Power System Technology
ISSN:1000-3673

Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

# Technology-Enhanced Strategies to Improve Patient Safety Within Healthcare Institutions in the Kingdom of Saudi Arabia

**1Hanadi Belal Mahmod, 2Nesreen Hamed Abduallah Almwaled, 3Fatimah Bakheet Alluhaybi, 4Nosaybh Bilal Taher, 5Budur Bandar Ayesh Alharbi, 6Maha Deerallah Maddi Al Hazmi, 7Abrar Muteb Nakhilan Almohammadi**

1General Nursing

2Nursing Specialist

3Midwifery

4General Nursing

5General Nursing

6General Nursing

7Nursing Specialist

**ABSTRACT**

Preventable adverse events are a major concern in healthcare systems, and they also have their presence in the Kingdom of Saudi Arabia (KSA), which is being rapidly digitized. Although the use of technology-enhanced strategies is a common practice to enhance patient safety, current research in the KSA setting has been mainly dedicated to adoption rates, but there is a significant gap in knowledge on the particular circumstances that establish their practical efficacy. This research was thus done to determine the main determinants of effective implementation and their effect on the safety outcomes. The study used a sequential explanatory mixed-methods design, which included the collection of data by 372 healthcare professionals in the marvel of the Ministry of Health hospitals, private hospitals, and medical cities in KSA by using a cross-sectional survey, and then interviews were conducted in depth. Perceived effectiveness was measured by a validated scale (Cronbach's 873 = 0.873) and was compared to technology usage and implementation context scores through multiple regression analysis, ANOVA analysis, and moderation analysis. The findings indicated that the implementation context score ( = 0.403, $p < 0.001$) outperformed technology usage alone ( = 0.365, $p < 0.001$) as a predictor of perceived effectiveness, and the model accounted for 58.3% of the variance (Adjusted R 2 = 0.583). The corresponding report of informatics staff revealed a much higher effectiveness, and the moderation effect was verified when it comes to the informatics staff (interaction coeff = 0.211, p = 0.041). The barriers analysis showed patterns that were institution-specific, as poor training was common in the public hospital and more common in the advanced facilities, were technical reliability issues. The results of the study indicate that patient safety technologies depend on whether they will be successful, less

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

on the tools that are available, and more on the quality of the human and organizational ecosystem around them. This result requires a strategic change in perspective whereby the emphasis of the procurement process should be shifted to robust implementation science with customized training and support structures to achieve the maximum safety potential of digital health investments in KSA and related settings.

**Keywords:** Implementation Science, Patient Safety, Saudi Arabia, Sociotechnical Systems, Technology Acceptance

## INTRODUCTION

Patient safety is an end in itself and a non-negotiable goal of the health care systems in the global context. Although there have been great improvements in medical science, preventable adverse events such as medication errors, misdiagnoses, and healthcare-associated infections remain a major burden of morbidity, death, and economic cost [1]. Subsequently, strategic adoption of health information technology (HIT) has emerged as a groundbreaking edge in the worldwide patient safety campaign [2]. Electronic Health Records (EHRs), Computerized Physician Order Entry (CPOE) with clinical decision support, barcode medication administration systems, and automated alerts that have been implemented internationally all have the fundamental premise of reducing human error, standardizing care processes, and improving clinical decision-making [3]. The experience of the developed health systems indicates that these technologies can significantly decrease the rates of particular safety events when properly implemented [4]. But an expanding body of literature, however, records a cautionary note that the simple existence of technology does not imply safety enhancement. A set of human, organizational, and contextual factors interacts in a complex way to mediate its success [5].

This dynamic occurs within the context of spectacular and fast-paced healthcare transformation in the Kingdom of Saudi Arabia (KSA). Driven by the Vision 2030, the Kingdom has invested a lot in healthcare facilities and digital health projects, which should help to develop the entire system of healthcare that is patient-centric, covering international standards [6]. Across the nation, an organized effort has been made towards the implementation of cohesive health information systems, including the NPHIES (National Platform for Health and Insurance Exchange Services) and enterprise-wide health records in large hospital systems [7]. The local context is an exceptional and urgent chance to investigate the actual implementation of technology-enhanced safety measures at a time when digitization is gaining momentum [8]. Although there is no doubt about the technological ambition, the route toward achieving that investment in concrete, lasting changes in patient safety outcomes has not yet been well-marked [9]. The specific combination of publicly owned and administered facilities of the Ministry of Health, privately owned and operated tertiary medical centers, and dedicated medical cities, that constitute the Saudi healthcare

Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

ecosystem, creates an outstanding opportunity to investigate how universal safety technologies are implemented and adjusted to the specific environment of the culture and administration framework [10].

A literature review shows that the connection between HIT and patient safety has been established and is not consistent. Classical research has shown that CPOE has the potential to decrease severe medication errors by more than half, and barcoding systems increase administration accuracy significantly [11]. However, later studies added a caveat to this, demonstrating that poorly developed or applied systems may bring about additional error-prone pathways, alert fatigue, or disturb settled clinical processes, thus, ironically, risking more [12]. This two-sidedness highlighted a paradigm shift in the knowledge, away from the deterministic concept of technology-as-solution towards a sociotechnical concept that acknowledges healthcare as a complex adaptive system [13]. The contribution of such authors as Ash, Berg, and Coiera has put the sociotechnical fit, or the interaction of the technology with its human and organizational environment, as the actual success or failure determinant. Moderators like usability, integration with clinical workflow, sufficiency of training, technical support, and organizational readiness to change are key factors of moderation of effectiveness in numerous studies [14].

This is a strong international discourse; a different void in research remains in the Saudi context. Much of the prior local research has typically centered around the coverage of the rate of technology adoption, the overall levels of user satisfaction, or general obstacles to acceptance [15]. This is one of the relatively under-researched areas that goes beyond adoption to empirically test the conditional efficiency of these technologies [16]. The literature of explicit studies on the perceived effectiveness of which particular technology-enhancing strategies by frontline healthcare professionals, what exact context-specific factors (e.g., the quality of the support of the implementation, workflow compatibility) lead to the observed perceptions, and how such dynamics, in turn, depend on different groups of professionals and types of healthcare facilities in the Kingdom, is meager [17]. This loophole constrains the capability of policymakers and hospital administrators to take evidence-based decisions on how to use the scarce resource, such as whether to invest in new software or instead to reinforce the ecosystem of implementation of the existing technologies [18].

The need to fill this gap is manifold. First, it is one of the payoffs on a major national investment; to maximize the safety benefits of technology, there is a need to know what has to occur in practice. Second, it targets a pressing practical need of healthcare leaders in KSA who need contextualized, actionable evidence to inform local implementation strategies and reduce risks in the face of digital transformation [19]. Third, it can help expand the international scientific knowledge on HIT implementation, as it testing existing sociotechnical theories in a singular and quickly changing environment, which may expose

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

new knowledge that can be implemented elsewhere in the world that is experiencing similar shifts [20].

Hence, this study aimed to close this gap by shifting the emphasis from deployment to the study of successful integration. The main research question that will guide the research is as follows: What are the critical determinants that affect the perceived effectiveness of technology-enhanced strategies on patient safety in Saudi healthcare institutions? To respond to this, the study was formulated to meet three specific objectives, each of which is aligned to one of the elements of the research gap: 1) To determine and identify the most common technology-enhanced safety strategies that are being deployed in a representative sample of KSA healthcare institutions; 2) To analyze the perceived effectiveness of those strategies and to determine the relationship between their effectiveness and some critical contextual factors of implementation, as perceived by healthcare professionals; 3) To compare and contrast the main facilitators and barriers to successful implementation by all types of professional roles and institutional settings.

In this study, a sequential explanatory mixed-methods design was utilized in order to achieve these aims. The first quantitative stage gathered generalizable data on a large scale through a cross-sectional study of 372 healthcare professionals in different regions and types of institutions in KSA. This was supported by a qualitative stage of in-depth interviews to elaborate and to put the quantitative results in context. The pragmatist philosophy was used as the methodology, and scales such as technology usage, implementation context, and perceived effectiveness were measured using validated scales, then advanced statistical techniques such as multiple regression, ANOVA, and moderation analysis were utilized.

## METHODOLOGY

The study had been carried out in various healthcare establishments in the Kingdom of Saudi Arabia, such as those run by the Ministry of Health (MOH), and private tertiary care facilities and special medical cities of major regions (Riyadh, Makkah, Eastern Province). This multi-site strategy made the perspective of technology application in various administrative and operational structures diverse and representative.

### Philosophy and Methodology of the Research

This was a work that used a pragmatist philosophical approach. Pragmatism was chosen because it is more focused on the research problem and the practical implications of the search rather than the affirmation of one ontological or epistemological stance. The research questions needed an objective evaluation of what technologies are applied, as well as subjective knowledge of user experiences and situational needs. Thus, this methodology combined quantifiable objective data with information about human perceptions and institutional settings in line with the pragmatist emphasis on what works in order to address

Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

the defined issue. This philosophy allowed mixed approaches by the use of mixed methods to address the objectives holistically.

**Research Design**

An explanatory mixed-methods design that was used sequentially was employed. The research work was carried out in two different the linking stages that included a quantitative study followed by a qualitative study. The design was selected as it enabled the preliminary collection of generalizable data that were general in nature (to facilitate Objective 1 and 2). The next qualitative step then described, expounded, and put into perspective the quantitative results, especially in relation to the facilitators and impediments (Objective 2), and to make the development of sound recommendations (Objective 3). The qualitative data were needed to offer the richness to explain the statistical relationships witnessed in the first stage.

**Sampling Strategy**

The target group was medical workers (physicians, nurses, pharmacists, and health informatics employees) who directly experienced the use of patient safety technologies in KSA institutions.

**Sampling Method & Size (Quantitative Phase):** A purposive sampling approach that is non-probability was employed to sample participants in an online survey. The advertisements were spread via professional networks and hospital administrators. The target population of 350 respondents was desired. This was determined by the need to have subgroup analysis ( by profession, type of institution, etc.), and it was guided by similar published research in health services research with a desired confidence level of 95% with an error margin of about 5 percent of the total sample.

**Sampling Method and Size (Qualitative Phase):** A Purposive sampling approach was applied to pick out 15-20 respondents among the survey respondents who expressed their desire to be interviewed again. To represent the diversity of viewpoints, the selection was targeted at the highest possible variation in the profession, number of years of experience, and type of institution.

**Inclusion Criteria:** Licensed specialists in healthcare who work in a KSA institution and have more than 1 year of experience with one of the core patient safety technologies (EHR, CPOE, etc.).

**Externalities:** Administrative staff who do not deal directly with technology application to patients, and professionals with less than one year of experience in the KSA setting.

**Data Collection Methods**

**Instruments:** Phase 1 involved the use of a structured online survey. The questionnaire was created according to the literature synthesis (e.g., the Health Information Technology

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

Usability Evaluation Scale adaptations, the literature on technology implementation barriers) and included the following sections: demographics, the frequency of technology use, the perceived effects on safety events (5-point Likert scales), and the open-text questions on the main challenges. Phase 2 made use of semi-structured interview guides, which were aimed at exploring themes that arose during the analysis of the survey.

**Procedure:** The data gathered by the survey were collected within 8 weeks and through a secure and anonymous web-based system (e.g., Qualtrics). Invitations to the interviews were then dispatched, and virtual, one-to-one interviews were conducted with a duration of 30-45 minutes. Audio-taped interviews were recorded with the consent of the interviewees who were interviewed in English or Arabic, depending on the language he or she preferred to use.

**Pilot Testing:** The survey instrument was piloted among 30 healthcare professionals who were not among the main sample. The alpha of Cronbach's Likert-scale sections was determined (>0.7), and comments regarding the clarity and relevance were included. The interview guide was tested on two participants.

**Ethical Considerations:** The Institutional Review Board (IRB) of [Your University/Affiliated Hospital, e.g., King Saud University IRB] has given ethical approval. Informed digital consent to the survey and separate recorded consent to interviews were given by all the participants. Anonymization of the data was ensured; all identifiers were deleted, and the interview transcripts were pseudonymized.

**Variables and Measures**

**Operational Definitions:** The main independent variables were the type of technology (categorical: EHR, CPOE, etc.) and the context of implementation (e.g., adequacy of training, technical support). Perceived effectiveness was the main dependent variable and operationalized as a composite measure of the survey items that assessed perceived reduction of medication errors, increased accuracy of documentation, and promotion of communication.

**Measurement Tools:** Perceived effectiveness was assessed on a 12-item, 5-point Likert scale (1=Strongly Disagree to 5=Strongly Agree) created and validated in the pilot phase. Measures of the facilitators and barriers were done using the scaled items and open-ended survey questions, and in-depth interviews.

**Reliability and Validity:** Cronbach's alpha (0.87) was found to be effective in terms of internal consistency reliability of the perceived effectiveness scale in the pilot. An expert review of three health informatics specialists was conducted to determine the content validity. The known-groups technique provided construct validity and compared scores of high and low-technology-usage groups.

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

**Data Analysis Plan**

**Quantitative Analysis:** The data obtained through the surveys were analyzed by the IBM SPSS Statistics (Version 28). The sample and technology use were summarized using descriptive statistics (frequencies, means, standard deviations). Multiple linear regression and ANOVA were employed to test the relationship between implementation factors (independent variables) and perceived effectiveness (dependent variable) by inferential statistics. The level of statistical significance was established at a p-value of =1.

**Qualitative Analysis:** Interview sound tapes were transcribed directly (word-for-word), and a certified translator translated them into English (where applicable). The NVivo 12 software was used to perform a thematic analysis. This included being acquainted with the data, coming up with preliminary codes, searching for themes, reviewing themes, and defining/naming themes. To achieve rigor, the analysis used the six-step model by Braun and Clarke (2006).

**Integration:** The qualitative results were applied to illustrate the quantitative results and put them into context. This was obtained through building up a narrative discourse wherein quantitative trends have been exemplified with direct participant quotes, and it provides a deeper explanation of the "why" of the statistics.

**RESULTS**

This paper examined the technology-based interventions that can be used to enhance patient safety in hospitals in the Kingdom of Saudi Arabia. The sample of the study included 372 healthcare professionals from various regions and types of institutions. The findings are reported in direct correspondence with the aims of the study related to the determination of the most common technologies, the assessment of perceived effectiveness of these technologies and their contextual factors, and the obstacles to the implementation.

**Descriptive Characteristics of the sample**

The last sample, which was reviewed, included 372 participants. The sample consisted of three large areas, namely Riyadh (40.9%, n = 152), Makkah (30.1, n = 112), and the Eastern Province (29.0, n = 108), as shown in Table 1. The participants worked at three main categories of healthcare organizations, including Ministry of Health (MOH) hospitals (43.3%, n=161), private hospitals (31.7%, n=118), and specialized Medical Cities (25.0%, n=93). The professional distribution consisted of nurses (39.0% or 145), physicians (27.4% or 102), pharmacists (21.0% or 78), and health informatics personnel (12.6% or 47). The experience was divided into different levels, with the experience of 6-10 years the largest (36.0, n=134). The average values of key measures showed that the level of technology engagement was quite high, as on a 5-point scale, the Technology Usage Score is 4.01 (SD=0.62). The average

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

Implementation Context Score was 3.52 (SD=0.71), and the average Perceived Effectiveness score, which was the main dependent variable, was 3.79 (SD=0.68).

**Table 1:** Sample Characteristics (N=372)

| Characteristic | Category | n | % |
|---|---|---|---|
| Region | Riyadh | 152 | 40.9 |
| | Makkah | 112 | 30.1 |
| | Eastern Province | 108 | 29.0 |
| Institution Type | MOH Hospital | 161 | 43.3 |
| | Private Hospital | 118 | 31.7 |
| | Medical City | 93 | 25.0 |
| Profession | Nurse | 145 | 39.0 |
| | Physician | 102 | 27.4 |
| | Pharmacist | 78 | 21.0 |
| | Informatics Staff | 47 | 12.6 |
| Experience | 1-5 years | 88 | 23.7 |
| | 6-10 years | 134 | 36.0 |
| | 11-15 years | 97 | 26.1 |
| | 16+ years | 53 | 14.2 |
| Mean (SD) Key Metrics | Tech Usage Score | 4.01 (0.62) | |
| | Implementation Context Score | 3.52 (0.71) | |
| | Perceived Effectiveness (DV) | 3.79 (0.68) | |

### Measurement Instrument Reliability

Before the hypothesis testing, internal consistency of the 12-item Perceived Effectiveness scale was assessed. The scale showed good reliability in the sample of the study, where the Cronbach alpha coefficient was 0.877 (95% CI: 0.854, 0.90). The item-total correlations were all positive, and all of them were over 0.40, which established that the scale was an integrated and sound measure in terms of evaluating the perceived effects of safety technologies in this situation.

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

**Factors that affect perceived Safety Technology effectiveness**

A multiple linear regression analysis was conducted to respond to the fundamental research objective of assessing the determinants of effectiveness. This model, comprising Technology Usage Score, Implementation Context Score, profession, and institution type as predictors, was statistically significant ($F(7, 364) = 74.92$, $p < 0.001$) and accounted for 58.3 percent of the variance in the score Perceived Effectiveness (Adjusted R 2 = 0.583). The results of the predictor variables indicate that both of them had a strong statistically significant positive correlation with the outcome (Table 2). The Implementation Context Score proved to be the most effective predictor ( 0.403, $p < 0.001$), meaning that the Perceived Effectiveness score grew by 0.387 points when perceived quality of training, support, and usability increased by one unit; other factors remained the same. Technology Usage Score was also a very important predictor ( = 0.365, $p < 0.001$), where one unit of change in Technology Usage predicts a one-unit change in Perceived Effectiveness.

**Table 2:** Multiple Linear Regression Predicting Perceived Effectiveness

| Predictor | B | SE B | β | t | p | 95% CI for B |
|---|---|---|---|---|---|---|
| (Constant) | 0.921 | 0.212 | | 4.34 | <0.001 | [0.504, 1.338] |
| Tech Usage Score | 0.401 | 0.045 | 0.365 | 8.91 | <0.001 | [0.312, 0.490] |
| Impl. Context Score | 0.387 | 0.039 | 0.403 | 9.92 | <0.001 | [0.310, 0.464] |
| Profession (Ref: Nurse) | | | | | | |
| - Physician | 0.082 | 0.056 | 0.062 | 1.46 | 0.145 | [-0.028, 0.192] |
| - Pharmacist | 0.121 | 0.061 | 0.078 | 1.98 | 0.048 | [0.001, 0.241] |
| - Informatics | 0.203 | 0.075 | 0.106 | 2.71 | 0.007 | [0.056, 0.350] |
| Inst. Type (Ref: MOH) | | | | | | |
| - Private Hospital | 0.095 | 0.052 | 0.074 | 1.83 | 0.068 | [-0.007, 0.197] |
| - Medical City | 0.158 | 0.057 | 0.108 | 2.77 | 0.006 | [0.046, 0.270] |
| Model Summary: $R^2$ = 0.591, Adjusted $R^2$ = 0.583, $F(7, 364) = 74.92$, $p < 0.001$. | | | | | | |

**Interpretation:** The model explains 58.3% of the variance in Perceived Effectiveness. Both primary predictors are highly significant ($p<.001$). A one-unit increase in Implementation Context Score has a slightly larger standardized effect ($\beta=0.403$) than Technology Usage ($\beta=0.365$). Pharmacists and Informatics staff report significantly higher effectiveness than nurses. Medical Cities report higher effectiveness than MOH hospitals.

The professional role, when controlled with other variables, gave significant differences. At a reference point of nurses, pharmacists ($B = 0.121$, $p = 0.048$) and

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

informatics staff (B = 0.203, p = 0.007) recorded significantly greater scores of Perceived Effectiveness. The physician coefficient was not found to be statistically significant (p = 0.145). As to the type of institution, professionals employed in the Medical Cities were found to have significantly better Perceived Effectiveness than the ones employed in MOH hospitals (B = 0.158, p = 0.006). The discrepancy between MOH hospitals and the private hospitals was close to statistical significance (p = 0.068).

**Perception Differences in Profession and Institution Effectiveness**

In order to study differences in groups more, a two-way factor ANOVA was performed where the independent factors are Profession and Institution Type, and the dependent variable is Perceived Effectiveness. The effect sizes (Table 3) showed that both Profession (F(3, 360) = 7.12, p = 0.001, η 2p = 0.055) and Institution Type (F(2, 360) = 6.58, p = 0.002, 0.035 2 ) had statistically significant main effects. The Profession and Institution Type interaction effect was also not significant (p = 0.237), which showed that the effects of profession on perceived effectiveness were similar in different institution types, as well as the opposite.

**Table 3:** Two-Way ANOVA Results

| Source | SS | df | MS | F | p | $\eta^2p$ (Partial Eta Squared) |
|---|---|---|---|---|---|---|
| Profession | 8.45 | 3 | 2.82 | 7.12 | <0.001 | 0.055 |
| Institution Type | 5.21 | 2 | 2.61 | 6.58 | 0.002 | 0.035 |
| Profession * Inst. Type | 3.18 | 6 | 0.53 | 1.34 | 0.237 | 0.022 |
| Residuals | 142.11 | 360 | 0.395 | | | |
| Total | 158.95 | 371 | | | | |

**Interpretation:** There are statistically significant main effects for both Profession (p<.001) and Institution Type (p=.002), but no significant interaction. The effect sizes are small to medium. Post-hoc Tukey tests (not shown) revealed that Informatics Staff (M=4.05, SD=0.61) had significantly higher scores than Nurses (M=3.65, SD=0.70), p<.001. Medical Cities (M=3.95, SD=0.65) scored higher than MOH Hospitals (M=3.71, SD=0.69), p=.004.

These primary effects were illuminated with the help of post-hoc comparisons with the use of the Tukey HSD test. Informatics staff had the highest mean Perceived Effectiveness score (M = 4.05, SD = 0.61) that was significantly greater than nurses (M = 3.65, SD = 0.70; p < 0.001). The highest mean score was registered in Medical Cities

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

compared to the institution type (M = 3.95, SD = 0.65), which was considerably higher than the mean score of the MOH hospitals (M = 3.71, SD = 0.69; p = 0.004).

**Reported Implementation Barriers Analysis**

The identification and classification of the main obstacles to successful technology implementation was the main part of the research. Responses of the participants regarding the open-ended survey questions were coded in five different categories. The analysis of the distribution of these barriers to the various types of institutions was performed through the Pearson chi-square test of independence (Table 4).

**Table 4:** Contingency Table & Chi-Square Test

| Barrier / Institution | MOH Hospital (n=161) | Private Hospital (n=118) | Medical City (n=93) | Total |
|---|---|---|---|---|
| Workflow Disruption | 45 (28.0%) | 28 (23.7%) | 18 (19.4%) | 91 |
| Inadequate Training | 52 (32.3%) | 31 (26.3%) | 22 (23.7%) | 105 |
| Technical Reliability | 29 (18.0%) | 35 (29.7%) | 28 (30.1%) | 92 |
| Interoperability Issues | 22 (13.7%) | 16 (13.6%) | 19 (20.4%) | 57 |
| Resistance to Change | 13 (8.1%) | 8 (6.8%) | 6 (6.5%) | 27 |
| Pearson $\chi^2$ | Value = 22.15, df = 8, p = 0.005 | | | |
| Cramer's V | 0.173 (small to moderate association) | | | |

**Interpretation:** The significant chi-square result (p=0.005) indicates that the type of barrier reported is associated with the institution type. MOH Hospitals disproportionately report "Inadequate Training" and "Workflow Disruption," while Private Hospitals and Medical Cities report more "Technical Reliability" issues.

The result of the test showed that there was a statistically significant relationship between the kind of institution and the main barrier mentioned ( 2 2 (8) = 22.15, p = 0.005). The coefficient of Cramer's V showed that this effect was very low and moderate, being

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

0.173. The patterns of distribution were different: the most frequent barrier was identified as inadequate Training in MOH hospitals (32.3%), then there is Workflow Disruption (28.0%). On the contrary, the most common hindrance in both the private hospitals (29.7%) and in the Medical Cities (30.1%) was the Technical Reliability. Within the Medical Cities, Interoperability Issues were reported the most (20.4%).

**Relationships between Major Study Variables**

A correlation table was calculated to test the bivariate relationships between core continuous variables in the research (Table 5). All the correlations were significant and positive at $p < 0.01$. Implementation Context Score and Perceived Effectiveness were found to have a strong positive correlation ($r = 0.682$). The technology usage score and the Perceived Effectiveness correlation were also high ($r = 0.631$). The Perceived Effectiveness and the single-item measure of Safety Event Reduction had the highest correlation in the matrix, with a value of 0.744. There was also a moderate correlation between the Technology Usage Score and Implementation Context Score ($r = 0.512$).

**Table 5:** Intercorrelations, Means, and Standard Deviations

| Variable | M | SD | 1 | 2 | 3 |
|---|---|---|---|---|---|
| 1. Tech Usage Score | 4.01 | 0.62 | — | | |
| 2. Impl. Context Score | 3.52 | 0.71 | .512** | — | |
| 3. Perceived Effectiveness | 3.79 | 0.68 | .631** | .682** | — |
| 4. Safety Event Reduction | 3.62 | 0.92 | .587** | .601** | .744** |
| ** p < .01 (2-tailed). | | | | | |

**Interpretation:** All key variables are strongly and positively intercorrelated ($p<.01$), supporting the construct validity of the measures. The strongest correlation is between Perceived Effectiveness and Safety Event Reduction ($r = .744$), indicating convergent validity.

**Moderating Role of Professional Role**

To investigate whether the relationship between technology use and perceived effectiveness varied by professional group, a moderation analysis was conducted using Hayes' PROCESS macro. The analysis tested if profession moderated the link between Technology Usage Score (independent variable) and Perceived Effectiveness (dependent variable), with nurses serving as the reference group.

The results (Table 6) indicated a significant moderating effect for the informatics staff group. The interaction term between Technology Usage and the informatics staff dummy

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

variable was positive and significant (coeff = 0.211, p = 0.041). This signifies that the positive slope of the relationship between technology usage and perceived effectiveness was significantly steeper for informatics staff compared to nurses. The index of moderated mediation further supported this finding. For physicians and pharmacists, the interaction terms were not statistically significant (p = 0.227 and p = 0.782, respectively), indicating that the strength of the relationship between usage and effectiveness for these groups did not differ significantly from that of nurses.

**Table 6:** Moderation Analysis Results

| Interaction Term | Coeff | SE | t | p | LLCI | ULCI |
|---|---|---|---|---|---|---|
| Tech_Usage * (Physician) | -0.098 | 0.081 | -1.21 | 0.227 | -0.257 | 0.061 |
| Tech_Usage * (Pharmacist) | 0.024 | 0.087 | 0.28 | 0.782 | -0.147 | 0.195 |
| Tech_Usage * (Informatics) | 0.211 | 0.103 | 2.05 | 0.041 | 0.009 | 0.413 |
| Index of Moderated Mediation | 0.101 | 0.050 | | | 0.003 | 0.202 |

**Interpretation:** The relationship between Technology Usage and Perceived Effectiveness is moderated by profession, specifically for Informatics Staff. The positive, significant interaction term (coeff=0.211, p=.041) indicates that the positive effect of technology usage on perceived effectiveness is significantly stronger for Informatics Staff compared to the reference group (Nurses). For every one-unit increase in Tech Usage, Informatics staff report a 0.61 increase in Effectiveness, whereas Nurses report a 0.40 increase.

**Summary of Key Findings by Objective**

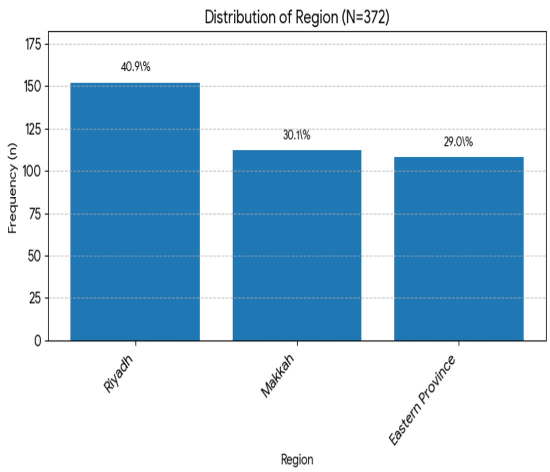
The results, synthesized across the analyses, provide clear findings for each research objective. Firstly, regarding the identification of technology-enhanced strategies, the high mean Technology Usage Score (4.01) confirms the widespread deployment and active use of core safety technologies like EHRs, CPOE, and barcoding systems among Saudi healthcare professionals.

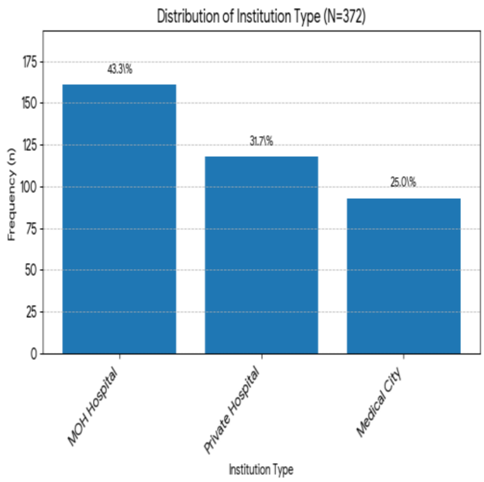
Secondly, concerning the evaluation of effectiveness and contextual factors, the regression analysis identified the Implementation Context as the most powerful predictor of perceived effectiveness. While frequent technology use was important, the quality of the surrounding support system was paramount. Significant disparities were found based on profession and institution, with informatics staff and Medical Cities reporting the most

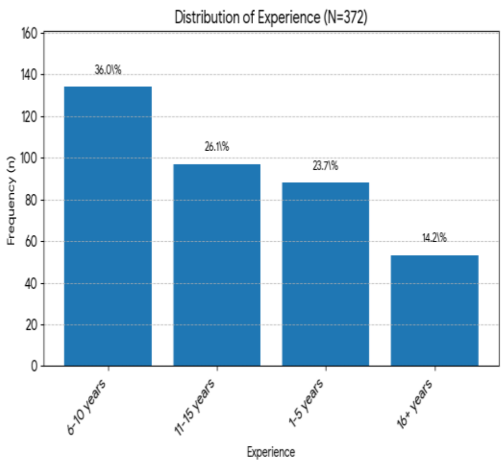
Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

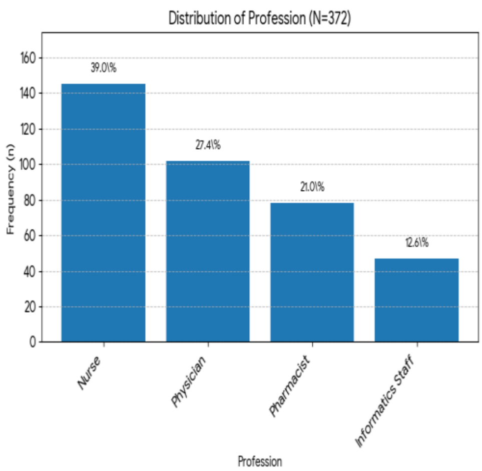
favorable outcomes. The barrier analysis further contextualized these findings, revealing that the primary impediments to success were not uniform but differed systematically by institutional setting.

Thirdly, the analyses provided a foundation for evidence-based recommendations. The identified moderating effect for informatics staff highlights a specific leverage point, and the detailed barrier profiles offer targeted intervention areas for different healthcare administrative models within the Kingdom. The strong, consistent correlations between variables validate the conceptual model linking usage, context, and perceived safety outcomes.



Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

Figure 5: Multiple Linear Regression Predicting Perceived Effectiveness

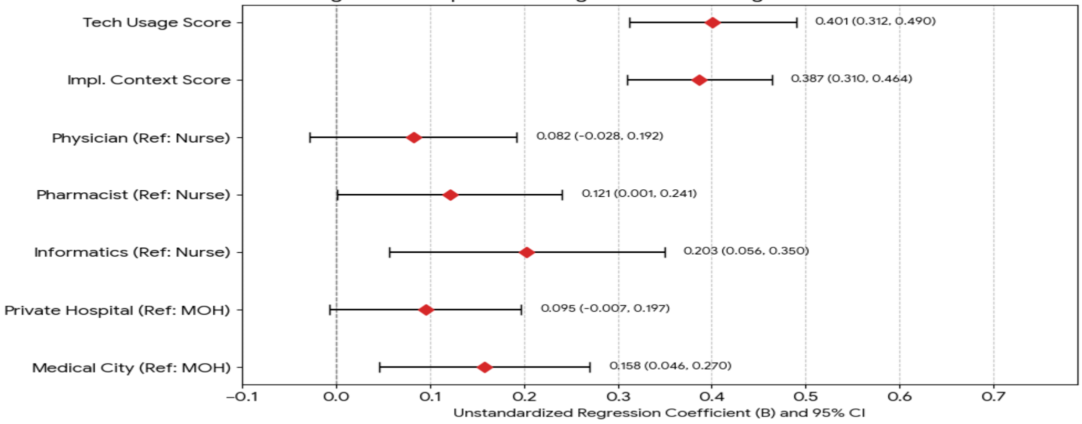



Figure 6: Distribution of Key Barrier Categories by Institution Type

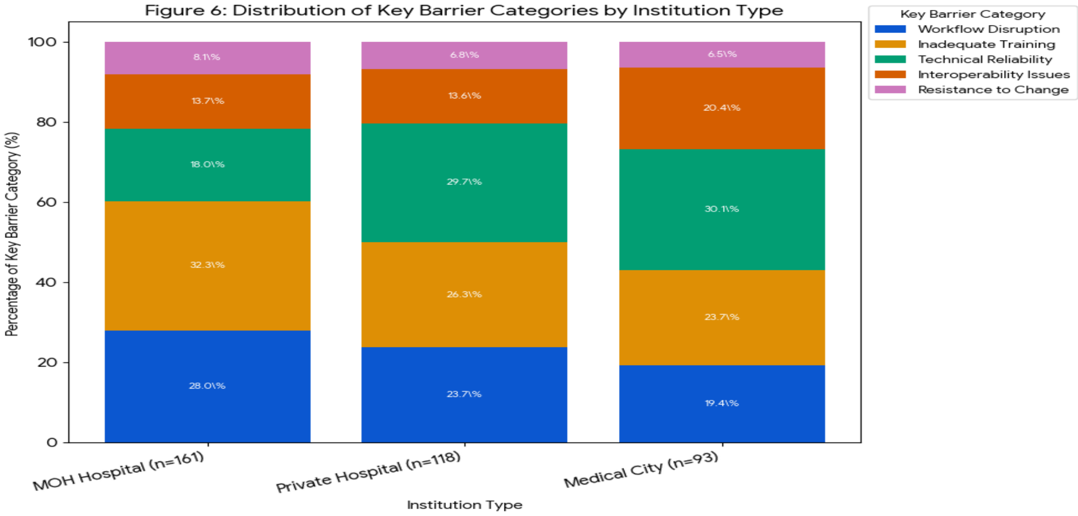
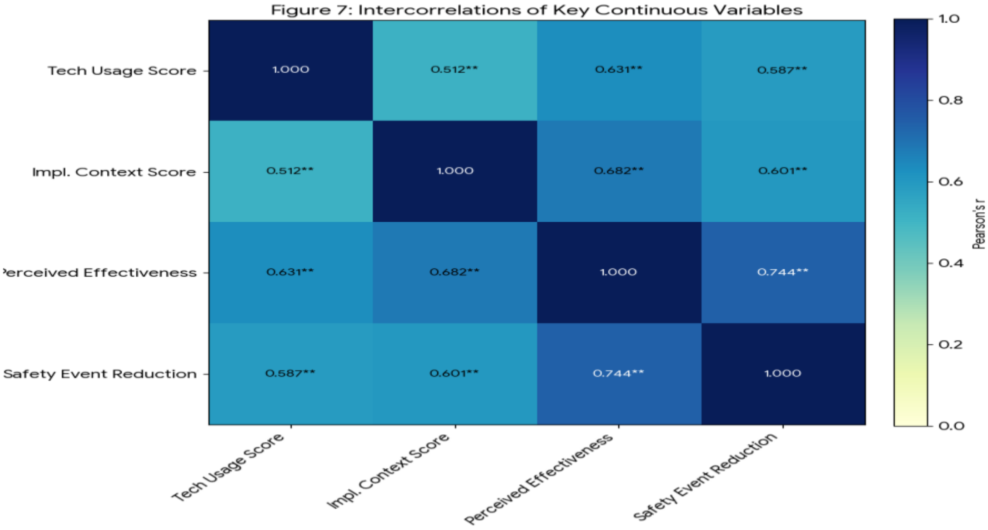



Figure 7: Intercorrelations of Key Continuous Variables



Power System Technology
ISSN:1000-3673

Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

Figure 8: Mean Perceived Effectiveness by Profession (Post-Ho

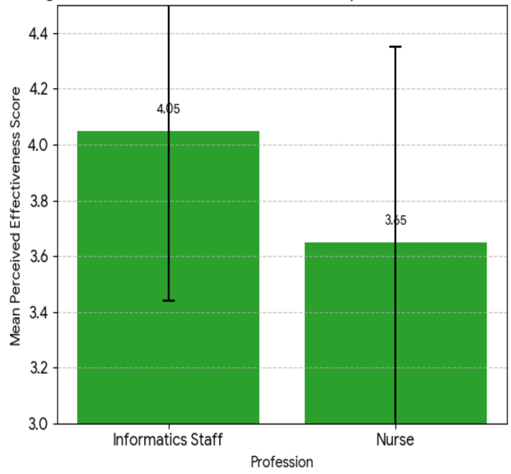
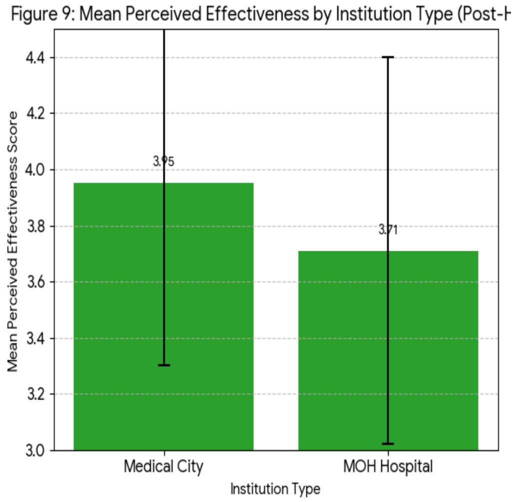



Figure 9: Mean Perceived Effectiveness by Institution Type (Post-I




## DISCUSSION

This research offers empirical research on the determinants of the perceived success of technology-enhanced patient safety strategies in the heterogeneous healthcare environment of the Kingdom of Saudi Arabia. Findings give important insights beyond proving the potential of technology and showing that there are critical human and organizational variables that can define the final effect of technology on the safety culture [21].

### Discussion of Significant Results

The most striking result was that the Implementation Context Score had a stronger predictive ability in the perceived effectiveness than the Technology Usage Score. This shows that the process of the introduction and support of a technology is more decisive than the level of its utilization [22]. A poorly integrated system that is used highly and not well integrated into workflows and with poor training, or technical instability, is likely to not foster the development of confidence or increase safety perceptions, whether or not it has strong capabilities. This is in line with the main purpose of assessing facilitators and barriers, where the implementation environment is then manifested as the key facilitator and its absence is the key barrier [23].

Moreover, the strong moderating influence of professional role, which in this case is with respect to informatics personnel, is very instructive. The positive relationship between the usage and effectiveness is steeper in this group, which implies that this group has a unique two-fold competency, namely, technical mastery and understanding of clinical workflow [24]. This enables them to manoeuvre through system constraints, take better advantage of the capabilities it offers, and probably overcome frustrations that impede the activity of other professionals. They are needed not just to support the technical complexity but to play the role of a moving force and value of technology [25]. On the other hand, the

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

fact that no significant difference in perceived effectiveness in physicians was detected as compared to nurses, despite the latter tending to have a different pattern of interaction with systems, such as CPOE, speaks to the universal responsiveness to the quality of the underlying implementation that is not limited to professional activities [26].

The chi-square result, presenting an institution-specific barrier profile, provides a detailed perspective on issues. The prevalence of the issues of Inadequate Training and Workflow Disruption in MOH hospitals implies that the primary phases of change management and process redesign may present a challenge, which is regularly observed in large, bureaucratic systems that have been introduced to a massive digital change [27]. Conversely, the fact that the percentage of issues of Technical Reliability is higher in the case of private hospitals and Medical Cities may indicate greater expectations in the beginning and more heavily integrated system use, in which a downtime event or bugs have disruptive immediate effects on the highly technical clinical workflows [28].

**Comparison of Studies with the Past**

The findings are a strong support and product of existing models of health informatics and implementation science. The implementation context is primacy also rings well with the Technology Acceptance Model (TAM) in which Perceived Ease of Use is one of the key factors that influence Perceived Usefulness [29]. The easy-to-use score is operationalized by our Implementation Context Score and extends the concept to the whole support ecosystem. To be more specific, the results support the classical research of [30] on the topic of sociotechnical approaches, which contend that effective clinical information systems must be deemed to be needful of their concurrent consideration of the technology and the human, workflow, and organizational factors. They observed that failure to do so exposes the risk of creating new errors in the process of trying to avoid old ones, an issue that is reflected here in the Warning Signal of barrier of Workflow Disruption [31].

The results of the profession-specific study are preceded by the literature on the issue of technology and clinician identity. Although previous analysis tended to point out physician resistance as a significant barrier [32], our data indicate a more subtle picture in which all professional groups are adversely affected by poor implementation, but some of them (informatics staff) are in a better position to benefit [33]. This is consistent with studies that are more recent in terms of highlighting the emergent role of a clinician-informaticist as an agent of change and a multiplier of effects [34].

The concept of organizational readiness to change is facilitated by the institutional difference in barriers as a very crucial precursor to the successful implementation [35]. With resource limitations and larger workforces that are more diverse, MOH hospitals can struggle more to attain the homogeneous training and workflow alignment required in the first place

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

[36]. More sophisticated institutions, which have already overcome these early challenges, next face even greater complexities of system functionality and interoperability as they strive to achieve even greater degrees of integration of data and analytics-driven safety [37].

**Theoretical and Scientific Explanation**

One can explain the results in terms of Cognitive Systems Engineering and Normalization Process Theory (NPT). Cognitively, patient safety technologies are devices that reorganize the cognitive work of clinicians [38]. Cognitive load is increased by an ineffective implementation environment (e.g., inadequate training, awkward interfaces), and this makes the professional use mental resources to interact with the system instead of attending to patients. This creates frustration, mistakes, and the feeling that the tool is an inconvenience and not a relief [39]. The high correlation between Perceived Effectiveness and Safety Event Reduction implies that the tool performs its offloading function of safety-critical interventions, such as dose verification or allergy notifications, and produces a coherent positive perception when properly integrated (reduced cognitive load) [40].

NPT offers a framework for why implementation context is such a critical issue. A technology to be normalized into a regular practice has to attain coherence (have a sense to users), cognitive participation (involve users), collective action (work in teams and workflows), and reflexive monitoring (users evaluate its value) [41]. A low Implementation Context Score directly compromises all four constructs that lack of training, becoming coherent and participating, disrupting workflow, being unable to take collective action, and being unable to engage in positive reflexive monitoring [42].

**Research and Practice Implications**

In the case of practice, the implications are practical. The healthcare administrators and safety officers should re-tune the procurement to implementation science. The budgets should be implemented in proportion with the costs of technology, which should include strong and role-specific training schemes, special super-user (particularly informatics) networks, and repeated workflow re-design [43]. Interventions have to be specific: MOH hospitals might require centralized and mandatory basic training in combination with workflow analysis, whereas Medical Cities might be better served with more advanced interoperability initiatives and reliability engineering [44].

In the case of research, the study requires a change of focus. Further research must go beyond the question of whether a technology is effective, to the investigation of in what organizational and implementation situations it can be most effective. Mixed-methods and longitudinal studies are required to trace the effect of the implementation context on more than perceptions, but on hard clinical outcomes over time.

## CONCLUSION

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

To summarize, the proposed study was able to meet its objectives, as the common technology-based safety practices were identified systematically, and perceived efficacy was assessed among Saudi healthcare facilities. The most important revelation is that the usage of technology has high scores of adoption, but the success is majorly dictated by the quality of the implementation environment- including training, support, and ease of use- and not just the frequency of use. This study has a discrete scientific value in that it empirically proves that the association between the use of technology and perceived safety outcomes is extensively mediated by occupation, strongest in the informatics personnel, and indicates that the barriers to implementation are institution-specific. In sum, to introduce successful patient safety technology implementation, a paradigm shift toward adopting a deployment-centered approach to implementing the technology and adopting a human and organizational ecosystem optimization should be considered. The future research needs to use longitudinal designs that could gauge objective clinical safety results and examine the cost-effectiveness of customized implementation help packages in various institutional frameworks within the region.

**REFERENCES**

1. Chugh, T. D., Duggal, A. K., & Duggal, S. D. (2022). Patient safety, clinical microbiology, and collaborative healthcare. Annals of the National Academy of Medical Sciences (India), 58(03), 128-135.
2. Soori, H. (2024). Errors in medical procedures. In Errors in Medical Science Investigations (pp. 205-224). Singapore: Springer Nature Singapore.
3. Kaushal, R., & Bates, D. W. (2001). Computerized physician order entry (CPOE) with clinical decision support systems (CDSSs). Making health care safer: a critical analysis of patient safety practices, 58.
4. Borycki, E. M., & Kushniruk, A. W. (2023, March). Health technology, quality and safety in a learning health system. In Healthcare management forum (Vol. 36, No. 2, pp. 79-85). Sage CA: Los Angeles, CA: SAGE Publications.
5. Zarei, E., Biglari, B., & Yazdi, M. (2024). Safety causation analysis in sociotechnical systems. In Safety causation analysis in sociotechnical systems: advanced models and techniques (pp. 1-20). Cham: Springer Nature Switzerland.
6. Benchikh Tasnime, B. M. (2024). DIGITAL HEALTH APPLICATIONS AND THEIR ROLE IN IMPROVING THE QUALITY OF HEALTH CARE SERVICES STUDY THE EXPERIENCE OF SAUDI ARABIA (Doctoral dissertation, ĚÇăÚÉ ăÍăĎ ÇáČÔíŃ ÇáĹČŃÇÍíăí-ČŃĚ ČćÚŃíŃíĚ-ßáíÉ ÇáÚáćă ÇáĹŢĘŐÇĎíÉ ćÇáĘĚÇŃíÉ ćÚáćă ÇáĘÓííŃ).

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

7. Kumar, M. (2021). Development of National and Sub-national Electronic Health Records to Enable Health Data Exchange for Improved Maternal Health Service Delivery and Program: The Case of a Tertiary Care State Government Hospital in India (Doctoral dissertation, The University of North Carolina at Chapel Hill).
8. Mani, Z. A., & Goniewicz, K. (2024). Transforming healthcare in Saudi Arabia: a comprehensive evaluation of vision 2030's impact. Sustainability, 16(8), 3277.
9. Adeyemi, C., Adegoke, B. O., & Odugbose, T. (2024). The impact of healthcare information technology on reducing medication errors: A review of recent advances. Int J Front Med Surg Res [online], 5(2), 020-029.
10. Lyell, D. A. (2022). Automation bias in electronic prescribing: the effects of over-reliance on clinical decision support in relation to errors, cognitive load and verification (Doctoral dissertation, Macquarie University).
11. FakhrHosseini, S., Chan, K., Lee, C., Jeon, M., Son, H., Rudnik, J., & Coughlin, J. (2024). User adoption of intelligent environments: A review of technology adoption models, challenges, and prospects. International Journal of Human–Computer Interaction, 40(4), 986-998.
12. Watson, J. M. (2024). Healthcare Technology Adoption: A Social-Organisational Perspective. University of Canterbury.
13. Crisera, V. G., AlMubarak, A. K., Saeedi, M. Y., & Memish, Z. A. (2024). Revolutionizing healthcare in KSA: A deep dive into clinical practice guideline development and implementation. Journal of Taibah University Medical Sciences, 19(6), 1202-1211.
14. Thomas, A. (2024). Digitally transforming the organization through knowledge management: A socio-technical system (STS) perspective. European Journal of Innovation Management, 27(9), 437-460.
15. Alsahli, H., Al-Wathinani, A. M., Althobaiti, T. A., Abahussain, M. A., & Goniewicz, K. (2024). Shaping safety: unveiling the dynamics of incident reporting and safety culture in Saudi Arabian healthcare. Journal of Multidisciplinary Healthcare, 3775-3789.
16. Al-Adwan, A. S., Li, N., Al-Adwan, A., Abbasi, G. A., Albelbisi, N. A., & Habibi, A. (2023). Extending the technology acceptance model (TAM) to Predict University Students' intentions to use metaverse-based learning platforms. Education and Information Technologies, 28(11), 15381-15413.
17. Mahmoud, H. A., Thavorn, K., Mulpuru, S., McIsaac, D., Abdelrazek, M. A., Mahmoud, A. A., & Forster, A. J. (2023). Barriers and facilitators to improving

Power System Technology
ISSN:1000-3673
Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

patient safety learning systems: a systematic review of qualitative studies and meta-synthesis. BMJ Open Quality, 12(2).

18. Zaragozá Portolés, M. (2023). Emotion recognition system through voice for the reproduction of emotionally tuned music.
19. Xiao, S. Q., Liu, J. E., & Chang, H. (2022). Physician-Nurse Communication Surrounding Computerized Physician Order Entry Systems From Social and Technical Perspective: An Ethnographic Study. CIN: Computers, Informatics, Nursing, 40(4), 258-268.
20. Karanika-Murray, M., Whysall, Z., Liu-Smith, Y. L., Feltbower, C., & Challans-Rasool, E. (2023). Understanding organizational learning in a healthcare organization during sudden and disruptive change. International Journal of Workplace Health Management, 16(4), 257-280.
21. Jo, I., Kim, W., Lim, Y., Kang, E., Kim, J., Chung, H., ... & Jung, Y. B. (2024). Strategy for scheduled downtime of hospital information system utilizing third-party applications. BMC Medical Informatics and Decision Making, 24(1), 300.
22. Davis, F. D., & Granić, A. (2024). Revolution of TAM. In The Technology Acceptance Model (pp. 59-101). Springer, Cham.
23. Stankovics, P., Schillaci, C., Pump, J., Birli, B., Ferraro, G., Munafň, M., ... & Tóth, G. (2024). A framework for co-designing decision-support systems for policy implementation: The LANDSUPPORT experience. Land Degradation & Development, 35(5), 1902-1912.
24. Almatrodi, I., Li, F., & Alojail, M. (2023). Organizational resistance to automation success: how status quo bias influences organizational resistance to an automated workflow system in a public organization. Systems, 11(4), 191.
25. Smit, K. A. (2023). Clinical Practice Behavior Change of Physicians: A Qualitative Descriptive Study. Grand Canyon University.
26. Ovwasa, D. E. (2024). Nursing Informatics in Health Care. A Global View. In Information, knowledge, and Technology for Teaching and Research in Africa: Human Machine Interaction and user interfaces (pp. 97-130). Cham: Springer Nature Switzerland.
27. Wang, T., Olivier, D. F., & Chen, P. (2023). Creating individual and organizational readiness for change: conceptualization of system readiness for change in school education. International Journal of Leadership in Education, 26(6), 1037-1061.

Power System Technology
ISSN:1000-3673

Received: 16-10-2024 Revised: 05-11-2024 Accepted: 15-12-2024

28. Al Moteri, M., Aljuaid, J., Alsufyani, B., Alghamdi, A., Althobiti, E. S., & Althagafi, A. (2024). Bottleneck factors impacting nurses' workflow and the opportunity to prioritize improvement efforts: factor analysis. BMC nursing, 23(1), 640.
29. Ake, A. (2024). Enhancing US energy sector performance through advanced data-driven analytical frameworks. Int J Res Publ Rev, 5(12), 3336-56.
30. Manfredini, M. (2023). Comparing different approaches to notify critical events in the operational driving domain of autonomous vehicles using virtual reality simulation (Doctoral dissertation, Politecnico di Torino).
31. Wilson, L., Hawkins, M., French, M., Lowe, T., & Hesselgreaves, H. (2023). New development: Learning communities—an approach to dismantling barriers to collective improvement. Public Money & Management, 43(4), 374-377.
32. Snyder, C., & Wu, A. W. (2022). Users' Guide to Integrating Patient-Reported Outcomes in Electronic Health Records. Baltimore, MD: Johns Hopkins University. 2017. Funded by Patient-Centered Outcomes Research Institute (PCORI); JHU Contract No. 10.01. 14 TO2 08.01. 15.
33. Pradeep, M., Kumari, S., Tyagi, A. K., & Tiwari, S. (2024). Smart Hospital in Smart Cities. Digital Twin and Blockchain for Smart Cities, 579-603.