

WORK SAFETY AND HEALTH – THE BUSINESS ANALYTICS USAGE IN INDUSTRY 4.0 CONDITIONS

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Purpose: The purpose of this publication is to present the applications of usage of business analytics in work safety and health.

Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

Findings: In the era of Industry 4.0, characterized by automation and smart technologies, the preservation of workforce health and well-being takes center stage. This paper explores the transformative integration of business analytics into work safety and health practices, signaling a paradigm shift in monitoring, managing, and elevating occupational safety standards. The publication underscores the proactive role of business analytics, especially through wearable device-driven physiological monitoring, in safeguarding worker health without compromising productivity. By aligning seamlessly with regulatory compliance, business analytics becomes a linchpin in mitigating legal and financial risks associated with workplace incidents. The synergy between work safety, health, and business analytics presents a transformative approach, empowering organizations to proactively address safety concerns and cultivate safer work environments. While delving into the software applications, the paper highlights the versatility of analytics in predicting incidents, monitoring compliance, and optimizing workloads. Challenges such as data quality, privacy concerns, and integration issues are acknowledged, yet the multitude of advantages showcased, including incident prevention, data-driven decision-making, and cost savings, affirm the transformative potential of business analytics in shaping a safer, more efficient, and healthier future workplace.

Originality/value: Detailed analysis of business analytics in work and safety area.

Keywords: business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; work safety and health.

Category of the paper: literature review.

1. Introduction

In the context of Industry 4.0, where automation and smart technologies are prevalent, the health and well-being of workers remain a priority. Business analytics aids in monitoring the physiological parameters of workers through wearable devices, ensuring that their health is not compromised in the pursuit of increased productivity. This proactive health monitoring not only prevents potential health issues but also contributes to employee satisfaction and retention. Furthermore, the integration of business analytics in work safety aligns with regulatory compliance requirements. By maintaining detailed records and analytics reports, organizations can demonstrate their commitment to safety standards, mitigating legal and financial risks associated with workplace incidents. This proactive approach not only safeguards the workforce but also protects the reputation of the business in an increasingly scrutinized corporate landscape.

The convergence of work safety and health with business analytics in the era of Industry 4.0 signifies a paradigm shift in how organizations approach employee well-being. The data-driven insights provided by business analytics empower businesses to proactively address safety concerns, optimize operations, and create a safer and healthier work environment. As Industry 4.0 continues to evolve, the synergy between work safety and business analytics will be a cornerstone in fostering a culture of safety and well-being within industrial settings (Ghibakholl et al., 2022).

The purpose of this publication is to present the applications of usage of business analytics in work safety and health.

2. The selected aspects of business analytics usage worker safety and health

Work safety and health have always been paramount concerns in industrial settings, with the well-being of employees being a top priority for businesses. In the rapidly evolving landscape of Industry 4.0, the integration of business analytics has emerged as a transformative force, bringing about significant advancements in monitoring, managing, and enhancing occupational safety and health standards.

The adoption of Industry 4.0 technologies, characterized by the interconnectedness of devices and the utilization of data-driven insights, has paved the way for a more comprehensive approach to work safety. Business analytics, in this context, plays a crucial role by leveraging data from various sources within the industrial ecosystem. This includes real-time data from sensors, wearable devices, and other IoT-enabled equipment, providing a holistic view of the work environment (Bakir, Dahlan, 2022).

One of the key advantages of business analytics in the realm of work safety is its ability to proactively identify potential hazards and risks. Through advanced analytics algorithms, patterns and anomalies in data can be detected, allowing organizations to preemptively address safety concerns before they escalate. This predictive capability empowers businesses to implement preventive measures, reducing the likelihood of accidents and injuries. Moreover, business analytics facilitates a data-driven approach to safety decision-making. By analyzing historical incident data, organizations can identify trends and root causes, enabling the development of targeted safety strategies. This insights-driven strategy not only enhances the overall safety culture within the workplace but also contributes to the optimization of resources and operational efficiency (Zeng et al., 2022; Pech, Vrchota, 2022).

Table 1 contains descriptions of how business analytics is used in the case of work safety and health. This table highlights various applications of business analytics in the context of work safety and health, showcasing how data-driven insights can contribute to a safer and healthier work environment.

Table 1.

The usage of business analytics in work safety and health

Application	Description
Incident Prediction	Incident prediction involves the analysis of historical safety data to identify patterns, trends, and contributing factors that may lead to workplace incidents. By leveraging advanced analytics, organizations can proactively identify potential hazards and implement preventive measures. This approach empowers businesses to stay ahead of safety risks and create a safer working environment for employees.
Safety Compliance Monitoring	Safety compliance monitoring utilizes business analytics to track and ensure adherence to safety regulations and standards within the workplace. By systematically analyzing data related to safety protocols and regulatory requirements, organizations can identify areas of non-compliance and take corrective actions promptly. This application of analytics promotes a culture of safety and helps organizations meet regulatory standards, ultimately reducing the risk of accidents and injuries.
Employee Health Monitoring	Employee health monitoring involves the use of analytics to assess and track the well-being of individuals within the workforce. By analyzing health-related data, such as employee wellness program participation, absenteeism patterns, and health insurance claims, organizations can identify potential health risks. This allows for the implementation of targeted wellness programs and interventions to improve overall employee health and safety.
Root Cause Analysis	Root cause analysis with business analytics is a process of investigating the underlying factors contributing to workplace incidents. By analyzing data related to accidents, injuries, or near misses, organizations can identify the root causes and address them systematically. This approach goes beyond addressing symptoms and helps in implementing effective preventive measures to eliminate or reduce the recurrence of safety incidents.
Workload Optimization	Workload optimization involves the use of analytics to analyze work patterns, employee schedules, and task distribution. By understanding how workloads are distributed across teams and individuals, organizations can identify potential stress points and mitigate risks associated with overburdened workforces. This application of analytics contributes to creating a balanced and manageable workload, promoting employee well-being and safety.
Real-time Safety Dashboards	Real-time safety dashboards provide a dynamic and visual representation of key safety metrics and indicators. By leveraging real-time analytics, organizations can monitor safety performance, identify potential hazards, and respond promptly to emerging safety issues. This application enables quick decision-making, enhances situational awareness, and contributes to a proactive safety culture within the workplace.

Cont. table 1.

Training Effectiveness	Training effectiveness analytics assess the impact and efficiency of safety training programs. By analyzing data related to training participation, test scores, and post-training performance, organizations can evaluate the effectiveness of their safety training initiatives. This data-driven approach helps in refining training programs, addressing knowledge gaps, and ensuring that employees are well-prepared to adhere to safety protocols and guidelines.
Predictive Maintenance	Predictive maintenance involves using analytics to predict equipment failures or malfunctions before they occur. In the context of work safety, this application helps organizations anticipate potential risks associated with malfunctioning equipment that may compromise safety. By proactively scheduling maintenance based on predictive analytics, organizations can minimize downtime, reduce the risk of accidents, and ensure the reliability of safety-critical equipment.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

3. Software used in worker safety and health in Industry 4.0 conditions

The integration of business analytics software has significantly transformed the landscape of worker safety and health, offering organizations powerful tools to proactively manage and enhance workplace well-being. These software solutions leverage advanced analytics to collect, process, and interpret vast amounts of data related to various aspects of safety and health within the workforce (Cillo et al., 2022).

Business analytics software enables organizations to predict potential workplace incidents by analyzing historical safety data. Machine learning algorithms identify patterns and trends, providing insights that facilitate the implementation of preventive measures. These tools empower businesses to move beyond reactive approaches, fostering a culture of proactive incident prevention. Compliance monitoring systems use analytics to track adherence to safety regulations and standards. They provide real-time insights into regulatory compliance, automate checks, and generate reports. By ensuring compliance, organizations reduce the risk of accidents and injuries, while also streamlining the reporting process for regulatory authorities (Gajdzik, Wolniak, 2022; Gajdzik et al., 2023).

Analytics software focused on employee health monitors various health-related data, from participation in wellness programs to absenteeism patterns. This comprehensive analysis aids in identifying potential health risks, allowing organizations to implement targeted wellness programs and interventions. By prioritizing employee well-being, businesses can create a healthier and more productive workforce. When incidents occur, business analytics software facilitates root cause analysis by systematically examining data related to accidents or near misses. It helps organizations identify the underlying factors contributing to incidents, enabling them to address root causes and implement effective preventive measures. This data-driven approach enhances the overall safety culture within the workplace (Akundi et al., 2022).

Workload optimization tools leverage analytics to analyze work patterns and employee schedules. By identifying stress points and optimizing workloads, organizations promote employee well-being and reduce the risk of burnout or injuries associated with overburdened workforces. This fosters a balanced and healthy work environment. Real-time safety dashboards provide dynamic visualizations of key safety metrics, allowing organizations to monitor safety performance in real-time. Integrated with alert systems, these dashboards enable quick decision-making and proactive intervention in response to emerging safety issues, minimizing the impact of potential risks (Jonek-Kowalska, Wolniak, 2021).

Table 2 highlighting examples of software and applications used in worker safety and health, along with descriptions of their usage. These key features highlight the capabilities of each software/application in promoting worker safety and health through the utilization of business analytics.

Table 2.

The usage of business analytics software in worker safety and health

Software/Application	Description	Key Features
Incident Prediction Tools	Incident prediction tools use advanced analytics to analyze historical safety data and identify patterns that predict potential workplace incidents. These tools enable proactive safety measures.	<ul style="list-style-type: none"> - Machine learning algorithms - - Data visualization for trends - Early warning systems - Integration with safety protocols and preventive measures
Compliance Monitoring Systems	Compliance monitoring systems utilize analytics to track and ensure adherence to safety regulations and standards. They identify non-compliance areas, enabling timely corrective actions.	<ul style="list-style-type: none"> - Regulatory tracking and reporting - - Automated compliance checks - Audit trail functionality - Notifications for non-compliance issues
Employee Health Analytics	Employee health analytics software assesses and monitors the well-being of employees by analyzing health-related data. It aids in identifying and addressing potential health risks.	<ul style="list-style-type: none"> - Health data analytics - Employee wellness program tracking - Absenteeism analysis - Integration with wearable devices and health monitoring tools
Root Cause Analysis Software	Root cause analysis software investigates the underlying factors contributing to workplace incidents. It systematically analyzes data to implement effective preventive measures.	<ul style="list-style-type: none"> - Incident data analysis - Trend identification - Workflow integration - Collaboration features for cross-functional analysis and problem-solving
Workload Optimization Tools	Workload optimization tools use analytics to analyze work patterns and employee schedules, ensuring balanced workloads for enhanced employee well-being and safety.	<ul style="list-style-type: none"> - Workload analytics - Schedule optimization - Stress point identification - Resource allocation optimization
Real-time Safety Dashboards	Real-time safety dashboards provide dynamic visualizations of key safety metrics. They enable real-time monitoring, quick decision-making, and proactive safety interventions.	<ul style="list-style-type: none"> - Real-time data visualization - Alert systems for safety issues - Customizable dashboards - Integration with IoT devices and sensors for live data feeds
Training Effectiveness Platforms	Training effectiveness platforms assess the impact of safety training programs. They analyze data to refine training initiatives and ensure employee readiness.	<ul style="list-style-type: none"> - Training program analytics - Performance assessments - Learning management system integration - Personalized training plans based on data analysis

Cont. table 2.

Predictive Maintenance Software	Predictive maintenance software uses analytics to predict equipment failures. In worker safety, it helps anticipate risks associated with malfunctioning equipment.	<ul style="list-style-type: none"> - Predictive analytics algorithms - Equipment health monitoring - Maintenance scheduling optimization - Integration with IoT sensors and predictive modeling
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Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

4. Advantages and problems of business analytics usage in workers safety and health

The integration of business analytics into worker safety and health practices heralds a transformative era, bringing forth a multitude of advantages that significantly enhance organizational safety protocols and employee well-being. Business analytics enables organizations to move beyond reactive safety management by predicting potential incidents. Through the analysis of historical data, predictive analytics identifies patterns and trends, allowing for the implementation of preventive measures before accidents occur. This proactive approach reduces the likelihood of workplace incidents and fosters a safer working environment (Scappini, 2016).

The use of analytics ensures that decisions related to worker safety and health are grounded in data-driven insights. Real-time and historical data analysis provides organizations with a comprehensive understanding of safety risks, enabling informed decision-making. This approach ensures that safety measures are strategically aligned with identified trends, contributing to a more effective and targeted safety strategy. Business analytics facilitates the monitoring of safety compliance, ensuring adherence to regulatory standards. Organizations can automate compliance checks, track regulatory changes, and generate reports efficiently. This not only reduces legal risks but also enhances overall regulatory adherence, ensuring that the workforce operates in accordance with safety standards (Adel., 2022).

Analyzing employee health data allows organizations to identify health risks, track the effectiveness of wellness programs, and implement targeted interventions. This proactive approach promotes a healthier workforce, reduces absenteeism, and enhances overall employee well-being and satisfaction, contributing to a positive workplace culture. In the event of incidents, business analytics expedites the root cause analysis process (Charles et al., 2023). Through data analysis, organizations can identify the underlying factors contributing to accidents, allowing for the implementation of effective corrective actions. This ensures that incidents are thoroughly investigated and addressed, minimizing the likelihood of similar occurrences in the future (Nourani, 2021).

Workload optimization tools leverage analytics to analyze work patterns and schedules, ensuring balanced workloads. By optimizing resource allocation and workload distribution, organizations reduce stress among employees, improve productivity, and minimize risks associated with overburdened workforces (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

Analytics assesses the effectiveness of safety training programs by analyzing participation, test scores, and post-training performance. This ensures that training initiatives are tailored to address specific needs, enhancing employee knowledge and adherence to safety protocols. Predictive maintenance using analytics allows organizations to anticipate equipment failures (Greasley, 2019). This proactive approach minimizes downtime, reduces the risk of accidents related to malfunctioning equipment, and ensures the reliability of safety-critical machinery and systems.

While there is an initial investment in implementing analytics solutions, the long-term benefits include cost savings. Efficient resource allocation, reduced incidents, lower maintenance costs, and improved productivity contribute to overall cost savings for organizations (Nourani, 2021).

Table 3 contains the advantages of using business analytics in worker safety and health within Industry 4.0 conditions, along with descriptions for each advantage. These advantages highlight how business analytics positively impacts worker safety and health by fostering a proactive safety culture, facilitating informed decision-making, and optimizing various aspects of organizational processes.

Table 3.

The advantages of using business analytics in worker safety and health

Advantage	Description
Proactive Incident Prevention	Business analytics enables organizations to proactively identify potential safety risks by analyzing historical data. Predictive analytics helps in forecasting incidents, allowing for the implementation of preventive measures before accidents occur.
Data-Driven Decision-Making	Analytics provides actionable insights based on real-time and historical data, empowering organizations to make informed decisions. Data-driven decision-making ensures that safety measures and interventions are strategically aligned with identified risks and trends.
Improved Compliance and Regulatory Adherence	Analytics facilitates the monitoring of safety compliance, ensuring adherence to regulatory standards. Organizations can automate compliance checks, track regulatory changes, and generate reports, leading to improved regulatory adherence and reduced legal risks.
Enhanced Employee Health and Well-being	By analyzing employee health data, organizations can identify health risks, track wellness program effectiveness, and implement targeted interventions. This promotes a healthier workforce, reduces absenteeism, and enhances overall employee well-being and satisfaction.
Efficient Root Cause Analysis	Business analytics expedites the root cause analysis process following incidents. Through data analysis, organizations can identify the underlying factors contributing to accidents, enabling the implementation of effective corrective actions to prevent future occurrences.

Cont. table 3.

Optimized Workload and Resource Allocation	Workload optimization tools leverage analytics to analyze work patterns and schedules, ensuring balanced workloads. This leads to reduced stress, improved productivity, and minimized risks associated with overburdened workforces through optimal resource allocation.
Real-Time Safety Monitoring	Real-time safety dashboards provide dynamic visualizations of key safety metrics. This enables organizations to monitor safety performance in real-time, respond promptly to emerging safety issues, and implement immediate interventions to mitigate potential risks.
Effective Training Programs	Analytics assesses the effectiveness of safety training programs by analyzing participation, test scores, and post-training performance. This ensures that training initiatives are tailored to address specific needs, enhancing employee knowledge and adherence to safety protocols.
Predictive Maintenance for Equipment Safety	Predictive maintenance using analytics allows organizations to anticipate equipment failures. This proactive approach minimizes downtime, reduces the risk of accidents related to malfunctioning equipment, and ensures the reliability of safety-critical machinery and systems.
Cost Savings and Resource Efficiency	While there is an initial investment in implementing analytics solutions, the long-term benefits include cost savings. Efficient resource allocation, reduced incidents, lower maintenance costs, and improved productivity contribute to overall cost savings for organizations.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Table 4 contains the problems of using business analytics in worker safety and health within Industry 4.0 conditions, along with descriptions for each advantage. These problems highlight the potential hurdles organizations may encounter when implementing business analytics in worker safety and health and underscore the importance of careful planning, ethical considerations, and addressing organizational and technical challenges.

Table 4.

The problems of using business analytics in worker safety and health

Problem	Description
Data Quality and Accuracy	Inaccurate or incomplete data can lead to flawed analytics outcomes. Poor data quality, inconsistencies, or outdated information may compromise the reliability of safety predictions and hinder the effectiveness of preventive measures.
Privacy Concerns	Collecting and analyzing employee data for safety purposes may raise privacy concerns. Balancing the need for safety insights with respecting individual privacy rights is crucial to maintaining trust and compliance with data protection regulations.
Integration Challenges	Integrating business analytics software with existing systems and workflows can be challenging. Incompatibility issues, data silos, or resistance to change within the organization may impede the seamless implementation and utilization of analytics solutions.
Complexity of Analytics Models	The complexity of advanced analytics models can be a barrier for organizations without the necessary expertise. Understanding and interpreting complex algorithms may require specialized skills, posing challenges for smaller or less tech-savvy enterprises.
Lack of Employee Buy-In	Successful implementation of safety analytics relies on employee cooperation and engagement. Resistance to new technologies, skepticism about the benefits of analytics, or a lack of understanding among the workforce can hinder the adoption and effectiveness of safety initiatives.
Overreliance on Historical Data	Relying solely on historical data for predictions may not account for evolving workplace conditions or emerging risks. Business analytics should be complemented with real-time data and continuous monitoring to ensure its relevance and responsiveness to changing circumstances.

Cont. table 4.

Unintended Consequences	Misinterpretation or overreliance on analytics predictions may lead to unintended consequences. Blindly following analytics recommendations without considering the broader context or human factors may result in suboptimal decisions or actions that negatively impact safety.
Cost of Implementation and Maintenance	Implementing and maintaining business analytics solutions can be resource-intensive. The initial investment in technology, training, and ongoing maintenance costs may pose financial challenges, particularly for smaller organizations with limited budgets.
Cultural Resistance and Organizational Dynamics	A cultural shift towards data-driven decision-making may face resistance within traditional organizational cultures. Addressing resistance, fostering a culture of safety, and ensuring effective communication are essential for the successful integration of analytics into safety practices.
Legal and Ethical Considerations	Adhering to legal and ethical standards in the collection and use of employee data is paramount. Organizations must navigate complex legal frameworks, ensuring compliance with regulations such as GDPR or HIPAA, to avoid legal repercussions and maintain ethical practices.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

5. Conclusion

In the dynamic landscape of Industry 4.0, where automation and smart technologies reign supreme, the health and well-being of the workforce persist as paramount concerns. The fusion of business analytics with work safety and health practices marks a paradigm shift, catalyzing significant advancements in monitoring, managing, and enhancing occupational safety standards. This publication aimed to elucidate the applications of business analytics in this context, shedding light on its transformative impact.

Business analytics, particularly in the form of wearable device-driven physiological parameter monitoring, stands as a sentinel against compromising worker health in the pursuit of productivity. This proactive health surveillance not only averts potential issues but also fosters employee satisfaction and retention. The integration of business analytics aligns seamlessly with regulatory compliance, as meticulous records and analytics reports demonstrate a steadfast commitment to safety standards, mitigating legal and financial risks associated with workplace incidents. The synergy of work safety and health with business analytics signifies a pivotal transformation in how organizations approach employee well-being. The data-driven insights from business analytics empower businesses to proactively address safety concerns, optimize operations, and cultivate safer and healthier work environments. As Industry 4.0 continues its evolution, the symbiotic relationship between work safety and business analytics becomes a cornerstone for fostering a culture of safety and well-being in industrial settings.

This publication delved into selected aspects of business analytics usage in worker safety and health, emphasizing the profound impact of Industry 4.0 technologies. The adoption of interconnected devices and data-driven insights ushers in a comprehensive approach to work

safety. Business analytics, leveraging data from diverse sources within the industrial ecosystem, provides a holistic view of the work environment, enabling organizations to make informed decisions. The subsequent focus on software used in worker safety and health showcased how business analytics software serves as a catalyst for transformative change. These tools, equipped with advanced analytics capabilities, predict incidents, monitor compliance, assess employee health, conduct root cause analyses, optimize workloads, and provide real-time safety dashboards. Table 2 detailed various software applications along with their key features, underlining the versatility of business analytics in enhancing worker safety and health.

However, this integration is not without its challenges, as outlined in Table 4. Data quality, privacy concerns, integration challenges, and the complexity of analytics models pose potential hurdles. Ensuring employee buy-in, avoiding overreliance on historical data, and navigating the cost implications are vital considerations. Cultural resistance and legal/ethical considerations further underscore the need for a meticulous and ethical approach to implementation. Yet, the advantages outlined in Table 3 demonstrate that the benefits far outweigh the challenges. Proactive incident prevention, data-driven decision-making, improved compliance, enhanced employee health, and cost savings are among the many advantages. Real-time safety monitoring, effective training programs, and predictive maintenance exemplify how business analytics fosters a culture of safety, efficiency, and well-being.

The integration of business analytics in worker safety and health within Industry 4.0 conditions is transformative. It empowers organizations to prioritize safety, make informed decisions, and create environments that not only comply with regulations but also foster the health and satisfaction of their workforce. The journey towards a safer and healthier workplace is navigable with strategic planning, ethical considerations, and a commitment to overcoming challenges. The future of work safety lies in the symbiotic relationship between human welfare and the insights gleaned from the data-driven world of business analytics.

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