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The adoption of ICT and robotic automation systems in the pharmaceutical industry

Authors:
Kebashnee Moodley[1]
Ross James[2]

Affiliations:
[1]Department of Information Systems, Faculty of Commerce, Law and Management, University of the Witwatersrand, Johannesburg, South Africa

[2]Department of Information Technology, Faculty of Technology, Eduvos, Midrand, South Africa

Corresponding author:
Kebashnee Moodley
kebashnee.moodley@wits.ac.za

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Background: South African pharmacies face challenges like cost reduction, inventory management, and employee efficiency. Balancing dispensing error rates and customer satisfaction, along with ensuring accurate medication dispensing, is also crucial. An effective solution to these challenges is adopting automatic robotic dispensing systems, which enhance stock inventory management, integrated systems, and accurate dispensing capabilities.

Objectives: The study delved into IT and robotic automation in South African pharmaceutical dispensing, assessing current methods and advocating for integrated IT and Automated Storage and Retrieval Systems in retail and hospital pharmacies.

Method: The research used a quantitative approach to gather data from public and private hospital pharmacy employees, aiming to understand their requirements and expectations. It assessed the potential improvements that could result from adopting a new system.

Results: The study found that most government and private pharmacies in South Africa prefer automated dispensing systems to reduce errors, lower costs, improve customer service, and enhance inventory management. Benefits also included minimising medication errors, improving operational efficiency, and ensuring patient safety.

Conclusion: The study holds importance as it underscores the necessity of integrating Information Technology (IT) and Robotic Automation in the pharmaceutical sector to address prevailing issues. It identifies factors contributing to medication dispensing errors and demonstrates the potential of automated robotic systems in mitigating these errors.

Contribution: South Africa's pharmaceutical sector must enhance efficiency and competitiveness by adopting integrated IT and Robotic Automation Systems. The study identified key factors for future implementation and emphasized the need for clear pre-implementation policies outlining functions and benefits.

Keywords: information technology; automated storage and retrieval system; pharmaceutical dispensing industry; robotic system; South Africa.

Introduction

Within the South African pharmaceutical landscape, retail, private, and government hospital pharmacies face several challenges in their day-to-day operations (Modisakeng et al. 2020). Management faces considerable pressure to reduce costs by improving inventory management and increasing employee efficiency, while balancing the need for patient safety (dispensing error rates) and customer satisfaction (Malakoane et al. 2020; Soffar 2018). Most of the problems pharmacies are faced with include the loss of time management and the continual search for the correct medication causing delays and the possibility of dispensing the incorrect medication. This results in the lack of time for more personalised attention and, as a result, the loss of customers and revenue (Malakoane et al. 2020; Soffar 2018).

This underscores the complex challenges faced by South African pharmacies. Thus emphasising the urgent necessity for strategic interventions to enhance the operational effectiveness and customer-centricity of pharmacies in the South African pharmaceutical landscape.

The urgency for South African pharmacies to adopt automatic robotic dispensing solutions is underscored not only by the imperative for improved stock inventory management and accurate dispensing but also by the opportunity to address workforce challenges (Malakoane et al. 2020; Soffar 2018). Embracing automation can alleviate personnel from routine dispensing tasks, enabling them to focus on specialised patient care and leveraging their expertise. This shift not

only streamlines operations but also has the potential to extend healthcare services to underserved areas, thereby optimising overall pharmacy efficiency and patient access.

Automated dispensing systems such as Mach4 Pharmacy Dispensing Units (PDUs) in South Africa (Hethel 2022) and the Pyxis® Automated Drug Dispensing system in Brazil (de-Carvalho, Alvim-Borges & Toscano 2017) have been adopted more progressively within the pharmaceutical industry to augment or substitute unit-dose distribution systems to improve medication availability, increase the operational efficacy and productivity of medication dispensing, reduce medication dispensing errors, and integrate with other medical management systems such as medical aid billing systems (Ahtiainen et al. 2020).

Within the South African landscape, the problem is that not many pharmacies (retail or private) have adopted integrated technology systems (smart pharmacies) and robotic automated storage and retrieval medication dispensing solutions (Modisakeng et al. 2020). Thus, this study aimed to investigate what role robotic automated storage and retrieval (medication dispensing) systems (AS/RS) can play in various pharmacy environments and how this can assist in medical dispensing error reduction and operational efficiencies. As the level of automation in South Africa is very low, the study will highlight how pharmaceutical automation will be implemented in the future given the challenges faced.

The healthcare industry (private and public) has long been utilising advanced digital equipment that is envisaged to advance medical progression on the one hand, while ensuring economic efficiency and cost pressure intensification on the other (Richardson, Mittmann & Kaunelis 2021).

Pharmacies integrate and connect various processes established in different segments within the complex practice of the use of medication in a hospital. Medication dispensing errors mean that a breach has occurred in one of the last safety links in the use of medication dispensing safety (Maharaj et al. 2020). Ciapponi et al. (2021) defined present-day concepts, namely side effects, unfavourable consequences, and drug errors as examples of medicine-related occurrences. Dispensing errors are one of them, and they are frequently linked to inadequate safety and inefficient dispensing methods (Rayhan et al. 2022). These challenges may be reduced with the adoption of an automated storage and retrieval system that dispenses medication in a controlled manner and traces the usage of patient medication (Ahtiainen et al. (2020). Furthermore, the dispensed medication data record can be electronically used by the hospital's financial administrative department for patient billing purposes (Modisakeng et al. 2020).

Automated storage and retrieval medication dispensing systems are large medication storage and refrigeration containers that are interfaced with the pharmacy's computer-controlled systems using a touch-screen interface (Maharaj et al. 2020). They operate similar to a vending machine, by dispensing medication to pharmacists and nursing resources as per prescriptions (Ahtiainen et al. 2020). Furthermore, depending on the AS/RS medication dispensing machine type, the system can count tablets, close bottles, place prescription labels on the vials, stockpile numerous types of medications, as well as ensure accuracy by accessing patient information (Ciapponi et al. 2021).

The pharmaceutical industry in South Africa does not currently measure the accuracy of the prescriptions dispensed manually to patients and thus there is potentially a high error rate because of incorrect dosages or prescribed medication (Modisakeng et al. 2020). The pharmaceutical companies have not ensured IT integration of their supply chain with the manufacturers and suppliers and thus medical stock management poses a potential problem (Moosivand, Rajabzadeh & Rasekh 2019).

The medical healthcare industry is an environment positioned ideally for innovation. With the rapid increase in the use of advanced technology and automation, health care could provide improved patient care while reducing overall operating costs (Lee & Yoon 2021). One of the foremost concerns for patient safety is medication dispensing errors. Within the healthcare industry, a challenge is dispensing errors as they directly correlate to potential injury to patients (Rayhan et al. 2022).

There has been a significant increase in medical errors, and it is estimated in the United States, the error rates have increased from 98 000 to 400 000 (Hisham et al. 2021). To decrease these errors, the impending problem must be recognised, measured, and reported on before a system can be developed to mitigate the identified problems (Hisham et al. 2021). A study conducted in England indicated that the impending hazard of dispensing errors accounted for 15.9% of the 237.4 million medication errors that occurred annually and that pharmacists and their teams are expected to manage the associated risks (Phipps et al. 2020).

According to Maharaj et al. (2020), a dispensing error is a mistake that happens when the pharmacist does not follow the written prescription correctly. It was concluded and found that an example of a deviation could include a dose/item error where the incorrect medication is selected or assembled, a labelling error where the medication is correct, but the label is incorrect, an issue error where the order is issued to the incorrect patient or not issued at all, and documentation error where the order is correctly issued but incorrectly documented (Phipps et al. 2020).

In a non-automated pharmacy, human involvement is essential during the dispensing process, irrespective of whether the pharmacist is assessing the prescription, interpreting the prescription, locating the applicable medication to fulfil the prescription, or evaluating the order to ensure correctness (Phipps et al. 2020). It was noted that pharmacists involved in the dispensing process face a degree of mental demand

because of dealing with several items of information that contrast in complexity and demand (Phipps et al. 2020).

Some of the most common errors identified while dispensing medication to patients include failure to communicate medication orders, indecipherable handwriting, incorrect medication selection on the pharmacy system, medication labelled or packaged similarly thus causing confusion, and medication dosage or weight errors (Phipps et al. 2020). With inadequate controls to detect mistakes, medication errors are because of human error, but it is often because of a defective system design (Rayhan et al. 2021). Significant morbidity and mortality rates have directly been correlated to unfortunate medical errors and underreported medical errors (Rayhan et al. 2021). These challenges together with the benefits are discussed in more detail further in the text.

Robotic automation within the pharmacy landscape has proven highly advantageous for patients and pharmacy staff to fulfil several medication prescriptions (Kent 2021). According to Firnhaber et al. (2018)and Mourral and Lesaffre (2020), some of the benefits of the adoption of the medical AS/RS dispensing robots are discussed in the following paragraphs.

Speed

A notable benefit that was identified was the speed of service offered to the pharmacists. The end customer (patient) does not have to queue for a long period to receive their medication, because of the automated dispensing robotic system dispensing a prescription more rapidly than a human can execute.

Safety

Medication such as similar pills may be easily miscounted or confused by pharmacists, whereas the automated dispensing robotic system does not have this problem. To reduce contamination of medication, which is a common occurrence, the medication is stored in a sterile environment.

Customer service

Permitting robotic automated storage and retrieval dispensing system to dispense medication enables pharmacists to dedicate more time to clinical and patient care. The automated system allows pharmacists to free up time to talk to patients about their prescribed medications, permits further patient relationship engagement, and allows the pharmacist to respond to queries that would assist in improving the quality of a patient's life. More time is freed up, allowing pharmacists to dedicate this time to offering preventative patient care, including the administration of immunisations, and conducting health screenings.

Security

The robotic automated storage and retrieval dispensing systems ensure that all the pharmacy's medication is securely stored, and the systems software tracks all the dispensed medication to patients. Identified pharmaceutical resources are trained on how to operate (use, open, and restock) the system, thus decreasing the likelihood of medication being misappropriated or human dispensing errors.

To investigate the benefits and if any challenges exist in the adoption of a robotic automated system, the researcher gathered data from various pharmacy workers. The next section will discuss the methodological process.

Research methods and design

The researcher adopted action research – Look, Think, and Act planning stages, while using a simple random sampling methodology.

A simple random sampling technique that forms part of the probability sampling method was used to collect data from retail and commercial pharmacy organisations in the Gauteng Province of South Africa. Gauteng is one of the nine provinces of South Africa and the smallest province of the country. It is the powerhouse of South Africa and the heart of its commercial business and industrial sectors (Britannica 2023).

Simple random sampling allowed the researcher to casually select a subset of the population of retail and private pharmacies and the associated employees managing the organisations in the Gauteng Province of South Africa. Thus, each member of the population from retail and commercial pharmacy organisations had an equal chance of being selected. The researcher investigated how pharmacies can *decrease medication dispensing error rates, integrate the various pharmaceutical ICT system capabilities, improve the medication inventory levels, and ensure improvement of the pharmacist's dispensing productivity efficiency and accuracy rate in retail and private pharmacies* through a structured survey questionnaire.

The sample size consisted of 50 retail and private pharmacies. The identified employees of the retail or private pharmacies were managing pharmacists, pharmacist(s), pharmacy associates, and nurses. This sample was chosen to understand the challenges faced in pharmacies and their views on automation adoption.

The study entailed getting ethical clearance from the academic institution (Eduvos) as well as gatekeepers' letters from the selected retail and private pharmacies permitting the collection of data from their employees.

A questionnaire was used to investigate and analyse the impact of the adoption of information technology and robotic automation systems in the pharmaceutical dispensing industry (retail, private, and government) within South Africa. The questionnaire was developed using a 1-to-5-point Likert scale. The questionnaire was administered using Microsoft Forms to participants in the pharmaceutical field. The respondent was then sent a link to anonymously complete the survey and the data were collected in the Microsoft Forms database.

Data were analysed using a combination of descriptive and non-parametric statistics and the statistical package SPSS was used for data processing and analytics. Statistical Package for the Social Sciences (SPSS) is a software package used for the analysis of statistical data. Descriptive statistics were used to determine the relative importance of the critical aspects for the effective productivity measurement of the pharmaceutical industry. To demonstrate the statistical findings, the researcher made use of tables, graphs, percentages, and frequency distribution tables. This is discussed in the next section.

Results and discussion

Pharmacies in the retail and private sectors including hospitals were chosen to participate in the study regarding the adoption of an automated robotic storage and retrieval dispensing solution. Demographic data such as professional qualification were collected to describe the pharmaceutical practitioners' profile (Figure 1) regarding the number of years of experience, the level of professional qualification, the pharmaceutical sector (private or public), and the type of pharmacy the medical practitioner functions in.

Figure 1 shows the various levels of professional qualification in the industry.

The respondents who participated across the pharmaceutical industry comprised 35% retail pharmacies, 49% hospital pharmacies, 6% hospital retail pharmacies, and 10% medicine depots.

Dispensing process and errors

The researcher focused on analysing the data gathered relating to the dispensing process, dispensing medication error types, administration issues (stock management, and IT related), resource management, and customer engagement.

Figure 2 shows the different medication dispensing errors resulting in patient fatality or serious adverse effects.

Figure 2 depicts the resulting dispensing errors as to whether a patient fatality has occurred or if there has been an adverse side effect. A total of 63% of respondents were either not aware or did not know of any patient issues; this could be because of a patient not reporting the dispensing error to the pharmaceutical practitioner. There was, however, a total of 37% of patients who suffered (fatality or adverse effects) because of errors in the dispensing of medication.

As displayed in Figure 3, the dispensing error rate in the pharmaceutical sectors that acknowledged dispensing errors is highest in hospital pharmacies (55%) and is closely followed by retail pharmacies at 28%, hospital retail pharmacies at 11%, and medical depots totalling 6%. These results are in line with the findings by Wondmieneh et al. (2020).

Figure 3 shows the different medication dispensing errors in the industry.

As displayed in Figure 3, the highest dispensing error counts among the respondents were medication labelling errors (13%), incorrect prescription dosage/preparation dosage (13%), incorrect prescription (12%), incorrect prescription timing (10%), omission of medication (10%), and pharmacy distractions (10%).

Medication prescription or administration errors account for 61% of serious medical errors that cause or have the potential to cause damage or injury (Malakoane et al. 2020). According to Malakoane et al. (2020), one error occurs for every five prescription items resulting in a potential or real adverse drug event. South African adverse drug events of 37% seem to be well below the international standard; however, this could be because of the lack of reporting of the events. In America, over 41% of citizens have experienced a medication dispensing error at some point in time (Jacobson 2021); this average range of between 1 and 5 also aligns with the South African industry of 39.5%.

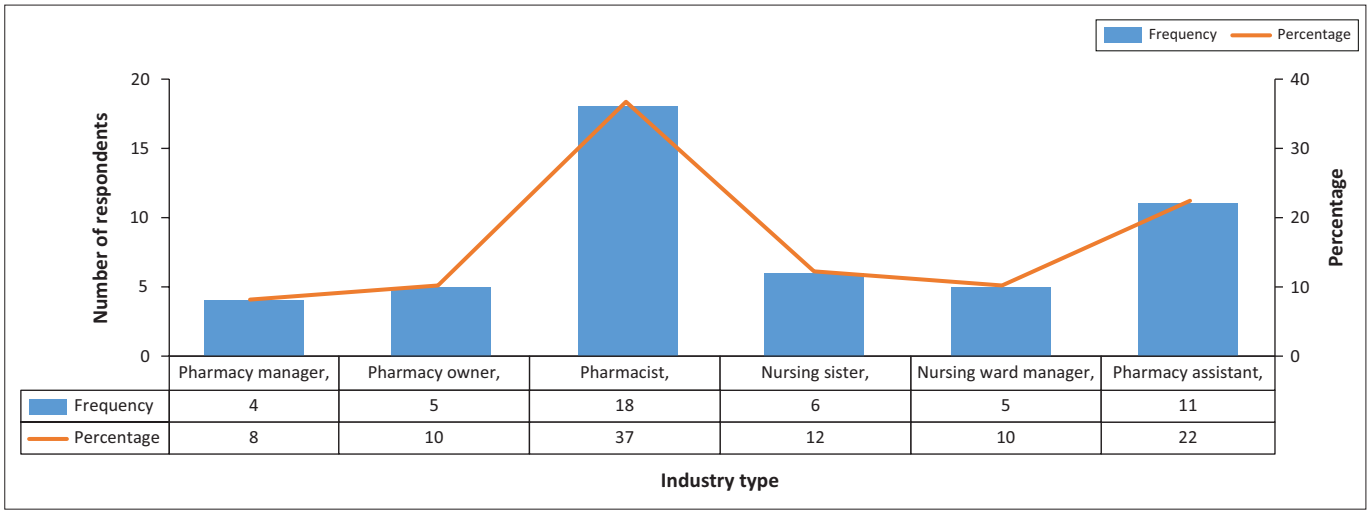


FIGURE 1: Professional qualification.

Medical stock management

Figure 4 shows the disruption in the medical distribution supply chain.

Figure 4 highlights the medical distribution supply chain, which has many factors that cause inefficiencies and frustrations for the end patients when visiting a pharmacy. The most frustrating factor of *out-of-stock medications* was selected by 23% of respondents, followed by *stock control* (25%) and *expired stock* (20%) as the leading cause of customer frustration and pharmaceutical inefficiencies. The other factors namely *delivery timelines* (16%), *alternative generic brands* (17%), and *others* (3%) were also among the frustrations experienced by patients.

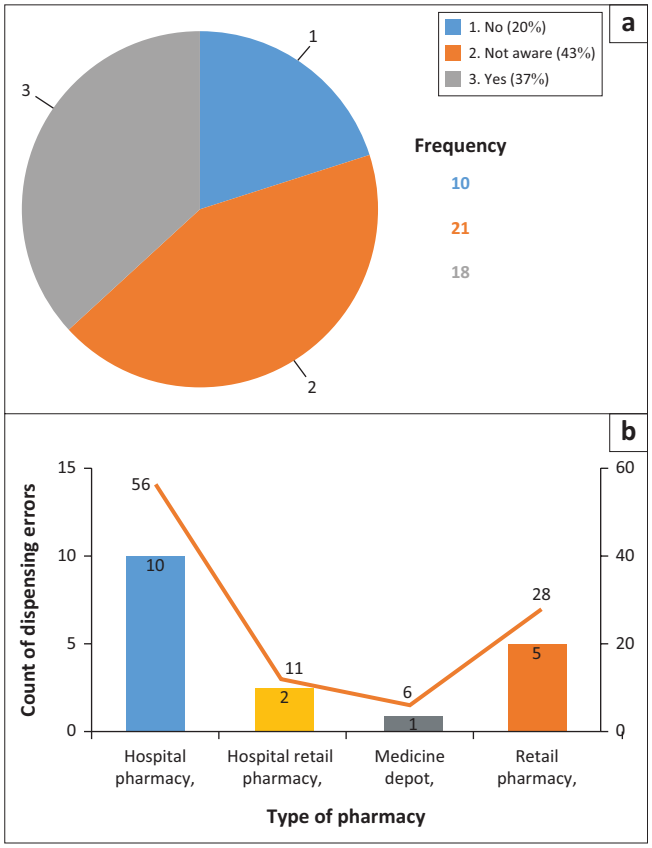


FIGURE 2: Medication dispensing errors that resulted in a patient fatality or serious adverse effects on the patient.

A total of 51% of respondents indicated they had four or more issues related to supply chain management, and 39% of respondents had less than three but more than one issue that frustrated patients. Only 10% of respondents had less than one issue and this correlates to the pharmacies that have implemented automated systems and who have integrated IT capabilities with their suppliers.

The results also showed that the adoption of an automated robotic storage and retrieval medication dispensing solution will improve stock management within the pharmacy. Over 62% and 18% of respondents agreed and strongly agreed respectively with the concept of an automated solution improving medication stock management (stock control and expired medication). The remaining 20% of respondents' opinions were neutral as to whether an automated system would improve stock management in the pharmacy.

A study conducted by the National Center for Biotechnology Information in 2019 indicated that over 10% of patients will be impacted because of incorrect management of stock (Jacobson 2021). Medication errors occur at a rate of 8% – 25% on average during administration (Jacobson 2021). A dispensing mistake occurs in around 1.5% of all prescriptions in the community environment (Jacobson 2021).

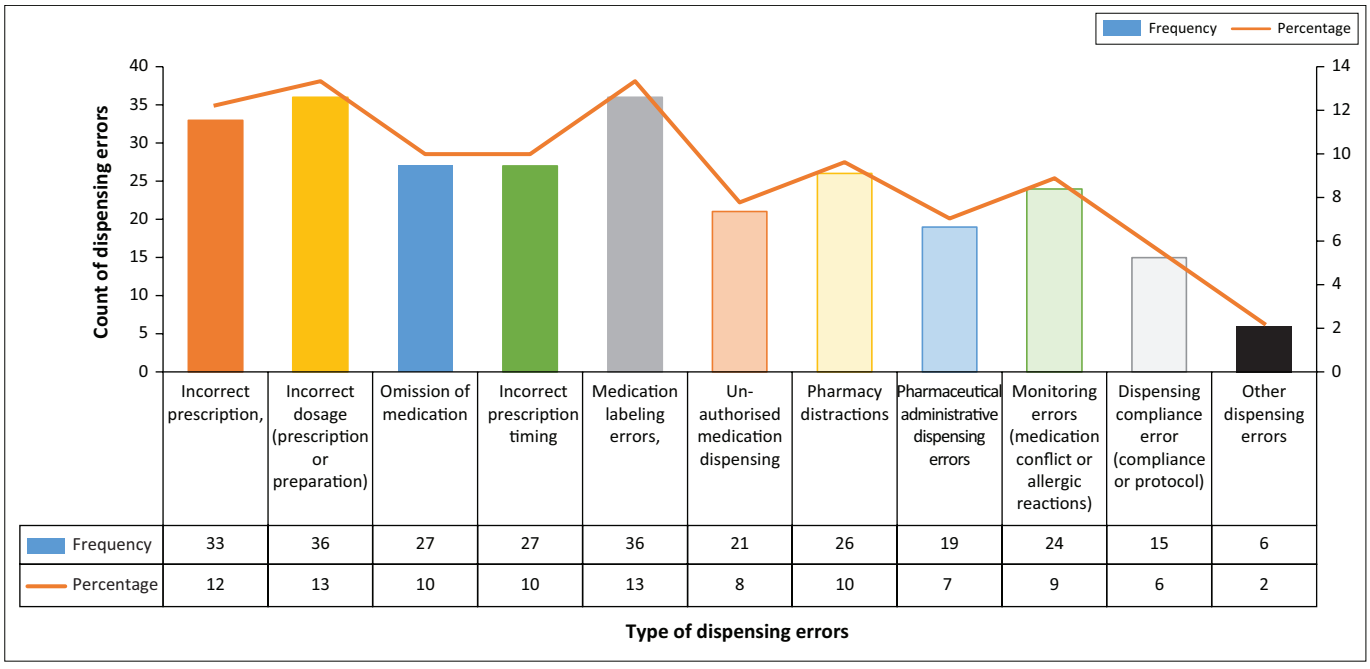


FIGURE 3: Type of medication dispensing errors you are aware of in the industry.

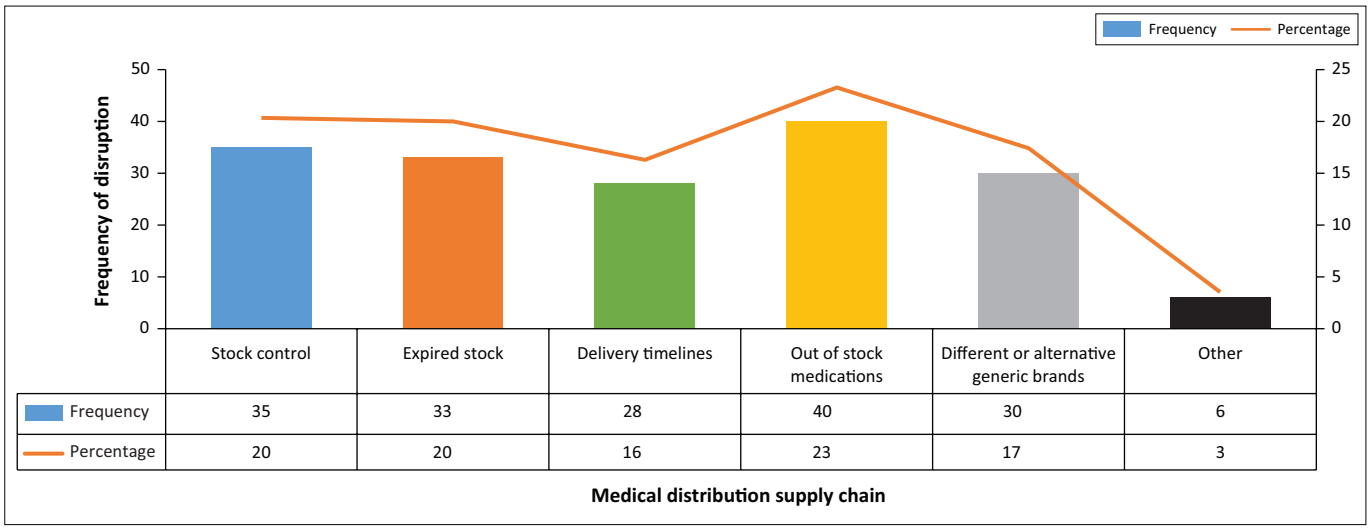


FIGURE 4: Medication distribution supply chain that causes inefficiencies and frustrations for patients at the pharmacy.

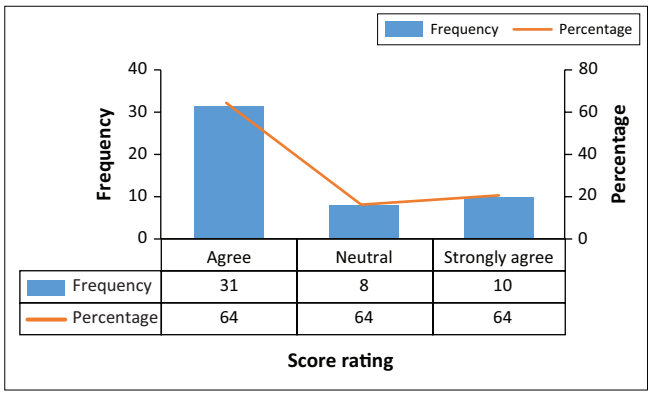


FIGURE 5: Implementation of an automated robotic storage and retrieval medication dispensing solution will reduce dispensing error rates.

As shown in Figure 5, a total of 84% of the respondents indicated that an automated system would reduce dispensing error rates in the pharmacy; however, the alignment of dispensing errors, 3.5% in the South African pharmacy sector is far greater than the international industry of 1.5% of all prescriptions.

Figure 5 highlights the reduction of errors in a pharmacy because of automation.

Further discoveries indicated that 86% of pharmaceutical professionals in the industry admitted to lacking automated robotic storage and retrieval systems for dispensing medications.

A total of 88% of respondents dispensed medication to patients via a manual process and 12% dispensed the medication to patients via an automated robotic storage and retrieval dispensing system.

Pharmacy administration

The surge in demand for real-time inventory tracking, pharmaceutical delivery system automation, and efficient order management underscores the imperative for automated dispensing equipment. This is crucial not only for reducing surplus inventory but also for meeting the timely needs of patients, as highlighted by Rayhan et al. (2022).

Automating dispensing and medication supply operations can significantly enhance the timeliness of drug delivery and administration. As Ahtiainen et al. (2020) point out, automated pharmacy distribution systems play a pivotal role in providing nursing staff with improved access to pharmaceuticals by minimising stock-outs and ensuring the prompt delivery of medications.

Resource management

Figure 6 shows the improvement in productivity levels with the adoption of an automated solution.

Based on Figure 6, 41% of respondents strongly agreed and 49% agreed that the adoption of an automated robotic storage and retrieval medication dispensing system will improve productivity levels within the pharmaceutical environment. The remaining 8% were neutral and 2% of respondents strongly disagreed that it would have little to no effect on productivity improvements, respectively.

The current study's results further showed that pharmacy staff (90%) stated that productivity levels will increase, 82% indicated that costs will reduce and that dispensing of medication will be enhanced with the use of an automated system. These statistics are aligned with previous studies relating to factors to consider when implementing an automated pharmacy distribution system in health services.

Figure 7 shows the reduction of administrative costs with the adoption of an automated solution.

Figure 7 highlights that 33% of respondents strongly agreed and 49% agreed that the adoption and implementation of an automated robotic storage and retrieval medication dispensing system will reduce administrative costs within

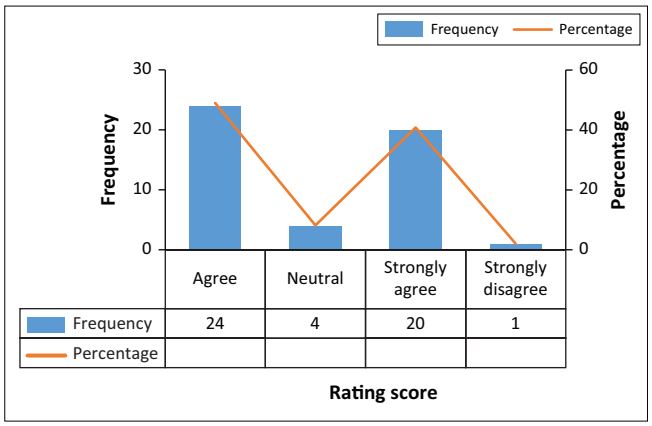


FIGURE 6: Productivity levels of the pharmaceutical staff with the adoption of an automated robotic storage and retrieval medication dispensing solution.

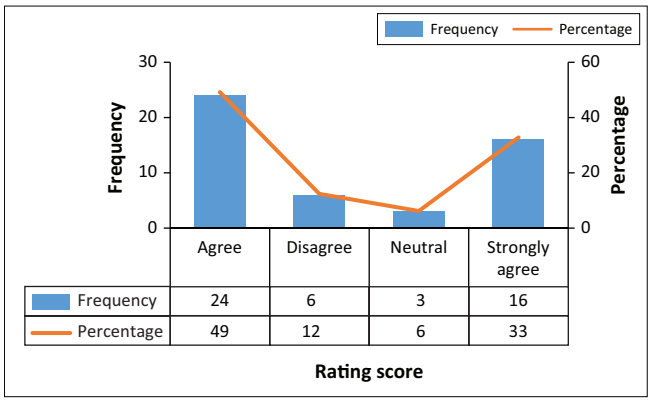


FIGURE 7: Administrative (employee and medication) costs with the adoption of an automated storage and retrieval medication dispensing solution.

the pharmaceutical environment. The remaining 6% of respondents were of a neutral opinion and 12% indicated that it would have minimal effect on productivity improvements in the pharmaceutical environment, respectively.

Conclusion

The study addressed key challenges faced by South African pharmacies, such as cost reduction, inventory management, and employee efficiency, while emphasising the delicate balance between dispensing errors and customer satisfaction. Proposing a solution, the research advocates for the widespread adoption of automatic robotic dispensing systems, highlighting their potential to transform stock management, integrate systems seamlessly, and ensure precise medication dispensing.

Using a quantitative approach, the study collected insights from public and private hospital pharmacy employees to understand their needs and assess potential improvements from adopting integrated IT and automated storage and retrieval systems.

Findings revealed a preference among both retail and private pharmacies for automated systems, citing benefits such as error reduction, cost savings, improved customer service, and enhanced inventory management. The study underscores the crucial role of these systems in minimising medication errors, improving efficiency, and ensuring patient safety.

Significantly, the research emphasises the imperative adoption of integrated IT and robotic automation in the pharmaceutical industry to overcome current challenges, offering actionable insights for industry stakeholders. It also highlights the broader implications for the South African pharmaceutical workforce, urging increased efficiency and competitiveness globally.

The study provided a roadmap for the transformative integration of information technology and robotic automation systems in South African pharmacies, informing future implementation strategies and stressing the need for well-defined policies before implementation. Moreover, the study exhibited a limitation by failing to employ an IT adoption model as a guiding framework for the investigated phenomena. The incorporation of a model to direct the study is imperative and warrants careful consideration in subsequent research endeavours. Notably, the integration of an established IT adoption model, such as the Technology Acceptance Model (TAM) or the Unified Theory of Acceptance and Use of Technology (UTAUT) Model, holds significant potential. The application of these models can systematically identify the pertinent factors influencing the adoption of information technology and robotic automation systems within the pharmaceutical dispensing sector in South Africa. This approach would contribute to a more comprehensive understanding of the dynamics surrounding IT adoption in the context of the study.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

K.M. contributed to this manuscript by writing the manuscript and presenting the findings. R.J. contributed by using his honours research report and findings as the foundation of the manuscript.

Ethical considerations

An application for full ethical approval was made to the University of Eduvos on 12 October 2021. The reference number is IT/01/2021.

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Data availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. It does not necessarily reflect the official policy or position of any affiliated institution, funder, agency, or that of the publisher. The authors are responsible for this article's results, findings, and content.

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