In EA level business capabilities can suggest the required components of an enterprise to enable particular knowledge domain. While lover level capabilities can be a basis for a business aligned information system development and knowledge patterns can be stored in knowledge management repositories. Such repositories could provide knowledge as services for external information systems. From an EA management perspective such mechanisms would enable centralized knowledge overview and communication to several stakeholder groups (business representatives, IT personnel). While, from application design and development perspective, the repository integration requires relatively low effort and enables models configuration without major changes in the platform.

This paper presents the platform design stage, demonstrating the experience on EA and CDD leverage. The models itself currently are implemented, meanwhile, evaluation is done only partly. Future research activities focus on the models' evaluation and enhancements.

Acknowledgements

Project "Platform for the Covid-19 safe work environment" (ID. 1.1.1.1/21/A/011) is founded by European Regional Development Fund specific objective 1.1.1 «Improve research and innovation capacity and the ability of Latvian research institutions to attract external funding, by investing in human capital and infrastructure». The project is co-financed by REACT-EU funding for mitigating the consequences of the pandemic crisis.

References

[1] World Health Organization, "Preventing and mitigating COVID-19 at work," 2021.
[2] X. Xu, Y. Lu, B. Vogel-Heuser, and L. Wang, "Industry 4.0 and Industry 5.0—Inception, conception and perception," *J Manuf Syst*, vol. 61, 2021.
[3] Maija. Breque, Lars. De Nul, and A. Petrides, *Industry 5.0 - Towards a sustainable, human-centric and resilient European industry*. 2021.
[4] Y. Dong and Y. D. Yao, "IoT platform for covid-19 prevention and control: A survey," *IEEE Access*, vol. 9. 2021.
[5] M. Otoom, N. Otoum, M. A. Alzubaidi, Y. Etoom, and R. Banihani, "An IoT-based framework for early identification and monitoring of COVID-19 cases," *Biomed Signal Process Control*, vol. 62, Sep. 2020.
[6] N. Petrovic and Đ. Kocić, "IoT-based System for COVID-19 Indoor Safety Monitoring SCOR (Semantic COordination for Rawfie) View project," 2020. [Online]. Available: http://mqtt.org/
[7] A. Bashir, U. Izhar, and C. Jones, "IoT-Based COVID-19 SOP Compliance and Monitoring System for Businesses and Public Offices," MDPI AG, Dec. 2020, p. 14.
[8] Z. Pang, *Technologies and Architectures of the Internet-of Things (IoT) for health and well-being*. KTH Royal Institute of Technology, 2013.
[9] S. K. Routray and S. Anand, "Narrowband IoT for healthcare," in *2017 International Conference on Information Communication and Embedded Systems, ICICES 2017*, 2017.

[10] M. N. Bhuiyan, M. M. Rahman, M. M. Billah, and D. Saha, "Internet of Things (IoT): A Review of Its Enabling Technologies in Healthcare Applications, Standards Protocols, Security, and Market Opportunities," *IEEE Internet of Things Journal*, vol. 8, no. 13. Institute of Electrical and Electronics Engineers Inc., pp. 10474–10498, Jul. 01, 2021.
[11] D. Kwon, K. Ok, and Y. Ji, "IBFRAME: IoT Data Processing Framework for Intelligent Building Management," in *Proceedings - 2019 IEEE International Conference on Big Data, Big Data 2019*, 2019.
[12] N. Sidek, N. Ali, and R. Rosman, "Internet of things-based smart facilities management services successful implementation instrument development, validity, and reliability," in *International Conference on Research and Innovation in Information Systems, ICRIIS*, 2019.
[13] S. Kotusev, "Enterprise architecture and enterprise architecture artifacts: Questioning the old concept in light of new findings," *Journal of Information Technology*, vol. 34, no. 2, 2019.
[14] J. Stirna, J. Grabis, M. Henkel, and J. Zdravkovic, "Capability driven development - An approach to support evolving organizations," in *Lecture Notes in Business Information Processing*, 2012.
[15] M. K. Sein, O. Henfridsson, S. Purao, M. Rossi, and R. Lindgren, "Action design research," *MIS Q*, vol. 35, no. 1, 2011.
[16] J. Skrebeca, R. Pirta-Dreimane, and R. Matisons, "Towards Multidimensional Infection Risk Monitoring," in *2022 63rd International Scientific Conference on Information Technology and Management Science of Riga Technical University, ITMS 2022 - Proceedings*, 2022.
[17] J. Grabis, R.-P. Dreimane, B. Dejus, A. Borodiņecs, and R. Zaharovs, "Triple Pi Sensing to Limit Spread of Infectious Diseases at Workplace," 2023.
[18] J. Grabis, "Workplace Topology Model for Assessment of Static and Dynamic Interactions Among Employees," in *Lecture Notes in Business Information Processing*, 2023.
[19] The Open Group, "The TOGAF ® Standard," 2005. [Online]. Available: www.opengroup.org/legal/licensing.
[20] S. Berziša *et al.*, "Capability Driven Development: An Approach to Designing Digital Enterprises," *Business and Information Systems Engineering*, vol. 57, no. 1, 2015.
[21] R. Pirta-Dreimane and J. Grabis, "Towards a Reference Architecture for a Business Continuity," in *International Conference on Enterprise Information Systems, ICEIS - Proceedings*, Science and Technology Publications, Lda, 2023, pp. 553–565.
[22] Simon Brown, "The C4 model for visualising software architecture," *https://c4model.com/*.
[23] A. W. Tell, "What capability is not," in *Lecture Notes in Business Information Processing*, 2014.
[24] V. Michell, "A focused approach to business capability," in *BMSD 2011 - Proceedings of the 1st International Symposium on Business Modeling and Software Design*, 2011.
[25] A. W. Tell and M. Henkel, "Foundations of Capability Maps – A Conceptual Comparison," in *Lecture Notes in Business Information Processing*, Springer Science and Business Media Deutschland GmbH, 2022, pp. 101–117.
[26] J. Grabis, J. Stirna, and J. Zdravkovic, "A Capability Based Method for Development of Resilient Digital Services," in *Lecture Notes in Business Information Processing*, 2021.
[27] The Open Group, "Open Group Guide Business Capabilities," 2016.
[28] M. Asah-Kissiedu, P. Manu, C. Booth, and A.-M. Mahamadu, "Organisational Attributes that Determine Integrated Safety, Health and Environmental Management Capability," *MATEC Web of Conferences*, vol. 312, 2020.
[29] M. Asah-Kissiedu, P. Manu, C. A. Booth, A. M. Mahamadu, and K. Agyekum, "An integrated safety, health and environmental management capability maturity model for construction organisations: A case study in Ghana," *Buildings*, vol. 11, no. 12, 2021.
[30] W. Tanpipat, H. W. Lim, and X. Deng, "Implementing remote working policy in corporate offices in Thailand: Strategic facility management perspective," *Sustainability (Switzerland)*, vol. 13, no. 3, 2021.
[31] "ARTSS: Advanced Resilience Technologies for Secure Service | ARTSS." https://artss.rtu.lv/en (accessed Jul. 15, 2023).