

Enhancing Sustainability and Workplace Safety Management Systems in the Manufacturing Industry through Digitalization

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Abstract

This study investigates the transformative impact of digitalization on workplace safety management systems within a Southern manufacturing company. Employing a mixed-methods approach, it explores the limitations of traditional paper-based systems and their repercussions on various facets including employee morale, contractor compliance, safety performance, and operational efficiency. Interventions during Cycle 1 introduce online reporting and interactive safety training, while Cycle 2 focuses on continuous education, website development, and SOP establishment, assessed through the Theory of Acceptance Model (TAM). Statistical analyses using SPSS unveil significant improvements between the baseline data and post cycle 1 intervention, supported by paired sample t-tests ($p < 0.001$). Subsequent analysis to compare the post cycle 1 and cycle 2 intervention utilizing the Wilcoxon Signed Ranks Test confirms the interventions' efficacy in enhancing participants' perceptions of usefulness (PU), ease of use (PEU), and attitude (AT). Data from the Safety Department demonstrate enhancements in report submissions, accident-free records, e-learning engagement, and incident reduction. This research underscores the critical role of technology acceptance in fostering resilient safety practices, offering valuable insights for industry implementation, and advocating for safer and more productive work environments.

Keywords: Safety Management, Workplace, Digitalization, Paperless.

Introduction

Background and Problem Statement

Guaranteeing a secure and healthy work environment is essential for effective organizational governance, especially within industries vulnerable to high-risk hazards like steel manufacturing (Arifin & Aiyub, 2012). Traditional paper-based safety management systems often lead to inefficiencies such as delays in hazard mitigation, decreased morale, and safety breaches. These issues necessitate a shift towards digital solutions that can streamline processes, enhance compliance, and improve safety performance.

Research Objectives

The primary objectives of this study are:

- 1) To analyse the issues affecting the company's safety management system.
- 2) To develop an intervention plan by designing and implementing the best solution to improve the company's safety management system.
- 3) To evaluate the effectiveness of the interventions in improving the safety management system in the organization.

Significance of Research

This research aims to enhance occupational safety practices in line with the Department of Occupational Safety & Health (DOSH) mission through digitalization, as previous research also has proven that it helps in optimize operational efficiencies and promote cost-effectiveness (Chao & Uk, 2015). The findings will provide valuable insights for future studies and industry stakeholders aiming to foster a safer and more productive work environment.

Literature Review

Digital Transformation in Safety Management

Digital transformation, particularly within the framework of the Fourth Industrial Revolution is imperative for contemporary organizations to enhance safety management practices (Kasim et al., 2021). The Technology Acceptance Model (TAM) is employed in this study to evaluate user acceptance of new technologies, considering variables such as perceived usefulness, perceived ease of use, and attitude (Taherdoost, 2018).

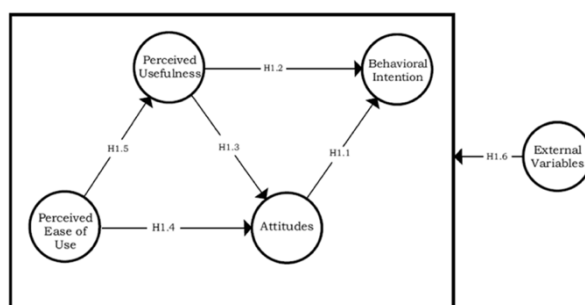


Figure 2-1 Theory of Acceptance Model

Challenges Faced by Manufacturing Industry in Adopting Digitalization

Abdallah et al. (2021) shed light on the challenges encountered by organizations, particularly small and medium-sized businesses (SMEs), in adopting digital transformation. These obstacles, prevalent across various industries, encompass issues such as the skills gap and uncertainties surrounding emerging technologies. Moreover, organizational reluctance to embrace new technologies is exacerbated by a risk-averse culture, notably observed in manufacturing enterprises striving to minimize risk exposure. The hesitance to invest in new technologies, as highlighted by the Made Smarter study, further underscores the sector's cautious approach.

Conversely, Chao & Uk (2015), explore the advantages and drawbacks of transitioning to paperless systems within organizations. While paperless systems offer benefits such as enhanced productivity, data security, and efficiency, they pose challenges, including the need

for significant investments in technology infrastructure and staff training. Particularly for SMEs, the transition to paperless practices may strain resources, given the requisite investments in IT infrastructure for effective digital document management.

Digitalization and Sustainable Development Goal (SDG)

Pérez-Martínez et al (2023), emphasize the significance of digitization in addressing sustainability challenges worldwide, as recognized by international organizations like the European Commission, the World Bank, and the OECD. Digitization is seen as a catalyst for innovation, dematerialization, and decarbonization of the productive system, enhancing efficiency, and facilitating access to essential services like education and healthcare. Furthermore, digital systems support the implementation of sustainable development programs and strategies, fostering connectivity and synergies between complementary initiatives aimed at achieving SDGs.

Gaps in Current Research

Existing research highlights the potential benefits of digital safety systems but often lacks empirical evidence from real-world applications. This study addresses this gap providing quantitative and qualitative data on the impact of digital interventions in a manufacturing setting.

Materials and Methods

Research Design

This study employs a mixed-method approach, combining qualitative and quantitative data collection and analysis to comprehensively assess the impact of digitalization on workplace safety.

Intervention Design

The interventions were carefully designed to address the identified issues in the safety management system. Two cycles of interventions were implemented.

Cycle 1 Interventions

- Designed and employed online reporting system for unsafe and permit to work.
- Designed and employed E-learning, an interactive safety training.

Cycle 2 Interventions:

- Conducted company-wide training.
- Designed and developed safety website.
- Established Standard Operating Procedures (SOP).

Each intervention was designed with the aim of improving specific aspects of the safety management system, such as reporting efficiency, employee engagement, and accessibility of safety information.

Implementation Process

Initially, a needs assessment was conducted to pinpoint areas requiring improvement within the safety management system. Subsequently, stakeholders including employees, management, and safety specialists were engaged to gather input and secure support for the interventions.

A collaboration with IT specialists led to the development and customization of digital tools and platforms essential for the interventions. Pilot testing ensued, where a small group of employees trialed the interventions to identify any issues and refine implementation strategies.

Upon successful testing, full deployment of the interventions was carried out across the organization, coupled with training sessions to ensure smooth adoption. Lastly, continuous monitoring and evaluation were conducted to collect feedback and assess the effectiveness of the interventions over time.

Data Collection

Qualitative Method

Structured open-ended interviews were conducted with the organization’s management, and employee representatives to gather detailed narratives on participant’s perspectives regarding the transition to a digital safety management system. The interview protocol covered background information, experiences with the electronic reporting system, perceived effectiveness and suggestions for improvement.

Quantitative Method

Surveys drawing from previous research associated with the TAM model by Taufiq et al. (2019) were administered to employees and statistical analysis using SPSS was performed. The survey included sections on demographic information, perceived usefulness, perceived ease of use, and attitude. Key performance indicators from the safety department were also collected and analyzed.

Table 3-1
Perceived of Usefulness

Context	Definition	Measured Items
Perceived Usefulness (PU)	Perceived usefulness reflects employee’s perception on whether the use of safety online form system will enhance their performance.	PU1 The safety online form system will improve my job performance. PU2 The safety online form system will increase my work productivity. PU3 The safety online form system could make it easier to submit unsafe report and issuing safety work permit. PU4 The safety online form system will enhance the effectiveness of safety management. PU5 I find the safety online form system is useful.

Results and Discussion

Qualitative Data

The thematic analysis revealed key areas of improvement in the current system and highlighted the importance of training and user adaptation. Participants expressed both anticipation and apprehension towards the digital transition, emphasizing the need for a well-structured strategy inclusive of training, customization and user feedback.

Context	Definition	Measured Items
Perceived Ease of Use (PEU)	Refers to employee's perception that using an online safety form require minimal effort.	PEU1 I find the safety online form system is easy to use.
		PEU2 Learning how to use the safety online form system is easy for me.
		PEU3 It is easy to be skilful in using the safety online form.
		PEU4 My interaction with the safety online form is clear.
		PEU5 My interaction with the safety online form is understandable.
		PEU6 it will be easy for me to find information through the digital website of safety.

Context	Definition	Measured Items
Attitude (AT)	Denotes the employee's assessment of whether utilizing the online safety form is advantageous for them	AT1 Submitting report using the safety online system is a good idea.
		AT2 I feel positive towards the use of safety online system
		AT3 I believe that the online safety system helps to enhance safety awareness and the effectiveness of the safety management system.
		AT4 I generally favour the use of the safety online system.
		AT5 I believe that it is a good idea for me to use this online safety system for future safety-related reporting.

Quantitative Data

Comparison between Pre and Post Cycle 1 Intervention

Table 4-1 Paired Sample T-Test

		Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference		t	df	Significance	
					Mean	Lower			Upper	One-Sided p
Pair 1	Perceived of Usefulness (B) - Perceived of Usefulness (A)	-.977	1.152	.160	-1.298	-.656	-6.117	51	<.001	<.001
Pair 2	Perceived of Easy to Use (B) - Perceived Easy of Use (A)	-.990	1.167	.162	-1.315	-.666	-6.122	51	<.001	<.001
Pair 3	Attitude (B) - Attitude (A)	-.996	1.143	.158	-1.314	-.678	-6.286	51	<.001	<.001

The total sample, comprising 52 participants, completed both the pre- and post-data surveys. Table 4-1 displays a remarkably low p-value of less than 0.001 (<0.001), indicating the data's high significance, falling below the conventional threshold of 0.05. Analysis of the t-values reveals that for perceived usefulness (6.117), perceived ease of use (6.122), and attitude (6.286), the values exceed the critical threshold of (2.021>). Thus, these findings are considered statistically significant.

Comparison between Post Cycle 1 and Cycle 2 Intervention

Table 4-2

Paired Samples Rank Comparison

		N	Mean Rank	Sum of Ranks
Perceived of Usefulness (Cycle 2) – Perceived of Usefulness (Cycle 1)	Negative Ranks	3 ^a	10.17	30.50
	Positive Ranks	35 ^b	20.30	710.50
	Ties	10 ^c		
	Total	48		
Perceived Ease of use (Cycle 2) – Perceived Ease of Use (Cycle 1)	Negative Ranks	3 ^d	12.33	37.00
	Positive Ranks	35 ^e	20.11	704.00
	Ties	9 ^f		
	Total	47		
Attitude (Cycle 2) – Attitude (Cycle 1)	Negative Ranks	1 ^g	20.00	20.00
	Positive Ranks	32 ^h	16.91	541.00
	Ties	15 ⁱ		
	Total	48		

The Wilcoxon Signed Ranks Test reveals highly significant differences in all three variables (perceived usefulness, perceived ease of use, and attitude) between the scores obtained in Cycle 1 and Cycle 2 interventions. The Asymp. Sig. (2-tailed) values for all variables are less than 0.001, indicating an extremely low probability of these results occurring by chance. Furthermore, the "Based on negative ranks" note that the sum of negative ranks for PEU, PU & AT are less than the critical value 434 (n=50, p<0.05), implying there is strong evidence to suggest that there are significant differences between Cycle 1 and Cycle 2 interventions for perceived usefulness, perceived ease of use, and attitude.

Organization Safety Performance

The safety department's analysis shown in Table 4-3 reveals significant progress in key areas.

The Cycle 1 post-intervention period reveals positive trends, with increased training participation, a surge in Kiken Yochi report submissions, and a decline in incidents. The slight increase in unsafe action or condition reports may indicate improved safety awareness and reporting under the new digital system. In cycle 2 post intervention, the safety department's analysis reveals substantial progress in several areas. Increased submissions of Kiken Yochi reports indicate a heightened awareness of potential hazards, reflecting a positive shift in safety culture. The surge in e-learning participation indicates successful integration of digital training, contributing to a safer work environment. Additionally, the prolonged period without accidents showcases the effectiveness of intervention programs in promoting workplace safety.

Table 4-3

Safety's KPI Performance

Key Performance Indicators	Baseline	Cycle 1	%	Trend	Cycle 2	%	Trend
Training Participants	876	958	9.36	↑	810	-15.45	↓
Kiken yochi report	158	171	8.28	↑	204	19.29	↑
Accidents	0	0	0	↔	0	0	↔
Near Misses	3	4	0	↑	0	-100	↓
Unsafe Action/Condition Reports Submission	298	358	20.13	↑	233	-34.9	↓
E-Learning	0	12	N/A	↑	220	1733	↑

Conclusion

In conclusion, the effectiveness of this Action Research highlights the considerable benefits of introducing a systematic and user-friendly digital system, complemented by

ongoing education efforts, in enhancing safety performance and awareness among employees. This emphasizes the potential of digital transformation to address shortcomings in manual safety management systems, leading to improved safety outcomes, reduced workload for safety personnel, heightened employee morale and safety attitudes, and increased overall safety management efficiency at manufacturing setting. Furthermore, the findings offer valuable insights for future research and industry stakeholders aiming to enhance safety management practice.

Acknowledgement

Attached

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Appendices

Thematic Analysis

Based on the gathered information from the interview session, the input was categorized into similar coding or subthemes. The input obtained from the interview is illustrated in the below table.

Table 5-1
The Interview Thematic Analysis

Theme	Meaning of theme	Subtheme	Evidence
THEME 1: Background	This section details the respondent's background, including their education, job title, years of experience, and function within the safety management system. In addition, the participants' knowledge and outlook on digitalization in the safety management system was revealed through this theme.	Working Background	(R1) Work as safety and health manager for 12 years at Company Z. (R2) Work as safety supervisor for almost 20 years at company Z. (R3) Has been working for 2 years at company Z as an IT specialist.
		Interviewee understanding	(R1) I have no experience using digital systems in a safety management system. But, with the current condition, it's good to have the system in place. (R2) Our job has been overloaded. Sometimes we misplace the received reports, causing delays in action. I support the implementation of a digital system in our workplace.
THEME 2: Perceive Digital Transformation	This theme examined stakeholders' views on digital transformation and safety management's paperless reporting system. It involves analyzing and categorizing participants' perceptions, attitudes, and beliefs on digital transformation as well as transitioning from paper-based reporting to a paperless safety management system.	Importance and benefits digitalization	(R1) Safety reporting system involves a lot of documentation and safety department would have to keep files and papers which sometimes troublesome. With digital system, so much things we can improve such as time, less filing and papers, a traceable records-keeping and systematic.
		High cost	(R1) It's good to have the system but the cost must be high. Plus, it requires on-going maintenance maybe for monthly or quarterly to avoid any disruption.
		Supportive Management and culture	(R1) We were always encouraged to do improvement, especially if the system improve efficiency. Bonus as the company has higher safety culture. Surely the Management will give support and commitment.
		Computer literacy	(R2) I do support digitalization and realize its importance. It just a matter of time to convince senior employees to use the system. More training requires as they have low computer literacy and scared to use.
		Skill and competency	(R3) Since I joining this company, I notice about the loads of documentation. I am qualified and experienced in developing online system. We need to initiate that in here, especially for safety department.

Theme	Meaning of theme	Subtheme	Evidence
THEME 3: Perceive on Efficiency and effectiveness	This theme explored participants' or stakeholders' perceptions, opinions, and evaluations of a paperless reporting system's efficiency and efficacy in the context of safety management.	Enhance efficiency – traceable report	(R1) This make the safety department easier as all records are well- kept in the system and we can trace the sender's name, date, time, location affected, and highlighted issue.
		Ease follow up action and ease communication	(R2) Safety personnel will be able to communicate this to related department and follow up action item without miss, as all the reports received captured in the system.
		Resources and ability	(R3) I can create and design the system with the financial support from the company. No worries, all the features required by safety department can be customized. This might take a few months to complete.
THEME 4: User's Experience	This theme disclosed participants' first-hand experience with the paperless reporting system in the context of safety management, including their experiences, feedback, and recommendations. This theme concentrates on asking participants whether they would like to see any changes made to the digital system.	In experience users	(R1) I have no experience with the digital system relating to safety management. But I fully hope that the system will be able to solve the missing forms and reduce complaints from employees to the safety department. important to enhance the morale among employees about safety. All unsafe reporting must be taken action on without fail to ensure a safe and healthy workplace. (R2) I have no experience. But hopefully, the system will ease the burden. I can easily communicate the pending items and highlight the issue to department PIC within the set time frame without delay. We need to gain the trust from employees.
		System trials and follow up	(R3) We can initiate the system in Company Z. Hope through this research project, coordination among safety department, HODs, and safety committee members or employee's representative can be done. Need to run the trials and follow up for improvement.
THEME 5: Training and support	This theme examines and analyzes participant responses, comments, and experiences regarding training and support during the digital reporting system transition. The goal is to understand their subjective assessments of the quality, relevance, and impact of implementation training and assistance.	Insufficient of training	(R1) To date, only certain level of employees were sent for computer training like engineers, executives and officers. Soon, when the system is completed, all employees must be trained on how to use the system. (R2) I can share about the system introduced in safety induction training, and daily morning briefing.
		Training manual	(R3) We can share the manual with employees. It will be accessible in our shared folders. And we can email out to HODs to disseminate to their subordinate, in English and Bahasa.