DROVIDS: A Platform for Workplace Safety

Juris Tihomirovs [1], Ralfs Matisons[1] and Rolands Zaharovs[2].

[1]*Riga Technical University, 6A Kipsalas Street, Riga LV-1658, Latvia*
[2]*DTG, Ltd., Ganību dambis 24A, Riga, Latvia*

Abstract
The Covid-19 pandemic has transformed the dynamics of workforce and workplace. Being affected by Covid-19, organizations had to mitigate the risks of workplace safety and their negative effects on the health of employees and society. The workplace conditions, such as optimal CO2 level, humidity, are essential factors to ensure the safety and wellbeing of the employees. A safe work environment and the wellbeing of the employees are catalysators of enterprise productivity and sustainability, and advanced digital technologies help to achieve these objectives. This paper describes an applied project on development of a platform for monitoring and controlling workplace conditions to reduce risks of infectious diseases as well as other adverse effects on workforce productivity. It focuses on platform design using the C4 design model. The platform combines conventional and less frequently used data sources, such as wastewater analysis, to evaluate the risk of infectious diseases and to interpret these in the organizational context.

Keywords
Infection safe workplace, Covid-19, IoT, sensors, C4 modeling

1. Introduction

The Covid-19 pandemic has created various challenges for organisations. They had to significantly change their operating patterns to avoid interruptions in supply chain, adapt services to customer demand and mitigate risks to working safety and their negative effects on the health of employees and society in general. The World Health Organisation emphasizes the importance of a safe working environment [1]. A safe workplace is an essential factor in limiting the spread of infection. Estimating employee health, maintaining safe distances between workers, and monitoring contacts among all employees to separate them in the case of infection with SARS-COV-2 or other contagious diseases are important for the maintenance of the economic sector [2]. The safe working environment is particularly important for organizations that, due to their specific nature, cannot resort fully to remote work. It is a prerequisite for maintaining their businesses and jobs in order to mitigate the economic recession at the national and global levels during the pandemic situation.

Research Projects Track @ RCIS 2023: The 17th International Conference on Research Challenges in Information Science, May 23–26, 2023, Corfu, Greece
juris.tihomirovs@rtu.lv (J. T); ralfs.matisons@rtu.lv (R.M.); rolands.zaharovs@dtg.lv (R.Z)

The safe workplace consists of many factors that include both the regulation of human resources and environmental resources. Through the combination of monitoring the environment around employees and the monitoring of employees, it is possible to create a safer work environment, but in order to do this, an autonomous solution is required, which could always be available.

During the epidemic, important contributions have been made to the identification, tracking, and prevention of Covid-19. The use of IoT to ensure a safe workplace for infections has been widely used [3]–[5] both in health surveillance monitoring [6]–[8] and in building and facilities management [9], [10], as it has the ability to sense, share and transfer data through the network of interconnected devices. Although several similar solutions exist, they primarily cover one of the risk factors, such as air quality monitoring or monitoring of compliance with the distancing requirements. Monitoring models cannot be supplemented with new diffusion models and risk factors. The solutions do not provide recommendations for adjusting the set of measures according to the company topology. The existing solutions do not include early warnings about the approaching potential outbreaks, which are essential for enterprises to be able to limit outbreaks as soon as possible.

The project aims to create a platform for a safe working environment (referred to as DROVIDS) that integrates advanced information and communication technologies and biotechnologies. The platform combines business continuity planning, IoT, computer vision, machine learning and wastewater analytics technologies for comprehensive Covid-19 and other infections risk assessment, mitigation and prevention in workplaces where the nature of work limits remote working options, such as shift-based manufacturing companies. This paper describes an approach to ensure safe work environment and presents the design of the DROVIDS platform.

The rest of the paper is organized as follows. Section 2 presents the research methodology. Section 3 describes the overall approach of the platform. The design of the platform is elaborated in Section 4. Section 5 concludes.

2. Research Methodology

The Action Design Research (ADR) method [11] is used for the research design. The ADR method requires a significant focus on the development of practical and theoretical relevance of the research, allowing an iterative development process to assess different design alternatives and combine different research methods. The method emphasises the dissemination of research results. The essence of the method is the cyclical development of project artefacts by conducting the main phases of the research (Figure 1): (1) problem formalization, (2) building, intervention and evaluation, (3) reflection and learning and (4) formalization and learning. All phases are primarily focused on the development of a new artefact, the DROVIDS platform.

The problem investigation relies on gained knowledge from the implementation of previous projects by the project partner - software development company DTG. It has been consolidated in the product development roadmap of DTG, which provides analytical solutions for improving the work environment of the enterprises. The empirical evidence is supplemented by analysis of the related research and existing IT solutions in the feasibility study of the project.

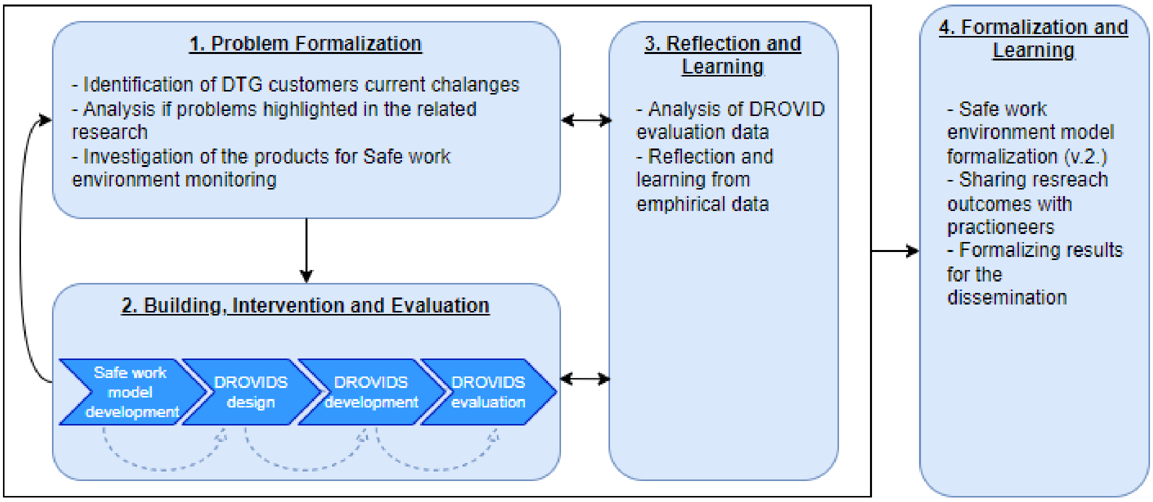

Figure 1: Research Methodology (adapted from [11])

The main tasks of the project are related to the building, intervention, and evaluation of the DROVIDS platform and its underlaying components (models and methods). 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, sensor model and enterprise topology model. Information systems analysis methods [12], the enterprise architecture framework TOGAF [13], 4EM method [14] and IDEF method [15] are used in the development and conceptualization of the artefacts of the safe work environment model. The enterprise architecture framework is used to describe high-level architecture of a business continuity, while 4EM and IDEF are used for the description of lower level architectural artefacts, such as an enterprise topology model. The platform is designed as a distributed system using a microservice architecture. The design of the platform follows the C4 model [16] which allows a gradual decomposition of the system, defining the main components and designing and detailing the specific services sequentially. The C4 model is an "abstraction-first" approach to diagramming software architecture, based on abstractions that reflect how software architects and developers think about and build software. The platform components are developed in the form of portable containers, and standardised APIs are used to integrate them. The development process uses incremental and iterative software development methods [17], which divide development into phases with periodic tests and demonstrations to assess progress and provide feedback. The evaluation of the platform is done in real operating conditions in the DTG office. Evaluation is performed for all developed services and intended data types (CO2 and humidity level, Covid-19 particle density in wastewater, application of restrictions). Physical experimental planning methods [18] are used to implement experiments, and statistical analysis and hypothesis testing methods [19] are used to process the results. The validation is performed gradually, starting with the collection of data and continuing with their analysis and development of recommendations.

Reflexion and learning are performed by analysing DROVID evaluation data. The evaluation results are used to adapt, adjust and formalize its underlying models and methods. The research results are shared with the stakeholders in the form of scientific papers, conferences presentations, and dissemination activities, such as demonstration of the platform prototypes.

3. Overall Approach

The central part of the platform is an integrated approach to managing infection risks in organizations (Figure 2). It uses cross-disciplinary scientific methods to ensure the nonintrusive and preventive minimization of infection risks. These sensor technologies offer predictive and preventive capabilities. They are used in the organisational context to improve the adaptation of mitigation measures and ensure business continuity.

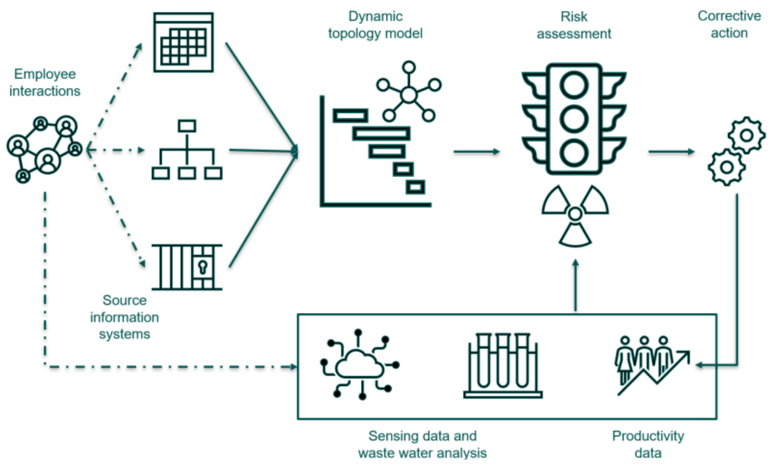

Figure 2: Overall Approach of the platform.

The platform uses IoT, waste water analysis data, and productivity data to gain a better understanding of the environment of the office. Employee interactions are combined with source information systems in a topology model. Having combined the data about the office environment and the topology model the office premises can be evaluated more precisely, keeping in mind such things as employee time spent together, etc. The risk assessment allows us to understand the quality of the environment in the office, and whether the office premises are more likely to spread malicious infections or not.

The DROVIDS platform provides an opportunity for early warnings about the risks of Covid-19 outbreaks by analysing the density of Covid-19 particles in the company's wastewater. The platform collects data on the density of Covid-19 particles in the wastewater and generates early warnings to responsible employees of the company. The platform includes a business continuity planning and risk analysis model that uses data from enterprise information systems (work management systems, project management systems, space management systems, etc.). The risk model is elaborated in [20] and the use of enterprise data and topology is presented in [21].

4. Platform Design

The initial DROVIDS architecture is shown in the C4 high-level System context diagram (Figure 3). The architecture includes the following concepts: the Covid safe work environment platform DROVIDS and integrations with external data sources, sensors, actuators, and messaging services. In that architectural model, the DROVIDS platform interacts with external building blocks and supports two different types of data flow:

- Incoming data for risk monitoring and analysis. Data from external data sources and sensors are used for risk monitoring and analysis. The DROVIDS platform receives data from related information systems – Covid-19 prevention legislation database (provides safe work-space requirements), enterprise ticketing system (provides employee efficiency data), knowledge management solution (provides best practices to reduce Covid-19 risks data), and Google Trends (provides search trends) as well as data from IoT devices and sensors - air quality sensors (provides CO_2 and humidity level data), camera sensors (provides data on whether employees wear face masks and distancing data), 3D laser vision sensors (provides people count in-room data) and manhole sensors for wastewater analysis;
- Outcoming data for actuator triggering and notifications for messaging services. The DROVIDS system calculates the risk levels based on the data received. As a result, actuators are triggered, and notification messages are sent to employees using messaging services.

Several stakeholder groups are involved in DROVIDS business processes. Employees accessing the DROVIDS platform can obtain information about the office's environment. Shift seniors update the status of the disinfectant availability in the system. System administrators administer the DROVIDS system - change system settings, manage sensors, register and update employee information, etc. Facility administrators deliver wastewater samples to the laboratory and upload the results to the DROVIDS system.

A Level 2 diagram (see Figure 4) demonstrates how the DROVIDS platform is broken into high-level containers (layers, building blocks, applications, and databases). The front-end layer is designed for user interaction with the DROVIDS platform. Using the web interface, company's employees after the authentication and authorization process can access the dashboard, where information about the office conditions is visible as well as Covid-19 related search statistics retrieved from Google Trends. In addition to the dashboard functionality, this front-end layer also provides other core functionalities like device and classifier management functionality, National wastewater monitoring solution results upload functionality, notifications for smart devices, enquiry possibilities with room condition and restrictions statuses, and reporting (actual compliance status, actual risk score, measures effectiveness score, flags about detected rules breaches/incompliances, historical compliance overview, etc.).

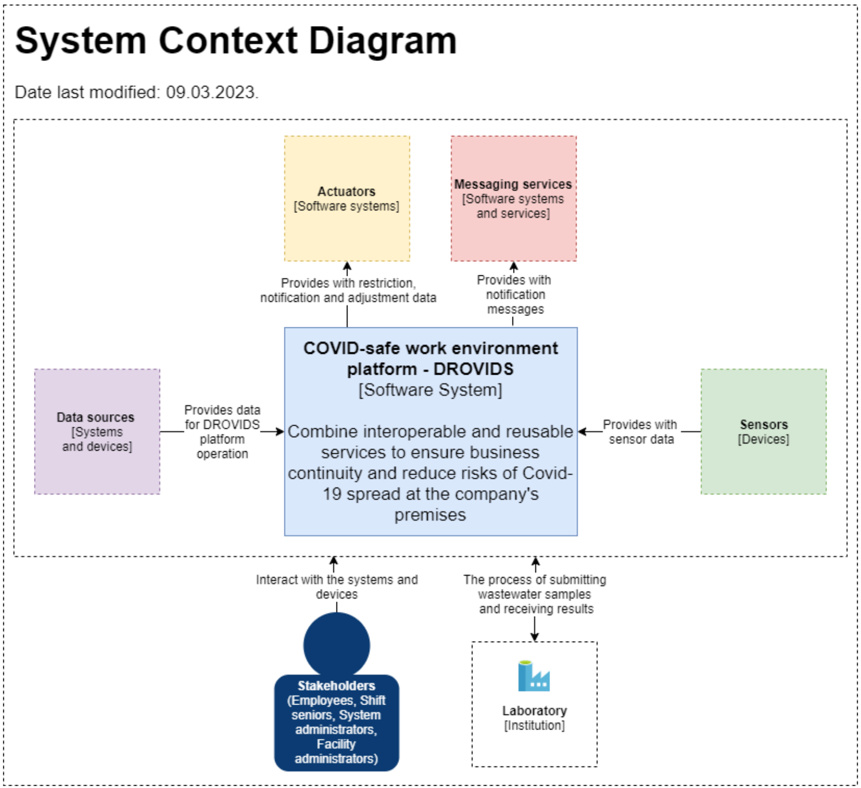

Figure 3: DROVIDS System context diagram

The back-end layer is designed for data retrieval, processing, and decision-making to estimate an infectious disease risk level, which in turn triggers actuators. A functional decomposition is used there to separate back-end responsibilities:

1. Data retrieval service - The purpose of the component is to retrieve data from external systems and IoT devices, and then store it in the database for further processing. In the given design, external systems are integrated through the use of a REST API, while IoT devices and sensors are integrated using either the LoRaWAN network or REST API. The air quality sensors operate in the LoRaWAN network using 868MHz frequency. Data from the camera and 3D laser vision sensors are transferred to the DROVIDS platform using REST API. The management of sensors in the LoRaWAN network is facilitated by the use of the open-source server ChirpStack, which enables the administration of gateways, devices, tenants, and the configuration of data integrations. Additionally, custom processing services are

being developed to incorporate other sensors that are not part of the LoRaWAN network.

2. Data collection and risk prevention service - The component collects data for risk level calculation and sends it to the Analytics service. Based on the response data from the Analytics service, this component performs the relevant adjustment using the actuator system or sends a notification. Given the wide range of actuator systems available on the market, each with potentially unique integration options, this service provides a REST API method for external actuator systems to access the necessary data and trigger appropriate actions.
3. Analytics service - The component ensures the interpretation of the collected data against risk assessment scores and threshold values. The component calculates risk levels and relevant adjustments. This component also includes the implementation of the Random Forest model to predict future IoT measurements. The technical decomposition of the Analytics service is discussed below the Figure 4.
4. Risk adjustment service - The component's purpose is to analyse historical adjustments and work process performance. Historical adjustments are the decisions the DROVIDS platform makes based on collected real-time sensor data and static data from external systems. This component analyses relationships between historical adjustments and work process performance data and adapts risk assessment scores and threshold values to trigger the adjustment. The service intends to use Apache Spark for data analysis, implementing several models for productivity calculation.
5. Notification service - The notification service provides notifications and inquiries for the personnel. The DROVID platform's notifications are designed to be displayed through the dashboard capabilities of the portal, which will be projected onto TVs and monitors situated on the company's premises. Although e-mail or SMS notifications may be considered in the future, such integrations are beyond the scope of this design.
6. Additional building blocks - All other necessary building blocks required for the solution's operation. These building blocks can be cache servers (e.g., Redis), queuing mechanisms (e.g., RabbitMQ), libraries, etc.

The data layer is designed to store various data - master data, configuration parameters, sensor data, data from external systems, calculated adjustment data, etc. The APIs are expected to be used to interact with data from external building blocks. The API interface is intended to serve as both a REST API and a database API.

The Analytics service is one of the key parts of the platform. Using machine learning capabilities, this service evaluates the risk of infectious disease spread in the workplace based on sensing data, providing real-time risk calculations and predictions. The predictions are made to estimate the risk for scheduled events such as office meetings. Figure 5 shows the technologies used to implement the analytical service, as well as data ingest and feedback of data into enterprise information systems.

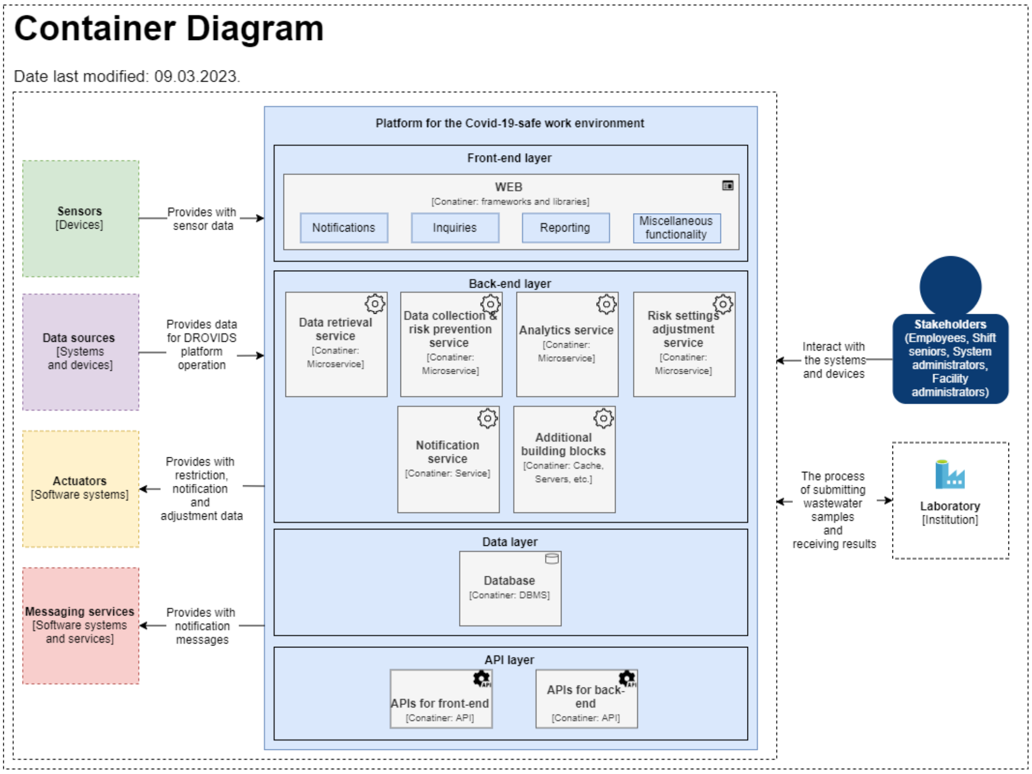

Figure 4: DROVIDS Container diagram

The DROVIDS platform receives live sensing and enterprise information systems data as JSON messages (referred to as DTG_POST). The messages are handled using the Apache Kafka messaging module. Depending on the request, the real-time risk is calculated or risk predictions are obtained. If the predictions are requested, Apache SparkML is invoked. It uses machine learning algorithms such as Random Forest to predict measurements of CO2, humidity, pressure, temperature, and others. Since Random Forest is integrated in Apache Spark MLlib, it allows to easily develop, train and integrate many models into a single streaming application, thus allowing to predict each measurement with high accuracy. The predicted measurements are passed to the risk calculation, which is also done in Apache Spark Streaming. To evaluate the performance of the platform in terms of accuracy, the predicted risk and measurements are saved in the Apache Cassandra database. The accumulated data are used for off-line analytics and adjustment of the risk calculation model. The calculated risk values are passed to the enterprise information systems (referred as to DTG) and the messaging services for enactment of preventive measures.

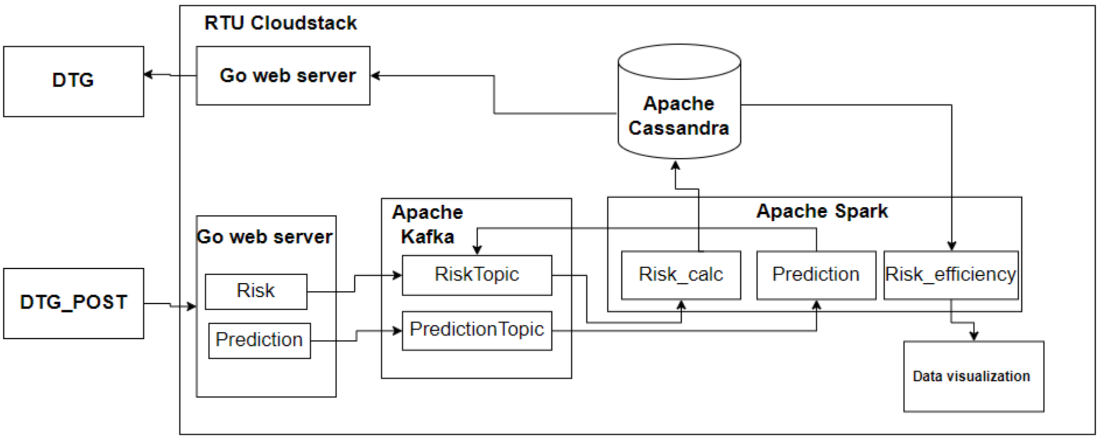

Figure 5: Risk calculation

5. Conclusions

The spread of Covid-19 infection in an organization can negatively impact its business continuity. Not all organisations can perform work in remote mode; safe workspace is essential to prevent virus spread across organisation employees, therefore reducing the negative impact on society's health as well as the local and global economy. IoT technology is widely used in healthcare care and building and facility management. It provides the necessary capabilities to enable real-time based risk measurement and monitoring.

The paper has presented the proposed solution for workspace safety, the DROVIDS platform and its design models. The proposed solution provides predictive, preventive and prescriptive capabilities to monitor and mitigate the risk of infections spread in the enterprise.

The given architecture of DROVIDS ensures the execution of several business processes (data collection, processing, decision-making, and execution of actions). These different business processes are decomposed at the level of services in this document. As a result, the system is based on event-driven microservices and is modular, scalable, and expandable in the future. The separate microservices approach, where each business process is implemented in a separate microservice, allows receiving raw sensory data as input using IoT devices and manhole sensors and further use the risk assessment model to evaluate the COVID-19 risk in the company. The obtained data is further used to analyze historical adjustments and work process performance and to determine future IoT measurements using the Random Forest model.

Besides the discussed C4 Level 1 and Level 2 diagrams that present the DROVIDS design in a high-level logical manner, the C4 Level 3 diagrams, which showcase technology and implementation details, have also been created. Additionally, the physical architecture of the DROVIDS solution has been developed, enabling the transition to the solution development phase. However, as these architecture diagrams contain highly detailed and technical information, they are beyond the scope of this document. Currently, the DROVIDS platform is in the development phase, with a focus on the Back-end layer services and the necessary integrations discussed in this document.

Acknowledgements

Identification of 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] M. Shamim Kaiser et al., "IWorksafe: Towards Healthy Workplaces during COVID-19 with an Intelligent Phealth App for Industrial Settings," IEEE Access, vol. 9, pp. 13814–13828, 2021, doi: 10.1109/ACCESS.2021.3050193.
[3] 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, doi: 10.1016/j.bspc.2020.102149.
[4] 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/
[5] 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. doi: 10.3390/ecsa-7-08267.
[6] Z. Pang, Technologies and Architectures of the Internet-of Things (IoT) for health and well-being. KTH Royal Institute of Technology, 2013.
[7] S. K. Routray and S. Anand, "Narrowband IoT for healthcare," in 2017 International Conference on Information Communication and Embedded Systems, ICICES 2017, 2017. doi: 10.1109/ICICES.2017.8070747.
[8] 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. doi: 10.1109/JIOT.2021.3062630.
[9] 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. doi: 10.1109/BigData47090.2019.9006367.

[10] 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. doi: 10.1109/ICRIIS48246.2019.9073655.
[11] M. K. Sein, O. Henfridsson, S. Purao, M. Rossi, and R. Lindgren, “Action design research,” MIS Q, vol. 35, no. 1, 2011, doi: 10.2307/23043488.
[12] S. Brinkkemper, “Method engineering: Engineering of information systems development methods and tools,” Inf Softw Technol, vol. 38, no. 4 SPEC. ISS., 1996, doi: 10.1016/0950-5849(95)01059-9.
[13] The Open Group, “The TOGAF ® Standard,” 2005. [Online]. Available: www.opengroup.org/legal/licensing.
[14] K. Sandkuhl, M. Wißotzki, J. Stirna, and A. Persson, “Enterprise modeling: Tackling business challenges with the 4EM method,” in Enterprise Engineering Series, Springer, 2014, pp. 1–309.
[15] A. Kusiak, T. Nick Larson, and J. (Ray) Wang, “Reengineering of design and manufacturing processes,” Comput Ind Eng, vol. 26, no. 3, 1994, doi: 10.1016/0360-8352(94)90048-5.
[16] Simon Brown, “The C4 model for visualising software architecture,” https://c4model.com/.
[17] C. Larman and V. R. Basili, “Iterative and incremental development: A brief history,” Computer, vol. 36, no. 6. 2003. doi: 10.1109/MC.2003.1204375.
[18] C. Wohlin, P. Runeson, M. Höst, M. C. Ohlsson, B. Regnell, and A. Wesslén, Experimentation in software engineering, vol. 9783642290442. 2012. doi: 10.1007/978-3-642-29044-2.
[19] F. Emmert-Streib and M. Dehmer, “Understanding Statistical Hypothesis Testing: The Logic of Statistical Inference,” Machine Learning and Knowledge Extraction, vol. 1, no. 3. 2019. doi: 10.3390/make1030054.
[20] 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, Institute of Electrical and Electronics Engineers Inc., 2022. doi: 10.1109/ITMS56974.2022.9937091.
[21] J. Grabis, R.-P. Dreimane, B. Dejus, A. Borodiņecs, and R. Zaharovs, “Triple Pi Sensing to Limit Spread of Infectious Diseases at Workplace,” 2023.