Analytic Hierarchy Process–based Method to Rank the Critical Success Factors of Implementing a Pharmacy Barcode System

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Abstract

Pharmacy barcode scanning is used to reduce errors during the medication dispensing process. However, this technology has rarely been used in hospital pharmacies in Saudi Arabia. This article describes the barriers to successful implementation of a barcode scanning system in Saudi Arabia. A literature review was conducted to identify the relevant critical success factors (CSFs) for a successful dispensing barcode system implementation. Twenty-eight pharmacists from a local hospital in Saudi Arabia were interviewed to obtain their perception of these CSFs. In this study, planning (process flow issues and training requirements), resistance (fear of change, communication issues, and negative perceptions about technology), and technology (software, hardware, and vendor support) were identified as the main barriers. The analytic hierarchy process (AHP), one of the most widely used tools for decision making in the presence of multiple criteria, was used to compare and rank these identified CSFs. The results of this study suggest that resistance barriers have a greater impact than planning and technology barriers. In particular, fear of change is the most critical factor, and training is the least critical factor.

Keywords: analytic hierarchy process (AHP), critical success factors (CSFs), pharmacy barcode system

Introduction

Medication errors in hospitals are common and often lead to serious harm for patients. These errors may occur during any stage of the medication process, including ordering, transcribing, dispensing, administering, and monitoring.[1] Most of the solutions to reduce this problem, such as computerized provider order entry (CPOE) systems, have focused on reducing errors at the medication ordering stage.[2,3] However, the error rate during the dispensing process is about 4 percent, and 80 percent of these errors are prevented.[4] These error rates possibly equate to more than 45,000 undetected dispensing errors annually in a large hospital.[5-7]

Recently, barcode scanning technology has begun to play an important role in reducing medication errors at the dispensing and administering stages. Studies have shown that the successful implementation of this technology can reduce medication dispensing errors by 85 percent.[8-10] In addition, barcode scanning improves inventory management and accurately tracks medications throughout the facility. However, few hospital pharmacies have implemented this technology. Several studies have been done regarding the critical success factors (CSFs) of information systems in health care organizations.[11-14] Nanji et al.[15] specified three main barriers to pharmacy barcode scanning system implementation: process barriers, with factors including training requirements and process flow issues; technology barriers, such as hardware, software, and the vendor's role; and resistance, including communication issues, changing roles, and negative perceptions of technology. Bates[16] discussed that a successful implementation of a new technology depends on five CSFs, three of which are consistent with the barriers found by Nanji et al.[17] However, the CSFs for a successful implementation of barcode systems in Saudi hospital pharmacies have rarely been studied. One purpose of this study is to identify the CSFs for a successful dispensing barcode system implementation.

The analytic hierarchy process (AHP) is a multiple-criteria decision-making process that is used to set priorities among different attributes. The AHP has been widely used to reflect the importance, or relative weights, of the factors associated with priorities. Many outstanding studies of the AHP have been done, including application of the AHP in different areas such as planning, selecting a best alternative, allocating resources, resolving conflict, optimizing processes, and others.[18-25] With the assistance of the AHP model, in this study we ranked the CSFs for a successful pharmacy barcode system implementation according to the perception of pharmacy staff in one local hospital.

Methodology

To identify the barriers to a successful dispensing barcode system implementation, we conducted interviews of pharmacy personnel at a local private hospital in Eastern Province, Saudi Arabia. For the interview, 28 pharmacists and pharmacy technicians were selected on the basis of either their use of a barcode scanning system or their involvement in the implementation of such a system. The data collection process lasted three months.

Ranking Approach: AHP

The AHP was invented by Saaty in 1980.[26] This process is a powerful multiple-criteria decision-making tool that has been used for decision making in numerous applications. It consists of an eigenvalue approach to pairwise comparisons. It provides a numeric scale for the measurement of quantitative as well as qualitative performance. The AHP method consists of three basic steps: first, the problem has to be broken down and structured into a hierarchy of subproblems; second, the data have to be collected and measured through pairwise comparisons of the attributes; and finally, the priority weights of factors or items in each level are calculated. A judgment or comparison consists of a numerical representation of a relationship between two elements that share a common parent.[27] The set of all relative comparisons are then reported in a square matrix, in which the elements are compared with each other. As shown in Table 1, the comparisons, in a scale ranging from 1 to 9, correspond to the level of dominance or contribution to the project.

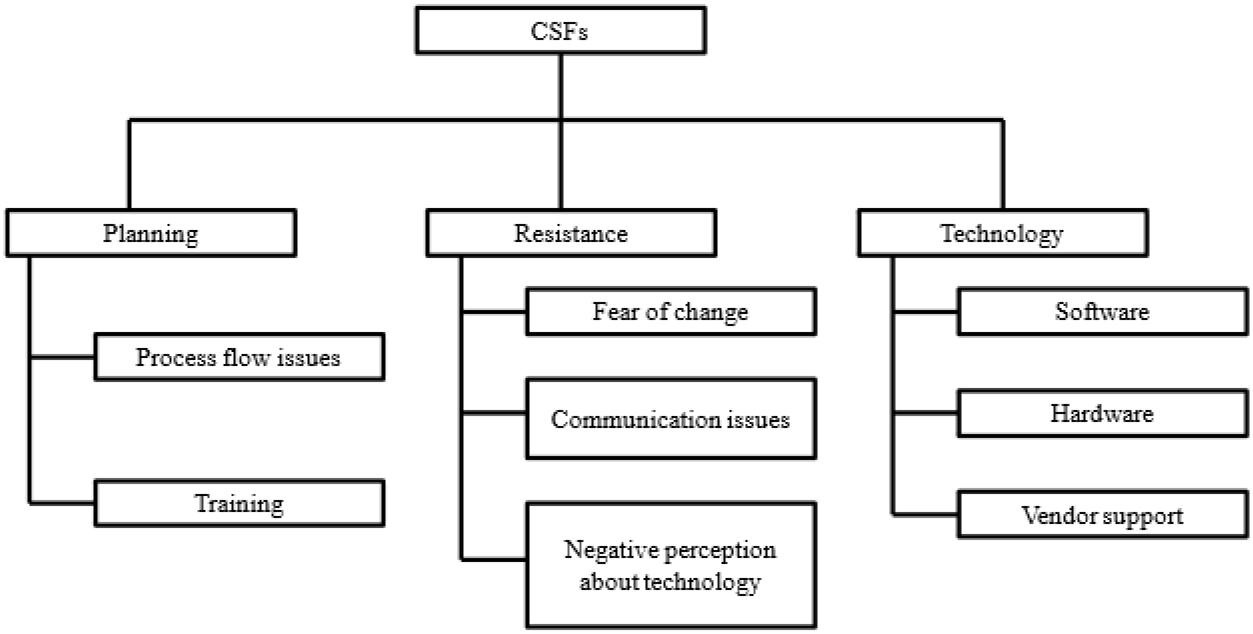
Table 1: Pairwise Comparison Scale

Rating	Description
1—Equal	Both alternatives have **equal importance**
3—Moderate	One of the alternatives is **slightly more important** than the other one.
5—Strong	One of the alternatives is **strongly more important** than the other one.
7—Very Strong	One of the alternatives is **very strongly important** compared to the other one.
9—Extreme Importance	One of the alternatives is **strictly superior** to the other one.

Constructing the Hierarchy

To study the CSFs affecting the dispensing barcode system implementation, we first conducted a literature review,[28-35] and then we interviewed 28 pharmacists from a local hospital in Saudi Arabia to determine their perception of these CSFs. We then established three main categories: planning, resistance, and technology. Finally, we identified the factors within these three categories. The decision of the degree of importance associated with each CSF can be resolved by decomposing it into subproblems within a hierarchy structure. The highest level with only one element is the goal to reach, and the elements in the lowest level are the factors. Elements in the middle levels are the criteria or categories for evaluating those factors. In this study, the hierarchy of all categories and factors were classified into three levels as shown in Figure 1.

Figure 1: Hierarchy Model of Critical Success Factors (CSFs) for Pharmacy Barcode Implementation



Planning

Planning is an ongoing process of addressing all aspects and situations before and during any implementation. Planning involves two concerns: training and process flow issues. In the planning for adoption of a new system, training is crucial and must begin in advance of the implementation. Many pharmacy technicians think that they are not adequately trained, and they recognize the importance of training. The lack of training would be an obstacle to the barcode system implementation. Additionally, as with any large project, a pharmacy barcode scanning system implementation has to overcome unexpected challenges, which usually involve workflow redesign.

Resistance

Staff resistance to barcode scanning system implementation can be an important barrier. Communication issues, fear of change, and negative perceptions of technology are the three main factors that cause resistance toward a barcode scanning system.

Communicating clearly and in a straightforward manner with staff regarding the need for change, while at the same time acknowledging their concerns, may reduce staff resistance. Staff members need to see and be reassured that their supervisors have thought through the situation, considered other alternatives, and have made a decision that is in the best interests of the organization. Fear of change could also be an important cause of staff resistance because some staff members may have entirely different job descriptions with the new system. Another contributor to resistance is a negative perception of technology. Three main negative perceptions were identified through the literature review: overdependence on technology, potential for harm, and concerns about increased performance monitoring.

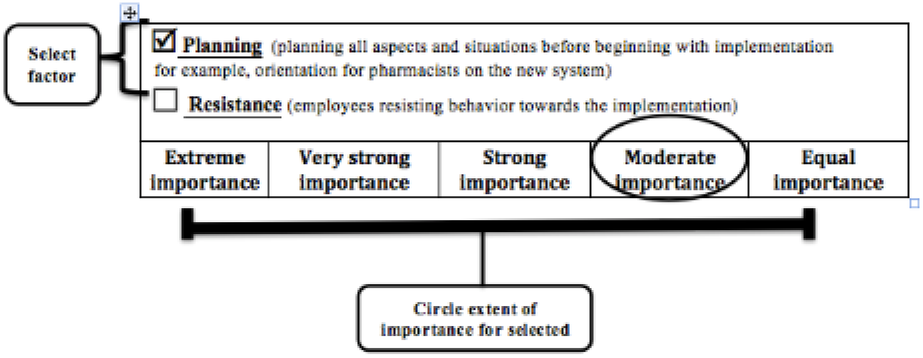
Technology

Several technical problems affect barcode scanning system implementation, as is the case with the implementation of most new technology. These problems include hardware and software problems and the role of vendors. The hardware problems are largely related to scanning equipment and its features. Software issues, such as customization to the user's needs and integration with the existing pharmacy system, may also arise. In addition, vendors play an important role in addressing many of these technology issues. Several strategies are suggested in the literature for choosing a vendor.[36]

Pairwise Comparisons and Computation of the Factors' Weights

The 28 interviewed pharmacy employees' perceptions of the priority of importance of the factors and categories are shown in Figure 1. The priority of the factors was captured by asking the importance of each factor with respect to the others in the same category using a pairwise comparison scale as described in Table 1. Categories are also compared with each other. A sample comparison from the survey is shown in Figure 2.

Figure 2: Sample Comparison of the Survey



The data were extracted from these surveys and entered into pairwise comparison matrices as scores on the pairwise comparison scale. A sample pairwise comparison matrix for the three categories is depicted in Table 2. The values in the cells of the matrix represent the results of the weighting (each cell shows the relation between the alternative in the row and the alternative in the column). For example, the element in row 1 and column 2 is 7, which means that the respondent answered that planning is very strongly more important than resistance. Comparing planning and technology, the respondent strongly favored technology; thus the value in row 1 and column 3 is 0.2. The values in the diagonal of the matrix are always 1 (when compared with itself, each alternative has equal importance), and the lower triangular values of the matrices are the reciprocal values of the upper triangle. Therefore, pairwise comparison is required for only half of the matrix, excluding the diagonal. Pairwise comparison matrices for factors are constructed in a similar way.

Table 2: Sample Pairwise Comparison Matrix

Categories	**Planning**	**Resistance**	**Technology>**
Planning	**1**	7	0.2
Resistance		**1**	3
Technology			**1**

Note: In this matrix, the element in row 1 and column 2 is 7, which means that planning is judged to be very strongly more important than resistance; the element in row 1 and column 3 is 0.2, which means that technology is strongly more important than planning; and the element in row 2 and column 3 is 3, which means that resistance is slightly more important than technology.

The priority weights of the factors represent the importance of these factors. Priority weights have two types: local priority weights and global priority weights. The local priority weights represent the relative weights of the nodes within a group of factors with respect to their categories.[37] The local priority weights are derived from each set of pairwise comparisons in each level. The global priority weights are obtained by multiplying the local priorities of the factors by the global priority of their corresponding categories. In this process, the importance of each local factor is balanced by the importance of the category to which it belongs. We used an AHP web-based calculation[38] and Excel software to calculate the weights in the AHP model from the pairwise comparison matrices.

Results and Discussion

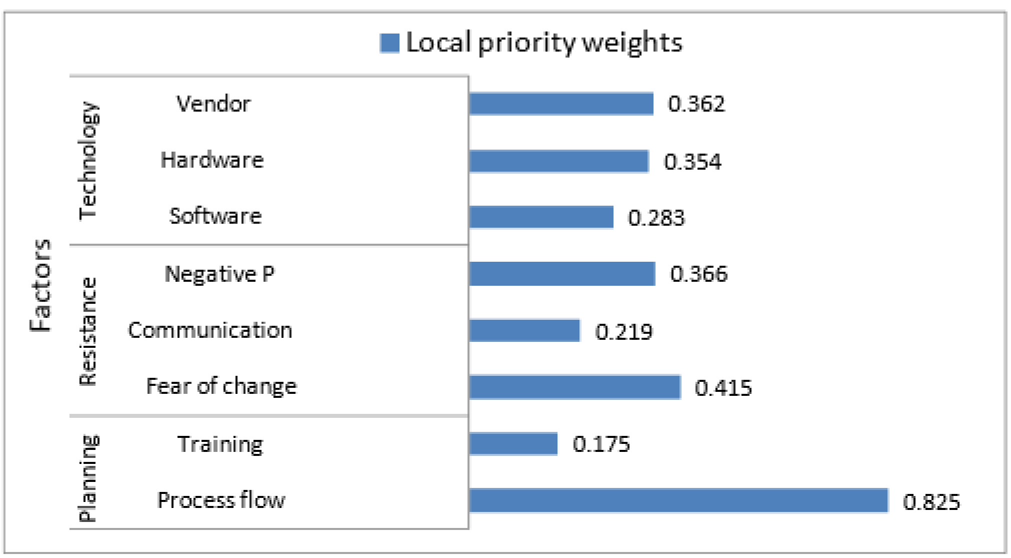
Multiple-criteria decision analysis (MCDA) approaches can be classified into three main categories: value measurement models, outranking models, and goal, aspiration, or reference-level models. In value measurement models, the degree to which one decision option is preferred over another is represented by constructing and comparing numerical scores. The scores are developed for each individual criteria initially and aggregated into higher-level value models. Most experts who use MCDA methodology for health technology assessment suggest applying value measurement models.[39-42] The AHP, a powerful and widely used MCDA technique, is similar to the value measurement modeling approach.[43,44] The other models for MCDA are not widely used in healthcare technology.

In this article, we proposed the application of the AHP to rank different CSFs related to the implementation of a pharmacy barcode scanning system. The technique seems to perform better than relying only on experts' assignation of the absolute priorities of each criteria[45] or relying on qualitative analysis alone. Furthermore, by using this technique, the level of importance of each attribute can be compared to the others. According to experts,[46] making comparisons between attributes seems to be an easier way to calibrate their importance. However, the AHP has been criticized mainly because of issues related to rank reversal.[47,48] Rank reversal means that the rank of an alternative resulting from the AHP may change if another new alternative is added to the initial group of alternatives that were compared. Introducing a new alternative includes new information in the model, and as a result the decision needs to be reevaluated.[49] However, this limitation did not affect our analysis because we did not need to include any new factors related to the implementation of a pharmacy barcode scanning system.

The barriers to successful implementation of the pharmacy barcode scanning system were structured into two levels: categories and their factors. Figure 3 summarizes the local priority weights of factors within each category. The summary of global priority weights for categories and their factors are described in Figure 4 and Figure 5, respectively. Since all participants' opinions were considered to be of the same importance, we used the geometric mean as the aggregation method for the calculation of the average local and global weights.

As shown in Figure 3, process flow is the most critical factor, with a local priority weight of 0.825 in the planning category. Its weight is about five times greater than that of training (local priority weight = 0.175). In the resistance category, fear of change (local priority weight = 0.415) is found to be the most important factor, while the least important factor is communication (local weight = 0.219). Vendor support is the most critical factor (local priority weight = 0.362) and software is the least important factor (local priority weight = 0.283) in the technology category.

Figure 3: Local Priority Weights of Factors



As shown in Figure 4, staff resistance (global priority weight = 0.562) is found to be more important in the second hierarchy level than the planning category (global priority weight = 0.226) and technology category (global priority weight = 0.211). It is not surprising that participants consider resistance to be more important than planning and technology because staff resistance barriers have a high impact and are more difficult to solve than planning or technology issues. Another reason may be that the respondents are end users and are not familiar with the development process. The high priority for resistance could also be a result of the respondents' experiences, especially given that they all came from the same hospital. Moreover, resisting new technologies is a long-standing problem, and many theories and models, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), have been conceived to ensure that users accept and benefit from technology. In the literature,[50] three basic theories of the causes of resistance that underlie many prescriptions and rules for management information system implementation have been discussed.

Figure 4: Global Priority Weights of Factors

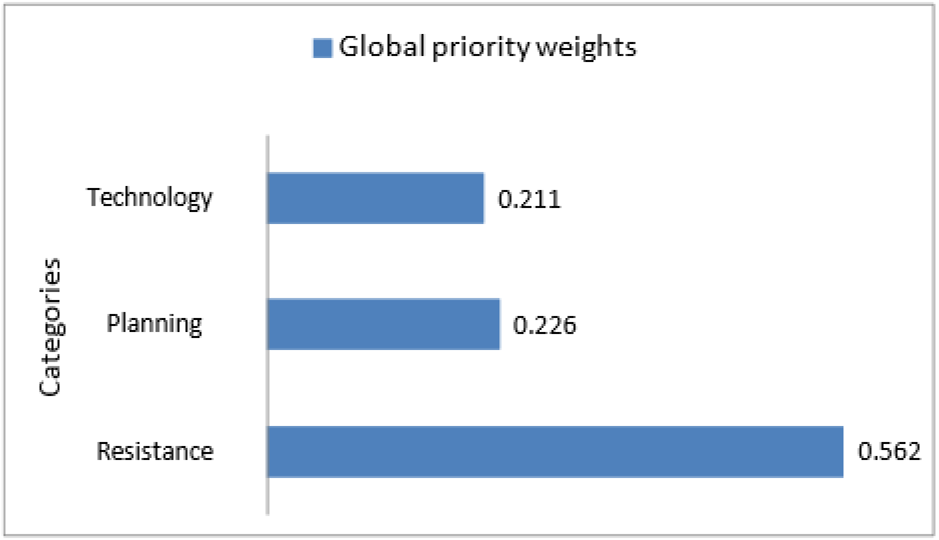
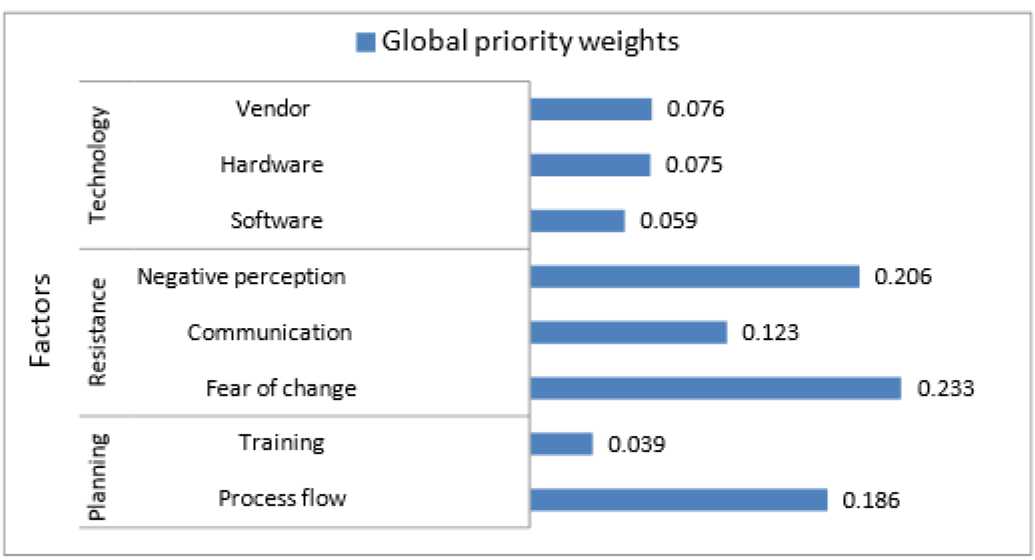


Figure 5 shows the CSF ranking based on global priority weights. The figure shows that the top three factors related to the barcode scanning system are as follows: fear of change (global priority weight = 0.233) in the resistance category, negative perception of technology (global priority weight = 0.206) in the same category, and process flow issues (global priority weight = 0.186) in the planning category. These three highest-ranked factors are related to the users' attitude toward the new system and its effect on their jobs. Similar results were found in a study regarding the adoption of radio-frequency identification (RFID) technology,[51] in which the most critical factors that affected the adoption of RFID technology were related to the users' behavior toward the system and the least critical factors were the technological factors. Fear of change comes with uncertainty and the threat of losing control. Vaughan[52] suggests four techniques in implementing new systems to enhance users' control.

Figure 5: Global Priority Weights of Factors



It is likely that the technology factors are lower ranked than resistance factors and training is the lowest-ranked factor because if the technology and technical support are not effective, then training would have no significant use. During implementation of an electronic administrative system at Valparaiso University, researchers found that there is "one principle that undergirds their success and it is about the people not the technology."[53] The results of our study confirm this principle by ranking the technology factors less critical for success than staff resistance factors.

Conclusion

Barcode scanning technology has significantly reduced the rate of dispensing errors and potential adverse drug events (ADEs) due to dispensing errors. However, barcode scanning system implementation is a difficult process with several barriers. In this study, the AHP was proposed to prioritize the categories and factors that present critical barriers to a successful implementation of pharmacy barcode scanning system. Prioritizing certain factors as barriers does not mean that other factors are not important or do not affect the system implementation. The results are the main issues should be considered to reduce the barriers to barcode scanning system adoption. In this study using the AHP, the most important barriers to the implementation of a barcode scanning system are fear of change, negative perception of technology, and process flow issues. The results indicate that staff resistance factors have a greater impact than any other factors on the successful implementation of a barcode dispensing system. The literature review suggests that staff resistance is one of the most pervasive problems encountered when implementing a new system, and our analytic results confirm this phenomenon. Our findings could be used in other healthcare centers to raise awareness of the barriers to the implementation of barcode scanning technology and also to overcome these barriers.

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Notes

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