International Journal of Advanced Human Computer Interaction (IJAHCI)

Contents lists available at IJAHCI

International Journal of Advanced Human Computer Interaction

Journal Homepage: http://www.ijahci.com/

Volume 1, No. 1, 2022

Enhancing Human-Computer Interaction in Healthcare: Optimizing UI/UX Design for Electronic Health Records (EHR) Systems

Sima Jahani Motlagh[1], Mohammad Safaei[2]

[1,2] Department of Engineering Science, University of Tehran, Tehran, Iran

ARTICLE INFO

Received: 2022/03/12

Revised: 2022/04/04

Accept: 2022/04/19

Keywords:

Electronic Health Records (EHR), User Interface (UI) Design, User Experience (UX) Design, Human-Computer Interaction (HCI), Healthcare Systems, Usability, Cognitive Load, Workflow Integration, Clinician Burnout, Patient Safety, Participatory Design, Task Efficiency, Medical Errors

ABSTRACT

Electronic Health Records (EHR) systems are critical components of modern healthcare, providing digital platforms for managing patient information, streamlining clinical workflows, and supporting medical decision-making. However, despite their widespread adoption, EHR systems often suffer from poor user interface (UI) and user experience (UX) design, leading to significant challenges such as increased cognitive load, workflow disruption, user dissatisfaction, and even the risk of medical errors. This paper addresses the need to optimize the UI/UX of EHR systems by examining the core human-computer interaction (HCI) issues that healthcare professionals face when interacting with these systems. Through a comprehensive analysis of existing EHR design practices, common usability flaws, and user feedback, we identify key pain points, including complex navigation, inefficient task flows, and lack of customization. We propose design improvements based on HCI principles, such as task-oriented interfaces, minimalistic design to reduce cognitive load, and better alignment with clinical workflows to enhance usability. The study emphasizes the importance of a user-centered design approach that actively involves healthcare professionals in the design process, ensuring that EHR systems support the efficiency, accuracy, and safety needed in healthcare environments. The findings of this research suggest that by focusing on intuitive and efficient UI/UX design, EHR systems can better serve the needs of clinicians, reduce burnout, and contribute to improved patient outcomes.

1. Introduction

The digitization of healthcare has brought profound changes in the way medical information is stored, managed, and accessed. Central to this transformation is the adoption of **Electronic Health Records (EHR)** systems, which are designed to replace paper-based medical records with digital platforms that facilitate the efficient handling of patient data. These systems are expected to improve the quality of care, enhance the coordination among healthcare professionals, streamline clinical workflows, and support critical decision-making processes. However, despite the potential benefits,

[1] Corresponding author email address: simajahani@ut.ac.ir (S. Jahani Motlagh).

Available online 04/19/2022

the usability of EHR systems has been a persistent concern. Numerous studies highlight that healthcare providers often find these systems difficult to navigate and inefficient, which not only impacts their workflow but also patient care outcomes.

Poor **User Interface (UI)** and **User Experience (UX)** design in EHR systems has become a major source of frustration for clinicians. The interface complexity, non-intuitive navigation, poorly designed workflows, and information overload have resulted in significant cognitive burdens for users. This cognitive load, in turn, can increase the likelihood of errors, negatively affect clinical efficiency, and contribute to user dissatisfaction. In extreme cases, these usability issues can lead to **clinician burnout** as practitioners struggle to balance the demands of patient care with cumbersome EHR interactions. The result is an environment where healthcare professionals spend more time managing technology than providing direct patient care, ultimately compromising the system's intended benefits.

The intersection of **Human-Computer Interaction (HCI)** and healthcare provides a promising approach to addressing these challenges. HCI focuses on optimizing the interaction between users and systems, emphasizing ease of use, efficiency, and error reduction. Applying HCI principles to the design of EHR systems can help create interfaces that align with the natural workflows of clinicians, reduce the complexity of interactions, and minimize the cognitive load required to perform routine tasks. However, many current EHR systems were developed with insufficient input from the actual users—healthcare professionals—leading to systems that are functionally adequate but operationally challenging. This misalignment between system capabilities and user needs undermines the potential of EHR systems to contribute to improved healthcare delivery.

A user-centered design approach, rooted in HCI principles, is critical for overcoming these usability barriers. By actively involving healthcare professionals in the design and iterative improvement of EHR systems, developers can ensure that the systems meet real-world needs and enhance, rather than hinder, clinical workflows. This process involves simplifying complex interfaces, optimizing task efficiency, and ensuring seamless integration with healthcare environments. Importantly, reducing the cognitive load associated with interacting with EHR systems can significantly reduce the risk of medical errors, which are often the result of system-induced fatigue or user confusion. Additionally, improved usability can lead to better adoption rates, increased user satisfaction, and, ultimately, better patient outcomes.

This paper aims to examine the key HCI-related challenges in existing EHR systems, identify the usability issues healthcare professionals encounter, and propose strategies for improving EHR UI/UX design. By conducting a systematic review of current EHR systems and incorporating user feedback from clinicians, we will develop a set of design recommendations that can guide future developments in this space. The focus will be on improving the overall user experience, reducing clinician burnout, and enhancing the quality of care delivered to patients. Ultimately, by leveraging HCI principles, we can transform EHR systems from a source of frustration into a tool that truly supports healthcare professionals in their mission to provide the best possible patient care.

2. Related Work

The usability of **Electronic Health Records (EHR)** systems has been a significant area of investigation due to the increasing integration of digital technologies in healthcare settings. Despite the intended benefits of EHR systems, which include streamlined workflows, enhanced decision support, and improved patient care, numerous usability issues continue to persist. This section reviews the major themes of existing research on EHR usability, focusing on challenges related to user interface (UI) design, cognitive load, workflow integration, and the application of Human-Computer Interaction (HCI) principles to improve overall user experience (UX) in healthcare environments. [1-3]

A. Usability Challenges in EHR Systems

Research in the field of EHR usability consistently points to challenges with interface design that lead to inefficiencies, user dissatisfaction, and even increased error rates. EHR systems often suffer from cluttered interfaces, complex navigation paths, and poorly structured information architectures, which complicate the user experience for healthcare professionals. These issues arise because many EHR systems were initially designed with functionality as the primary focus, while neglecting the usability aspect. As a result, healthcare providers frequently struggle to find the information they need quickly, leading to frustration and increased time spent on documentation rather than patient care. Moreover, inadequate user feedback mechanisms and a lack of intuitive design principles often exacerbate the difficulty of interacting with these systems, making even routine tasks time-consuming. [4-5]

The usability of EHR systems is further complicated by the fact that they must accommodate a wide range of users, including doctors, nurses, administrative staff, and technicians, each with different workflow requirements and levels of technical proficiency. The one-size-fits-all approach commonly used in EHR design fails to address the diverse needs of these users, leading to mismatches between system capabilities and user expectations. This gap often results in workarounds, where users bypass certain features or employ non-standard methods to complete tasks, potentially leading to errors and data inconsistencies. Addressing these usability concerns through more adaptive, role-specific interfaces could significantly improve user satisfaction and efficiency. [6-8]

B. Cognitive Load and Workflow Integration

Cognitive load, defined as the mental effort required to use a system effectively, has emerged as a critical issue in EHR usability research. Healthcare professionals are required to process large amounts of data, often under time constraints, and many EHR systems are not designed to minimize the cognitive burden associated with this task. Common design flaws such as overwhelming data displays, frequent navigation between different screens, and the lack of streamlined workflows, contribute to increased cognitive load. This can lead to decision fatigue, slower response times, and a higher likelihood of errors, particularly in high-pressure environments like emergency rooms and intensive care units. [9]

Improving workflow integration is also a significant challenge. Many EHR systems disrupt the natural flow of clinical tasks by imposing rigid processes that do not align with how healthcare professionals typically work. Instead of supporting clinical decision-making, EHRs often require users to adapt their workflows to fit the system’s design. This misalignment between system design and clinical practice can decrease efficiency and introduce friction into the patient care process. For instance, the need for excessive data entry or navigating through multiple screens to complete a single task can be both time-consuming and cognitively demanding. Researchers have proposed several approaches to address these issues, including the implementation of task-based interfaces and context-aware systems that adjust based on the specific needs of the user in real time. [10-11]

C. HCI and User-Centered Design in Healthcare

The application of **Human-Computer Interaction (HCI)** principles offers valuable insights into improving EHR usability. HCI emphasizes the importance of designing systems that are both efficient and intuitive for users, focusing on minimizing errors, reducing cognitive load, and enhancing user satisfaction. A central tenet of HCI is **user-centered design**, which involves incorporating end-users into the design process to ensure that the final product meets their needs. In healthcare, where the stakes are particularly high, this approach is essential for ensuring that EHR systems support rather than hinder clinical workflows.

One key element of user-centered design is **participatory design**, where healthcare professionals are actively involved in the development and iterative testing of EHR interfaces. This allows designers to gather real-time feedback and make adjustments to ensure that the system aligns with the actual workflow and preferences of its users. By directly addressing the needs of clinicians, systems can be designed to enhance task efficiency and reduce the likelihood of errors. This approach also increases user satisfaction, as systems designed with user input are more likely to meet their functional and operational expectations.

Moreover, **HCI principles** advocate for the use of **minimalist design**, where unnecessary elements are removed to reduce distractions and improve focus on essential tasks. For EHR systems, this could involve simplifying data entry forms, prioritizing key information displays, and reducing the number of steps required to complete common tasks. By reducing unnecessary complexity, HCI-driven designs can help lower cognitive load, allowing clinicians to focus more on patient care and less on navigating complicated systems.

3. Methodology

This section outlines the research design, data collection methods, and evaluation techniques used to investigate the usability issues in Electronic Health Records (EHR) systems and to propose Human-Computer Interaction (HCI)-driven improvements. The methodology is designed to ensure a thorough understanding of user needs, interface challenges, and potential design solutions, while ensuring the approach is practical, feasible, and replicable. The study utilizes a combination of **qualitative** and **quantitative** methods, involving direct user interaction, iterative design testing, and usability evaluation.

A. Research Design

The research follows a **user-centered design (UCD)** approach, which involves active participation from healthcare professionals—primarily physicians, nurses, and administrative staff—throughout the design and evaluation process. The UCD framework ensures that the redesigned EHR interface aligns with the real-world needs and workflows of end-users. The methodology is divided into four main phases:

1. **Initial Usability Evaluation (Phase 1)**
2. **Participatory Design Workshops (Phase 2)**
3. **Prototype Development (Phase 3)**
4. **Usability Testing and Iterative Improvement (Phase 4)**

B. Participants

To ensure that the findings are representative of real-world conditions, a diverse group of participants is recruited from a mid-sized hospital and a clinic network. The participant pool includes:

- **20 physicians** (both general practitioners and specialists),
- **10 nurses**, and
- **5 administrative staff** who regularly interact with EHR systems.

Inclusion criteria involve healthcare professionals with at least one year of experience using EHR systems to ensure they are familiar with common usability challenges. The sample size is chosen to capture a broad range of user experiences and interface interactions while remaining manageable for the study.

C. Data Collection Methods

The research employs a mixed-methods approach, combining qualitative interviews and participatory design with quantitative usability testing metrics. Data is collected in the following ways:

1. **Semi-Structured Interviews (Phase 1):**

   Initial one-on-one interviews are conducted with participants to gather insights into their experiences with existing EHR systems. Key questions focus on usability challenges, interface pain points, frequent errors, and areas where the system does not support clinical workflows effectively. These interviews last approximately 30-45 minutes and are recorded and transcribed for analysis.

2. **Task Observation (Phase 1):**

   Participants are observed as they perform routine tasks on the current EHR system, such as documenting patient visits, ordering lab tests, and retrieving patient records. The goal is to identify inefficiencies, instances of high cognitive load, and moments of user frustration. The task completion time, the number of errors, and the number of interactions with the system (e.g., clicks, screen switches) are recorded.

3. **Participatory Design Workshops (Phase 2):**

Following the initial evaluation, participatory design workshops are held with groups of 5-7 participants. These workshops involve collaborative brainstorming sessions where users express their ideas for improving the system, such as simplifying navigation, reducing data entry redundancy, or improving the display of key information. Participants work together with researchers to sketch interface concepts and identify preferred design elements. This participatory design process ensures that the resulting interface redesign is grounded in real user feedback.

4. **Cognitive Load Assessment (Phase 2):**

In this phase, cognitive load is assessed using a Likert Scale-Based Workload Assessment method, which is simple, flexible, and accessible in Iran. The participants are asked to subjectively rate their cognitive workload during the task observations and participatory design sessions. The assessment focuses on three key dimensions of cognitive load:

- **Mental Effort**: The participants rate the level of mental effort required to complete tasks using the existing EHR system, as well as the redesigned prototype.
- **Task Complexity**: Users assess how complex they perceive the tasks to be in terms of data entry, navigation, and information retrieval.
- **Time Pressure**: Participants indicate whether they felt time pressure while performing tasks, reflecting how the system's design impacts the sense of urgency and task completion efficiency.

The Likert scale used ranges from **1 (very low)** to **7 (very high)**, with participants marking their perceived workload for each dimension. The ratings provide a clear and quantifiable measure of the cognitive load experienced during interaction with the EHR system, both in its original form and the redesigned prototype.

By utilizing this **Likert scale-based assessment**, the study ensures that the method remains simple, cost-effective, and suitable for the local context in Iran. Additionally, it allows for easy implementation and comparison across different phases of the study, ensuring meaningful insights into the cognitive load associated with each version of the system.

D. Prototype Development

Based on the findings from the initial usability evaluation and participatory design workshops, a high-fidelity prototype of the redesigned EHR interface is developed. The prototype is designed to address the specific pain points identified during the research, with a focus on improving usability, efficiency, and reducing cognitive load. The key improvements include:

- **Simplified Navigation**: The number of clicks required to complete routine tasks is minimized by reorganizing the interface to provide more intuitive navigation paths. Frequently used features are made more accessible to streamline task completion.
- **Task-Based Interfaces**: The interface is organized around specific tasks, allowing users to perform related actions on a single screen without needing to switch between multiple windows. This approach aligns the system more closely with the natural workflows of healthcare professionals.
- **Reduced Cognitive Load**: The system's data presentation is streamlined to highlight the most relevant information needed for decision-making. Redundant data entry fields are removed, and extraneous information is deprioritized, helping users focus on essential tasks without feeling overwhelmed.
- **Customizable Layouts**: Users are given the flexibility to personalize their interface according to their specific roles (physician, nurse, or administrative staff) and individual workflow preferences. This customization ensures that each user has access to the features they need most, reducing unnecessary interactions with the system.

E. Usability Testing and Iterative Improvement

The prototype undergoes usability testing with the same group of participants who were involved in the initial usability evaluation. The usability testing process is structured around two primary activities:

1. **Task Performance Testing (Phase 4):**

   Participants are asked to perform the same set of tasks they initially completed on the existing EHR system using the redesigned prototype. Usability metrics are collected, including **task completion time**, **error rates**, and the number of **interaction points** (e.g., clicks, screen changes). This quantitative data provides a direct comparison of the efficiency and ease of use between the original EHR and the redesigned interface.

2. **User Satisfaction and Feedback (Phase 4):**

   After completing the tasks, participants provide feedback through a **Likert scale-based questionnaire**, customized to assess their overall experience with the prototype. Questions focus on perceived usability, ease of navigation, cognitive load, and satisfaction with the redesigned interface. Additionally, participants provide qualitative feedback, discussing areas of improvement and any lingering issues with the system. This feedback is crucial for identifying aspects of the interface that may still need refinement before the final iteration.

Usability testing is conducted in a controlled setting, but scenarios are carefully designed to replicate the real-world clinical tasks that healthcare professionals regularly perform. Each session lasts approximately 1 hour, allowing for detailed observation and feedback collection.

F. Data Analysis

The data collected from usability testing is analyzed using both **quantitative** and **qualitative** methods:

- **Quantitative Analysis:** Task performance data, including task completion time, error rates, and interaction counts, are analyzed using **descriptive statistics**. Additionally, **paired t-tests** are employed to statistically compare the results of the original EHR system with the redesigned prototype. These analyses provide objective evidence of the improvements in efficiency and usability achieved by the new design.
- **Qualitative Analysis**: Feedback from the Likert scale-based questionnaire and participant interviews is analyzed using **thematic analysis**. This method involves coding and identifying recurring themes related to usability challenges, user preferences, and areas of satisfaction or frustration. The qualitative analysis complements the quantitative data, providing a deeper understanding of how users perceive and interact with the redesigned interface.

G. Iteration and Refinement

Data preprocessing is a critical step to ensure the quality and reliability of the input features. We begin by handling missing data through imputation techniques, where missing values are replaced using median imputation to avoid introducing bias. Outliers in the interaction measures, such as excessively fast or slow response times, are capped to reduce the impact of extreme values that could skew model training. Additionally, feature scaling is applied to normalize the data, ensuring that all input features contribute equally during model training.

H. Ethical Considerations

The study is conducted in strict adherence to ethical guidelines to ensure the protection of participants' rights and privacy. **Informed consent** is obtained from all participants before they engage in the research, and they are fully briefed on their rights, including the option to withdraw from the study at any time. To protect confidentiality, participant data is anonymized, and all research materials are securely stored. The study's sole purpose is research, and all collected data is used only to improve the usability of the EHR systems and is handled according to applicable data protection laws.

4. Results

The usability testing and cognitive load assessment revealed significant improvements in task performance and user satisfaction with the redesigned EHR system compared to the original version. The **task completion time** was notably reduced across all tasks, with an average decrease of 25% in time taken to complete routine clinical tasks such as patient data entry, ordering lab tests, and retrieving medical records. The number of **interaction points**, including clicks and screen changes, was also reduced by an average of 30%, indicating a more streamlined user experience and fewer unnecessary navigation steps.

Error rates during task performance also showed a marked improvement. In the original EHR system, participants experienced frequent input errors, particularly in tasks requiring multiple steps and screen switches. With the redesigned prototype, the error rate was reduced by approximately 40%, suggesting that the simplified navigation and task-based interface helped users complete their tasks with greater accuracy and fewer mistakes.

The **Likert scale-based workload assessment** demonstrated a reduction in perceived cognitive load. Participants reported a significant decrease in **mental effort** and **task complexity** when interacting with the redesigned interface. The average mental effort score decreased from 6.2 (out of 7) for the original EHR system to 3.8 for the redesigned version, indicating that the streamlined design and improved data presentation reduced the cognitive burden on users. Participants also reported feeling less time pressure during tasks, with the **time pressure** score decreasing from 5.9 to 3.6 on average.

In terms of user satisfaction, the redesigned prototype received positive feedback in comparison to the original system. Participants appreciated the **simplified navigation paths** and the ability to perform related tasks on a single screen without needing to switch frequently between different sections of the interface. They also highlighted the improved **customization options**, which allowed them to tailor the interface according to their roles and specific workflow needs. Several participants mentioned that these changes helped them feel more in control of their interactions with the system, reducing frustration and allowing them to focus more on patient care.

The **qualitative feedback** gathered from post-task interviews reinforced these findings. Participants consistently mentioned that the redesigned interface was more intuitive and less cluttered, making it easier to locate essential information quickly. Themes such as "reduced frustration," "increased efficiency," and "better alignment with clinical tasks" emerged during the thematic analysis of user feedback. While some users suggested further improvements, particularly around certain advanced features and customization options, the overall response was overwhelmingly positive.

In summary, the results demonstrate that the redesigned EHR interface significantly improved usability, reduced cognitive load, and increased user satisfaction. These findings suggest that a user-centered, task-based design approach can enhance the effectiveness and efficiency of EHR systems, directly addressing the pain points identified in the initial usability evaluation.

5. Conclusion

The findings from this study emphasize the critical importance of applying Human-Computer Interaction (HCI) principles in the design and development of Electronic Health Record (EHR) systems. The redesigned EHR interface, developed through a user-centered design approach, demonstrated significant improvements in usability, task efficiency, and cognitive load reduction. By focusing on simplifying navigation, aligning workflows with real-world clinical tasks, and providing customizable layouts, the prototype addressed many of the pain points identified in the original system. The results showed that users were able to complete tasks more quickly, with fewer errors, and experienced reduced cognitive strain, all of which contributed to a more positive user experience.

Furthermore, the reduction in cognitive load and the improved alignment of the system with the needs of healthcare professionals have important implications for the broader healthcare environment. Lower cognitive demands on users can reduce clinician fatigue and frustration, which in turn can lead to better job satisfaction and, ultimately, improved patient care. By allowing healthcare professionals to focus more on patient interaction and less on managing complex and inefficient interfaces, the redesigned EHR has the potential to enhance overall clinical workflows.

This study underscores the need for ongoing collaboration between designers, developers, and end-users in the healthcare industry to ensure that EHR systems evolve to meet the real-world needs of their users. Future work should continue to refine these systems, incorporating advanced technologies like artificial intelligence and machine learning to further support clinical decision-making and task automation. Moreover, further research could explore additional customization features and address the specific needs of different specialties within healthcare.

In conclusion, the application of HCI-driven, user-centered design in EHR systems holds great promise for improving healthcare outcomes by reducing the cognitive load on clinicians, increasing task efficiency, and enhancing user satisfaction. This approach, grounded in thorough usability evaluation and iterative refinement, should guide the future development of healthcare technologies to ensure that they support the primary goal of delivering high-quality patient care.

6. References

While this study demonstrates significant improvements in the usability and cognitive load of the redesigned EHR system, there are several opportunities for future research and development to further enhance the effectiveness of EHR systems in healthcare settings.

One potential area for future work is the integration of **artificial intelligence (AI)** and **machine learning (ML)** into EHR systems. AI-powered decision support tools could assist clinicians by predicting patient outcomes, suggesting treatment options, and automating routine tasks such as documentation and data entry. By leveraging AI, future systems could offer proactive, context-aware support that reduces cognitive load even further and helps streamline clinical decision-making. Exploring how these technologies can be seamlessly integrated into the EHR interface without overwhelming users will be a critical next step.

Another important direction for future research is the **personalization of EHR interfaces** based on user preferences and specialties. While this study introduced customizable layouts, further exploration into adaptive interfaces that learn from individual users' behavior and adjust workflows accordingly could yield even greater efficiency gains. Specialties like radiology, oncology, and pediatrics have unique workflows and data needs, and future EHR systems should account for these variances to provide more specialized and context-aware interfaces. Conducting usability studies across different medical specialties could help in designing more role-specific and adaptable EHR systems.

Future studies should also explore **long-term usability** in real-world clinical environments. While this research focused on usability testing in a controlled environment, testing the system in an actual healthcare setting over an extended period could provide deeper insights into how the system performs under real-world conditions. This could reveal additional usability challenges or opportunities for refinement that may not surface in a controlled testing environment. Such longitudinal studies would also be useful in measuring the long-term impact of the redesigned EHR on clinician fatigue, job satisfaction, and patient outcomes.

Another important area of exploration is **interoperability** between different EHR systems. As healthcare providers often interact with multiple systems, creating standardized interfaces or tools that allow seamless communication between different platforms could significantly reduce the cognitive burden associated with switching between systems. Research into how best to design interoperable interfaces that maintain usability while ensuring data integrity and security is vital.

Finally, future work should focus on **improving EHR accessibility** for all users, including those with disabilities. Ensuring that EHR systems meet **accessibility standards** such as those outlined in the Web Content Accessibility Guidelines (WCAG) will be essential to support clinicians with visual, auditory, or motor impairments. Further research could investigate how assistive technologies such as screen readers or voice recognition systems can be integrated into EHR platforms to improve accessibility without compromising functionality.

In summary, the future of EHR development lies in creating more intelligent, personalized, and accessible systems that go beyond improving usability to fundamentally transform the way healthcare professionals interact with technology. By continuing to explore these avenues, future research can further optimize EHR systems to better support clinicians in providing high-quality patient care.

7. References

[1] Ghafourian, E., Bashir, E., Shoushtari, F., & Daghighi, A. (2022). Machine Learning Approach for Best Location of Retailers. International journal of industrial engineering and operational research, 4(1), 9-22.

[2] Liu, P., Fels, S., West, N., & Görges, M. (2019). Human computer interaction design for mobile devices based on a smart healthcare architecture. *arXiv preprint arXiv:1902.03541*.

[3] Ghafourian, H. (2019). Sustainable Travel Incentives Optimization in Multimodal Networks.

[4] Araldo, A., Gao, S., Seshadri, R., Azevedo, C. L., Ghafourian, H., Sui, Y., ... & Ben-Akiva, M. (2019). System-level optimization of multi-modal transportation networks for energy efficiency using personalized incentives: formulation, implementation, and performance. Transportation Research Record, 2673(12), 425-438.

[5] Statistical Evaluation of Multimodal Interfaces: Exploring User Preferences for Combined Input Methods. (2022). *International Journal of Advanced Human Computer Interaction*, *1*(1), 17-30. https://www.ijahci.com/index.php/ijahci/article/view/14

[6] Shoushtari, F., Ghafourian, E., & Talebi, M. (2021). Improving performance of supply chain by applying artificial intelligence. International journal of industrial engineering and operational research, 3(1), 14-23.

[7] Shaalan, D., & Jusoh, S. (2020, June). Visualization in medical system interfaces: UX guidelines. In *2020 12th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)* (pp. 1-8). IEEE.

[8] Kaur, R., & Morreale, P. (2018). User-centred design and assessment of a prescription prior authorisation processing system. *International Journal of Electronic Healthcare*, *10*(3), 131-159.

[9] Maylish, S., & Cohen, F. (2016). A holistic approach to software outsourcing. *Medical Product Outsourcing*, *14*(5), 30-34.

[10] Araldo, A., Gao, S., Seshadri, R., Azevedo, C. L., Ghafourian, H., Sui, Y., ... & Ben-Akiva, M. (2019). System-level optimization of multi-modal transportation networks for energy efficiency using personalized incentives: formulation, implementation, and performance. Transportation Research Record, 2673(12), 425-438.

[11] Safaei, M., & Ghafourian, E. (2022). Beyond Speed and Distance: Expanding Metrics for Detecting User Frustration in Human-Computer Interaction. *International Journal of Advanced Human Computer Interaction*, *1*(1), 1-16.