



SWISS BUSINESS SCHOOL

UNIVERSITY OF APPLIED SCIENCES INSTITUTE

Working Paper Series

**KEY SUCCESS FACTORS OF TOTAL LABORATORY AUTOMATION AND THEIR
IMPACT ON THE TURNAROUND TIME OF PATIENT RESULTS IN QATAR**

Aarathy Radhakrishnan

SBS Swiss Business School, Research Scholar

SBS-WP-2024-25

27 December 2025

**SBS SWISS BUSINESS SCHOOL – UNIVERSITY OF APPLIED SCIENCES
INSTITUTE**

WORKING PAPER SERIES

At SBS Swiss Business School – University of Applied Sciences Institute, we believe that managerial success in the 21st Century will be related to the ability to put business knowledge into practice in a way that can be understood and shared by all the stakeholders of the organization.

In order to support this idea and contribute to excellence in management skills, SBS Swiss Business School – University of Applied Science Institute has developed the SBS Working Paper Series.

The purpose of SBS-Working Papers is to create a fast channel for the dissemination of early-stage research findings and ideas from the work-in-progress by professors, lecturers and students at SBS. In addition, provided that there is a co-author with SBS Swiss Business School affiliation, executives, policy makers and administrators in the private and public sectors, strategists, management consultants and others interested in the field of first-class management and postgraduate education are also welcome to submit their work-in-progress to open up further discussion on their topics. SBS Working Papers also aim to promote academic discussion and strategic analysis for practitioners on managing global competition in products and services for all sectors on a worldwide basis.

The SBS Working Papers Series represent a first concrete step towards academic publications. They are not formally peer reviewed; but they are screened for their academic suitability. The findings and ideas presented in the working papers may be improved upon further research by the authors.

The SBS Working Paper Series particularly welcomes conceptual and applied research papers that advance knowledge in the fields of General Business, Human Resources, Marketing and Sales Management, Economics, Finance, International Business, Sustainable Business, Management Information Systems, and Digitalization.

The authors of the working papers are solely responsible for the contents of their work. The views expressed in the papers do not necessarily represent those of SBS Swiss Business School. The material presented in the working papers may be cited or quoted with full indication of source. Submissions should be directed to the Head of Research at SBS, Dr. Erdal Atukeren, at erdal.atukeren@faculty.sbs.edu.

All submissions must comply with the formatting guidelines available at https://jabr.sbs.edu/JABR_SubmissionGuidelines.pdf. References should follow APA Version 7. For further information on policies or manuscript preparation, contact Prof. Dr. Milos Petkovic.

SBS Swiss Business School

Flughafenstrasse 3

8302 Kloten-Zurich

Switzerland

Call us: +41 44 880 00 88

General inquiries: editor@sbs.edu

Working Paper Series Inquiries: editor@sbs.edu

Abstract

The Qatar healthcare laboratories have considerable challenges with regard to effective realization of laboratory automation systems. The positivist philosophy and the quantitative, cross sectional research design used in the study examines the empirical associations of these variables. The research design is the investigation of the key success factors (independent variables) total laboratory automation (mediation variable) and the effect on the turnaround time of patient results (dependent variable) in Qatar. Laboratories, which depend on large automation systems, are highly complex and there are high chances of failures in the system that can considerably discontinue the laboratory activities. The purpose of the study is to identify and analyze the impact of the main success factors on the laboratory performance and turnaround time related to providing patient results. A questionnaire was created to do this, and it was sent to the professionals of the laboratories using email and LinkedIn through Qualtrics. A 7-point Likert scale was used to obtain more than 400 answers in an attempt to obtain valid and reliable data to do further analysis. The focus on EFA in order to recognize underlying factors. The structural model was affirmed by using Confirmatory Factor Analysis (CFA). Structural Research hypotheses and mediation effects were tested by Equation Modelling (SEM). Using Indirect effect, SEM, is the path relationships that are not direct subsidiary to $P1 \times P2$ where $P1$ represents the path coefficient of the path from $\langle \text{human} \rangle$ Indirect effect, SEM, is the relationship paths that were not direct as subsidiaries of $P1 \times P2$ where $P1$ is the path coefficient of the path between. The path coefficient of MV to DV, IV to MV and $P2$, were tested whether they were statistically significant. using the formula $C' = P1 \times P2 + P3$. The findings revealed that there are substantial indirect effects ($p < 0.05$). of six of the six IVs which means that it was the IVs which affected the DV using the MV therefore endorsing partial mediation in five cases on main and case study sample.

Keywords: Laboratory Automation, Turnaround time, Laboratory workflow, Pre-analytical, and Specimen transportation.

Introduction

A medical lab is a place that examines human clinical samples to find details concerning the well-being of a patient and contribute to managing an illness like its avoidance, diagnosis and therapy. At this point in time, a significant number of laboratories have adopted total laboratory automation (TLA), whereby numerical everyday procedure and part of the job work has been automated by robots which lowers the prices of medical testing. Nevertheless, TLA has its merits on the one hand and downsides on the other. The advantages of TLA are minimization of human error in the process of managing clinical specimens, enhancement of the overall control over the process, and minimization of turnaround times (TAT) of the results of the specimen. It has been intensively proven that automation brings not only better quality, faster time, and a stronger ability of specific labs but also increasing profitability (Genzen, et al., 2018). A laboratory specimen tracking system is a sophisticated integrated tool that builds a paradigm shift in regard to sample management and automated tracking of the sample along its life cycle. It also assists in the effective communication between the different departments and employees that were a part of the testing workflow. Nevertheless, the lack of appropriate systems to track the specimens can lead to specimen loss or mislabeling, potentially affecting patient care in a harmful way, delaying diagnoses, and increasing healthcare expenses. The practice of losing a specimen once they have been collected can result in life-threatening effects when applied to patients (Le, et al., 2023).

The high possibility of loss of specimens can be significantly minimized by implementing stringent protocol and a culture of accuracy and responsibility. The proposed research will determine the major success aspects of total laboratory automation (TLA) and reveal the gaps in the current specimen tracking system. Sediment collection, transportation,

storage, and informing of the specimens can be greatly reduced with the introduction of standard protocols, which will reduce the risks of losing specimens greatly. Also, it is necessary to cultivate such culture of accountability, attention to detail and continuous quality improvement among the laboratory personnel that will make sure that the integrity and traceability of the specimens throughout the entire testing process are ensured. The automation systems used in laboratories are their best in proving efficiency, accuracy, and productivity though they are faced with complexities in cost, complexity, and maintenance. These factors are very important to the consideration of automation in the laboratories. The merits and demerits of implementing TLA in healthcare settings are listed in Table 1 below.

Table 1: Merits and Demerits of Laboratory Automation.

Source: (Author, 2024)

Merits of TLA	Demerits of TLA
Lower costs in the long-term	Higher cost on initial phase
Decreased congestion in work area	Higher space requirement
Improves testing efficiency	Increased cost for supplies
Improves TAT	Increases noise and heat generation
Improves sample management	Increased risk of downtime
Enhances standardization	Psychological dependence on automation
Minimizes manual error	Reduces staff knowledge of manual procedure
Improves quality of testing	Difficulty managing down-time
Minimizes biological risk for staff	Manufacturer-driven laboratory
Increasing staff job satisfaction	High maintenance cost

Research Objectives

The main goals of this work are to determine the key success factors of total lab automation, to determine gaps in automated systems of specimen-tracking in medical lab settings, and to investigate the effects of automation on operations of labs, which places strong stress on the appropriate implementation of robotics and tracking processes. The objectives of the current research are the following.

- To investigate the effect of the major success factors of LAS implementation on patient results turnaround time.
- To determine the impact of key success factors on the effectiveness of laboratory automation systems.
- To examine whether the laboratory automation system serves as an intermediary between the key success factors and the turnaround time of patient results.

Literature Review

The literature review considers and finds various best key success factor (KSF) strategies and models that enable successful automation of labs and provision of timely patient results. There are several articles and journals found in this field of study. In this research paper, some key investigations that have been conducted across different countries on the success of TLA and its critical factors of success have been highlighted. In that regard, successful total automation of laboratory performance requires a syncretic combination of factors, such as experience of work force, recruitment and training of staff along with their skills and experience, quality of equipment, finances, management support and policies, and integration of technologies. Focusing on these aspects, the medical laboratories can be at a position to achieve long-term success in a very challenging environment.

The issue was extensively researched through several web-based databases, including Google Scholar, Scopus, Web of Science, and ScienceDirect. The search key words were as follows: Key Success Factors, Laboratory Automation System, Turnaround time, Laboratory Path of Workflow, Specimen Tracking System, and Patient Test Results. The search was limited to peer-reviewed journal articles published in English between the years 2000 to 2024, but two of the articles from 1975 and 1975 were also found to be similar and reviewed for this study. A total of 87 articles were reviewed, out of which over 23 articles were selected for this literature review based on their relevance to the research topic.

Table 2: Overview of Literature Study.

Source: (Author, 2024)

Author, Year	Topic of Study	Conclusion/Outcome
Gurevitch, 2004	Economic Justification of Laboratory Automation	Islands of automation system
Balis & Pantanowitz, 2012	Specimen tracking and identification systems	RFID and Barcode
Seaberg, Stallone, & Statland, 2000	The Role of Total Laboratory Automation in a Consolidated Laboratory Network.	Automation system saves cost
Nam & Ying, 2020	Pre-analytical pitfalls: Missing & mislabeled specimen	RFID and Barcode, Specimen inventory
Pollock, 2018	Benefits of implementing STS in anatomic pathology	Implement STS
Genzen, et al., 2018	Challenges and opportunities of total laboratory automation (TLA)	Automation & its demerits

Author, Year	Topic of Study	Conclusion/Outcome
Rasanen, 2024	Specimen tracking system: Tracking samples helps reduce misdiagnosis	Barcoded STS
Muriithi, 2020	Laboratory test tracking	Good STS

The preceding literature review shows that numerous studies have explored specimen tracking systems and process optimization by adopting advanced technologies. Nonetheless, most of these works primarily emphasize automated systems and RFID solutions aimed at reducing staff workload. Research studies were not found that identified gaps in the specimen tracking system, its practical processes, and quality improvement in the STS. That is why this research focuses on identifying gaps and process improvement.

Comparative Analysis of Literature Studies

From the comparison of studies on laboratory, as shown in Figure 1, out of 23 articles listed, ten were from the USA, five from Italy, and one each from Australia, Germany, Japan, Singapore, and Ireland. For three of the studies, the location was not mentioned.

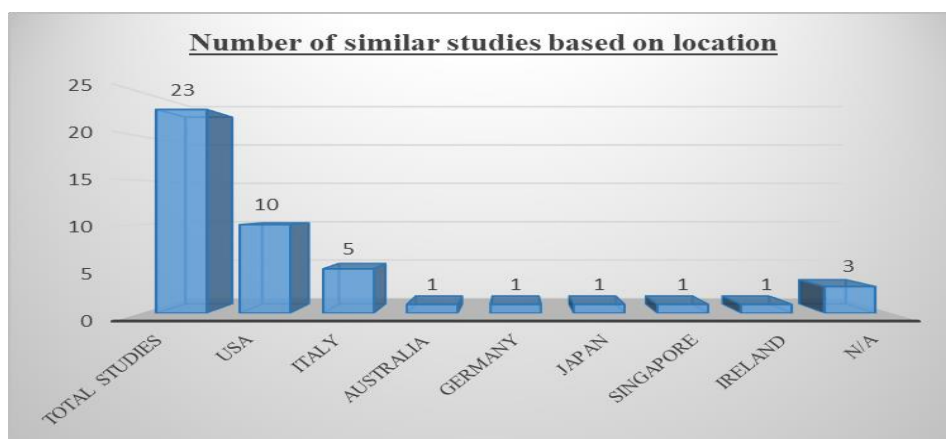


Figure 1 : Number of Similar Studies Based on Location.

Source: (Author, 2024)

The study period ranges from 1969 to 2024, as shown in Figure 2.

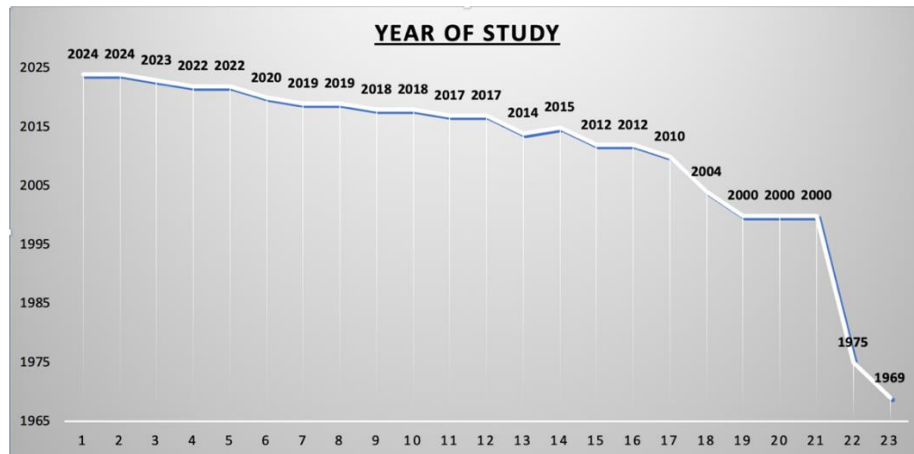


Figure 2 : Year Range of Similar Studies.

Source: (Author, 2024)

After analyzing the research topic, it was noted that 20 out of 23 studies were directly related to the laboratory automation system with only the other 3 studies indirectly related to the research topic. The researcher also indicated that within the 23 papers turnaround time was measured in 10 papers and costs in 12 that included equipment, labor, labelling, space renovation, and testing expenses. A significant number of the articles are based on case studies in healthcare facilities; the other five articles are considered as a guide in planning the automation by the laboratories; the three articles are featured.

To sum up, an outline of a comparison of the studies demonstrates that the success factors, the barriers as well as the outcomes of automation implementation into the laboratory environment have been diverse in different countries and, in different eras of time. Although there are studies showing better turnaround time, cost-effectiveness and safety of the staff, others express issues like their initial high cost, technical failures, and longer turnaround time. More work and standardization work could be required to eliminate these discrepancies and to maximize the advantages of laboratory automation. The gaps of the research are determined to

develop research objectives and research questions of future studies. The gaps in the research found based on the literature studies above are recorded into a list as indicated in Table 3.

Table 3 : Research Gaps Identified in the Study

Source: (Author, 2024)

Gap No.	Research Gap	Reference
Gap 1	Limited research exists on the relationship between technology integration and laboratory automation system in laboratory automation, particularly within the context of Qatar's healthcare sector.	Rupp, Ries, Wienbruch, & Zuchner, 2023. Kim, Lee, Kim, & Lee, 2022.
Gap 2	The research studies are missing the investigation of the influence of the staff education and skills on the effective utilization of automated laboratory systems in developing economies such as Qatar.	Genzen, et al., 2018.
Gap 3	The effects of workflow efficiency on the utilization of laboratory automation systems remain underexplored, with limited studies addressing this relationship in the context of healthcare settings within Qatar.	Rasanen, 2024. Zachary, Tijerina, & Joligon, 2020. Pollock, 2018. Lam & Jacob, 2012. Markin & Whalen, 2000.
Gap 4	Existing literature lacks comprehensive analysis of the impact of equipment quality on the performance and utilization of laboratory automation in Qatar's healthcare laboratories.	Lippi & Rin, 2019. Norgan, et al., 2020.
Gap 5	The role of management support and policies in facilitating successful laboratory automation implementation is insufficiently	Kay, Ploetzener, & Gritter, 1975. Nelson, 1969.

Gap No.	Research Gap	Reference
	studied, particularly in the healthcare context of Qatar.	
Gap 6	The effects of workflow efficiency on the use of laboratory automation systems remain under-explored, and limited studies have covered the same in relation to the healthcare settings in Qatar.	Angeletti, 2015. Gurevitch, 2004. Seaberg, Stallone, & Statland, 2000.
Gap 7	Very little is known about how the relationship between key success factors and the turnaround time of patient results mediates through the laboratory automation system, particularly in Qatari healthcare laboratories.	Pilkington, 2022. Ialongo, Porzio, Giambini, & Bernardini, 2016. Choi, 2012. Young, 2000.
Gap 8	There are not many empirically supported studies that offer practical recommendations on how to enhance total laboratory automation in Qatar, which inherently indicates insufficient practical advice to be given to healthcare managers and policymakers.	Angeletti, 2015. Zaninotto & Plebani, 2010.

Summary of Literature Review

Modern clinical laboratories have drastically used automation in the last couple of years, leading to an improvement in quality of service delivered to the patients, as well as heightened safety of the staff, which several recently published study instances demonstrate, see studies by (Archetti, et al., 2017). It is considered that the key to this desired outcome, the goal of having maximum efficiency and being strategically placed in the future, lies in automation which, together with consolidation and integration is the key prerequisite (Zaninotto & Plebani,

2010). This goal does not however guarantee the quality or even the analytical reliability of a laboratory. In the current times, due to the increasing workload, the pressure to cut costs, and the difficulty to find qualified technical staff, the laboratories are increasingly putting pressure to automate their operations (Lam & Jacob, 2012). Automation is achieved in reaching the desired high efficiency in the laboratory. Full automation affects the lab as it allows managing lab work more efficiently and smoothly. LAS is in the development process and can also benefit patients, doctors, and other healthcare practitioners by boosting TAT and providing throughput consistency (Markin & Whalen, 2000).

However, there are also potential drawbacks to developing a TLA model. These include increased initial costs, increased supply costs, space and infrastructure requirements, staff overcrowding, increased noise and heat generation, increased risk of downtime, psychological dependence, critical issues for managing biospecimens, disruption of staff trained in specific technologies, and the possibility of moving toward a manufacturer-driven laboratory (Lippi & Rin, 2019). There is no denying that laboratory automation improves quality, saves time, increases throughput, and lessens staff workloads in the bioanalytical industry. But only if it is established successfully.

Methodology

The research methodology is explained using the research onion model (Saunders, Lewis, & Thornhill, 2019) as shown in Table 4. Data was also obtained from the survey questionnaire.

Table 4 : Research Methodology.

Source: (Author, 2024).

Section	Methodology	Method
1	Research Philosophy	Positivism
2	Research Approach	Deductive

3	Research Strategies	Survey Questionnaire
4	Research Choices	Quantitative
5	Research Time Horizon	Cross Sectional
6	Research Techniques	Data Collection and Analysis

Research Problem Definition

TLA in health care laboratories is a great way to come up with a better patient outcome turnaround time. However, the process of introducing TLA is a complicated task, which, in many cases, results in inefficient work in the laboratory and barriers that can postpone the receipt of results up to unexpected levels. The implementation of TLA will be successful when a number of important factors are met, such as energy-efficiency in the integration of technology, provision of quality and qualified staff, streamline workflow, quality equipment and good management support. These are not necessarily optimized factors in the implementation process. As a result, laboratories find it challenging to realize the desirable outcomes of TLA especially in provision of patient results in a timely manner.

Research Paradigm

The given study used a positivist research design with an aim to objectively determine the correlation between the key success factors (KSFs) of TLA and the turnaround time (TAT) of patient results. The paradigm was the positivist one since the study adhere to a quantitative design, which puts more focus on empirical evidence and statistical research to explain the underlying patterns and relationships.

Research Approach

The study has utilized a quantitative design whereby the numerical data was gathered, and the analysis was conducted by Structural Equation Modeling (SEM), a key approach employed to study the complex interconnection among the variables. SEM enabled testing several

hypotheses at a go and in addition to that, it was able to test direct and indirect effects in the theoretical framework that was developed in this study. It is deductive approach because it entails testing formulated hypotheses.

Data Collection Instrument

The questionnaire was administered to 33 items on a seven-point Likert scale to gather feedback on the experiences with laboratory automation across the board of laboratory professionals who were surveyed by the researcher. It has also been found that the seven-point Likert questions are more precise, easier to use, and more realistic to evaluate how a respondent will respond (Finstad, 2010).

Questionnaire Item Development

In order to come up with the questionnaire items, the pertinent passages in the extant literature were masterfully modified to suit the specific purposes. This made the survey questions based on pre-existing research as well as relevant to the context of the study. The adaptation process entailed improving the wording and formulation of the items by increasing the clarity, relevancy and applicability to the targeted respondents (Hinkin, Tracey, & Enz, 1997). A structured questionnaire helped the researcher collect the necessary information involving the staff and managers in one of the healthcare laboratories in Qatar. The questionnaire was structured to gauge the success factors that are vital in TLA and Laboratory Automation System, and the turnaround time of patient results. The items to determine the perception and experience of respondents had seven-point Likert scale items that made it possible to quantify variables.

Ethical Considerations

This study strictly adhered to research ethics in conducting a study that involved the use of human subjects. There was informed consent of all participants after the assurance that their

participation was voluntary, and that they could not disclose their answers. They also received the information that they could pull out of the study whenever they wished. Anonymity of participants and their confidentiality was preserved, no pictures of participants were taken.

The participants were promised that they were not pressurized into participating in the study and that their participation or non-participation would not be used to influence their job in any respect. The questionnaire was formulated very well to avoid sensitive questions that touched on gender, race, or religion.

Pilot Study

The pilot study will entail a small-scale data gathering to determine the viability of the processes, to approximate the time required to proceed through the questionnaire as well as to examine logistics involved in the actual conduction of the main study. These research projects aid in determining design flaws, evaluate the feasibility and practicality of the study, and calculate the overheads in the form of costs and time and proceed with the actual study (Creswell & Creswell, 2017). The pilot study was done on a small sample of the target population (29 respondents). This was a small number of respondents who did not belong to the main study.

Main Study

The primary research encompassed collection and analysis of data that was based on descriptive statistics, analyses of confirmative and exploratory factors, nonparametric tests and structural equation modeling. According to the published literature on factor analysis, the minimum sample required to be used in the analysis of factors is a minimum of 200 (MacCallum, Widaman, Preacher, & Hong, 2001). The sample size was determined on a large population, as per the formula: $n = \frac{Z^2 * p(1-p)}{M^2}$

Results

The SEM techniques were utilized to analyze quantitative data collected with the help of the questionnaire. To start with, the data were entered into the Statistical Package of Social Sciences, version 21 (SPSS v21) to have them processed preliminarily. SEM analysis was consequently performed with Software Analysis of Moment Structures, version 21 (AMOS v21) to approximate complicated relationships among observed variables and latent constructs. This approach produced additional insights of how key success factors influence turnaround times of patient results, where Laboratory Automation System is used as a mediating variable to both positive and negative influences.

Exploratory Factor Analysis

To reveal the underlying factors in the questionnaire structure, the Exploratory Factor Analysis (EFA) was performed to determine the underlying factors. The first approach was to perform a Kaiser-Meyer-Olkin (KMO) test and determine that it had to be greater than 0.80 (Kaiser, 1974) and then to perform a Bartlett's test of sphericity in finding out whether the correlation matrix was the right one to factor or not and in case it was it was less than 0.05 on testing the correlation matrix (Bartlett, 1950). It was then subjected to factor analysis by using Principal Component Analysis (PCA) to ensure the factors extracted were equal to the number of constructs intended, which is endorsed by Scree plot. A varimax rotation was used in order to obtain the most appropriate factor structure. The outcome groupings of factors were then employed in measuring convergent and divergent constructs. Convergent validity proved to be satisfactory when the Average Variance Extracted (AVE) value was greater than 0.50, and the Composite Reliability (CR) value was more than 0.70. Discriminant validity was determined to ensure that all the constructs have strong loadings to the indicators and low loadings to the other constructs.

Confirmatory Factor Analysis

CFA is used in situations where the latent variables are not directly measurable but rather estimated based on an agreed number of measured indicators which include questionnaire items. It is applied to determine whether these observed variables are sufficient to measure target constructs that are meant to be measured. In addition, CFA is used to determine the relationship between the observed variables (survey items) and the latent variable to determine its acceptability through estimation of the factor loadings.

And finally, it evaluated goodness-of-fit of the measurement models with the help of often used fit indices, which include the Chi-square statistic, the Root Mean Square Error of Approximation (RMSEA) and the Comparative Fit Index (CFI) (Uedufy, 2022).

Structural Equation Modelling

The hypotheses of the study were formulated and tested based on the theoretical framework as it was developed based on the literature review. Structural Equation Model (SEM) was identified by proper model identification methods (Chin, et al., 2020), its parameters were estimated by the use of SPSS-AMOS v21. Goodness-of-fit was checked by using the existing fit indices (Uedufy, 2022).

The presence of the Mediator (M) in which there is a direct association between the dependent variable and an independent variable is referred to as a direct effect. Indirect effect illustrates the connection of the independent variables and the affected dependent variable that is adopted via the mediator. An indirect effect is thus determined by looking at the product of the individual paths that form a specific effect and the magnitude of the effect is a good measure of the mediation amount that is achieved through the mediator variables in question.

Intraclass Correlation

Intraclass correlation was also used to determine the reliability of the raw data of respondents. To establish the consistency of the responses among groups, an Intraclass Correlation Coefficient (ICC) was estimated. This method is used to analyze whether the respondents are consistent in their ratings, i.e. whether the respondents favor to give the same high or low ratings to similar subjects. Intraclass Correlation (ICC) analysis was done in order to evaluate the reliability of group-based measurements. The scale had an overall ICC of 0.955 describing an optimal level of reliability.

Summary of Hypothesis Tests for Main Study

A summary of the hypothesis results is presented in table 5. The results suggest that all the areas crucial to success such as technology integration, staff training and expertise, workflow efficiency, quality of equipment, management support and policies and financial impact played a significant role in influencing TAT and LAS except the quality of equipment and financial impact that did not influence LAS significantly. Moreover, all the key success factors had a complete mediating role between LAS and TAT, except the management support and policies.

Table 5 : Summary of Hypothesis Tests for Main Study.

Source: (Author, 2024)

Hypotheses	Path	Significance	
H1	TAT<---TI	Sig	
H2	TAT<---ST	Sig	
H3	TAT<---WE	Sig	
H4	TAT<---QE	Sig	
H5	TAT<---MS	Sig	
H6	TAT<---FI	Sig	

Hypotheses	Path	Significance	
H7	LAS<---TI	Sig	
H8	LAS<---ST	Sig	
H9	LAS<---WE	Sig	
H10	LAS<---QE	Not Sig	
H11	LAS<---MS	Sig	
H12	LAS<---FI	Not Sig	
Hypotheses	Path	Significance	
H13	TAT<---LAS	Sig	
Hypotheses	Path	Significance	Mediation
H13_1	TI>LAS>TAT	Sig	Indirect Only (Full Mediation)
H13_2	ST>LAS>TAT	Sig	Indirect Only (Full Mediation)
H13_3	WE>LAS>TAT	Sig	Indirect Only (Full Mediation)
H13_4	QE>LAS>TAT	Sig	Indirect Only (Full Mediation)
H13_5	MS>LAS>TAT	Not Sig	No Effect (Non-Mediation)
H13_6	FI>LAS>TAT	Sig	Indirect Only (Full Mediation)

Case Study

This case study is used to confirm the findings of the main study within a confirmatory research framework. Although the main study produced strong conclusions, the case study is intended to test the generalizability of these results using a smaller sample. The research approach involved comparing key factors from both the main study and the case study that influence patient turnaround time. In the case study, the research identifies which factors are critical to the mediation effects as completed in the main study.

The main study was conducted on a large population, with a sample size of 400 respondents. In the case study, a small group of respondents unrelated to those in the main study was evaluated to assess whether the same model held. Thus, mediation effects were constructed for the case study and compared with those of the main study.

Comparison of the Main Study and Case Study

A detailed comparison of the findings from the main study and the case study was conducted, focusing on the mediation results across the two datasets, since mediation analysis is pivotal to this study and is shown in Table 6.

Table 6 : Comparison of Hypothesis Test Findings.

Source: (SPSS, v 21).

Path	Main	Case	Consistent Finding
TI>LAS>TAT	Significant	Significant	Yes
ST>LAS>TAT	Significant	Significant	Yes
WE>LAS>TAT	Significant	Significant	Yes
QE>LAS>TAT	Significant	Significant	Yes
MS>LAS>TAT	Not Significant	Not Significant	Yes
FI>LAS>TAT	Significant	Significant	Yes
TAT<---LAS	Significant	Significant	Yes

Comparison of Main Study and Case Study Outcomes

The comparison evaluated whether the proposed mediating relationships were supported in both studies, thereby testing the strength and generalizability of the theoretical model, as shown in Table 7.

Table 7: Comparison of Main Study and Case Study Outcomes.

Source: (SPSS, v 21).

No	Hypothesis	Main Study	Case Study	Comments
Med	H013: The laboratory automation system has no significant impact on the turnaround time of patient results.			
	Ha13: The laboratory automation system has a significant impact on the turnaround time of patient results.	Sig	Sig	Mediation
1	H013_1: Technology integration, while mediated through the laboratory automation system, has no significant impact on the turnaround time of patient results.			
	Ha13_1: Technology integration, while mediated through the laboratory automation system, has a significant impact on the turnaround time of patient results.	Sig	Sig	Mediation
2	H013_2: Staff training and expertise, while mediated through the laboratory automation system, have no significant effect on the turnaround time of patient results.			
	Ha13_2: Staff training and expertise, while mediated through the laboratory automation system, have a significant effect on the turnaround time of patient results.	Sig	Sig	Mediation
3	H013_3: The workflow efficiency, while mediated through the laboratory automation system, has no significant effect on the turnaround time of patient results.			
	Ha13_3: The workflow efficiency, while mediated through the laboratory automation system, has a	Sig	Sig	Mediation

No	Hypothesis	Main Study	Case Study	Comments
	significant effect on the turnaround time of patient results.			
4	H _{013_4} : The quality of equipment, while mediated through the laboratory automation system, has no significant effect on the turnaround time of patient results.			
	H _{a13_4} : The quality of equipment, while mediated through the laboratory automation system, has a significant effect on the turnaround time of patient results.	Sig	Sig	Mediation
5	H _{013_5} : The management support and policies, while mediated through the laboratory automation system, have no significant effect on the turnaround time of patient results.	Not Sig	Not Sig	Non-Mediation
	H _{a13_5} : The management support and policies, while mediated through the laboratory automation system, have a significant effect on the turnaround time of patient results.			
6	H _{013_6} : The financial impact, while mediated through the laboratory automation system, has no significant effect on the turnaround time of patient results.			
	H _{a13_6} : The financial impact, while mediated through the laboratory automation system, has a significant effect on the turnaround time of patient results.	Sig	Sig	Mediation

Given this dual confirmation of the findings, management support does not appear to function as a mediating factor. Alternatively, this may be interpreted as an indication that management support is insufficient to improve the turnaround time for patient results.

Discussion of Comparison of Main and Case Study

The mediation effects in the main study (n = 400) and the case study (n = 80) were found to be very consistent, which further supports the validity of the strength of the research model under the different conditions of classes in the sample. Structural equation modeling in both studies confirmed mediation hypothesis of the five key success variables out of the six. This is to affirm that the directions of the independent variables to the dependent variable (patient turnaround time) are stable via the mediator variable (laboratory automation system). The non-mediation for one key success factor (management support and policies) was consistently observed in both the main study and the case study. This suggests that the lack of mediation for this factor is not due to sample variability or external influences, but to the factor itself.

Management support and policies were not perceived by respondents in both the main study and the case study to mediate the turnaround time for patient results. This consideration is also discussed in the section for future work. The findings of the study contribute to the body of knowledge by validating the model's pathways, and the dual study strengthens the understanding of the key success factors.

Conclusions

The findings indicate that the main study results were successfully reproduced in the case study, thereby supporting the generalizability of the primary study's conclusions. The case study confirmed a high degree of reproducibility of the main study, with only minor variations, likely due to differences in sample size and characteristics of the sampled population. Hence, it must be noted that the respondents in the case study were not part of the main study. The case study results confirmed the results of the primary study and made empirical evidence of the model generalization.

As indicated in the case study, the observed relationships between independent variables, mediators and the dependent variables in main study were also found in the smaller case study. Following the confirmation of the unidirectionality and recursive properties of the structural equation model, the data on the case study was re-estimated. The case study conditions have the important paths that are found to exist within the main study. The case study was a cross-validation instrument by using the same model and approach.

The recursive model was consistent with the findings of the main study although the sample size used in the case study was smaller. The two studies had similar results in terms of path coefficients, significant level of results, and mediation results, but some statistical power could be lost. Therefore, the stability of the relationships is a testimony that the findings of the main study can be replicated in the case study.

This study has a significant contribution to the knowledge of the interplay between six independent and one mediator and a dependent variable to develop patient result turnaround time. The literature review conducted was extensive, and it helped reveal existing gaps that were further informative in formulating research hypotheses. These hypotheses were tested by a specially created Likert-scale questionnaire, and the data obtained were analyzed based on the structural equation modeling. The results have highlighted the importance of the essential variables under analysis. The high reliability of the findings was an indication that the theoretical model formulated in this study was effective. The study contributes to the existing literature by giving empirical evidence on the proposed busybodies mediation model. It also provided recommendations, which highlight the critical success factors. This means that the study can be useful in theoretical concepts, as well as practical recommendations to stakeholders in the field of automation of labs that are interested in reducing the turnaround time of patient results.

Contribution to Knowledge

The proposed study makes new contributions that can fill critical gaps in literature especially in the association among independent variables (IVs), mediators (MVs), and dependent variables (DVs) in the setting of laboratory automation. The present research enhanced the knowledge of the role played by mediation in the dynamics of the laboratory automation systems and subsequently patient result turnaround time.

The study has contributed to the body of knowledge in the indirect effects that can operate through the mediating variables by analyzing the translatability of the mediation pathways in various key success factors. The main sample in this study had a large sample size whereas the case study had a small sample size. Conducting such a study design is a new methodological procedure of testing the strength of structural equation modeling (SEM) in various settings. The comparative approach offers a distinctive evaluation of stability of the model despite large sample size variations.

This study represented a very strict empirical procedure, such as the organizational collection of data, elimination of outliers, controlled test of centrality, descriptive statistics, identification of factors, convergent and divergent validity assessment before using SEM. The research reinforced the empirical data of the external validity of theoretical model by demonstrating that the main study findings were almost replicated in the case study.

Research Implications

The results of the current research have few implications which provide a basis that the research is supposed to be applied, whether in academics or in practice. The present study provides new insights that expand the existing knowledge about the role played by key success factors in determining how lateral automation systems mediate the relationships between key success factors and the turnaround time of patient results. The gaps in research that have been

identified in this case were the main focus of the study, and their addressing has produced new knowledge in this field. Another contribution of the study is a systematic implementation of the structural equation modelling and how data may be collected, examined, and evaluated. It offers a procedural process of data collection, analysis, measurement and modelling that could be replicated or modified in future studies.

Recommendations

The organization that collaborates with the study should use the findings of this study to improve its strategic decision-making activities. It is through the identification and exploitation of mediation effects that the organization can come up with specific interventions to enhance the turnaround time of patient results and record more positive results. The proposed approach and results may assist them in formulating frameworks that facilitate the culture of making data-driven decisions. Elucidating the major topics of success and the intermediation of the turnaround time can also be the foundation of predictive models that can inspire operational and strategic programs on critically mediating variables.

Future Work

Despite the fact that close consideration was done to the degrees of freedom when compared to the number of samples, a large sample is further to increase the level of statistical accuracy and reproducibility. Since one of the mediation effects (management support and policies) noted in the main study was not established in the case study, future investigation would be the reasons behind the non-occurrence of the effect. Further analysis of the possible reasons for such discrepancy can provide important information.

Limitations of the Study

The research involved six independent variables, a mediator and one dependent variable. The constraint is that the number of independent variables that were studied is low i.e., there are other possible variables that it would be important to consider in the analysis. The other variables that can be considered are perceived usefulness, trust in technology, and user experience. The study was conducted in a particular industry, namely, laboratories employing laboratory automation. Therefore, in this research, the findings can only be generalized to the similar industries. The geographical area covered by the study was restricted to Qatar. Therefore, the results might not be extrapolated to other geographic locations that differ in terms of their cultural, economic and social realities.

References

- Angeletti, e. a. (2015). Laboratory Automation and Intro-Laboratory Turnaround Time: Experience. *University Hospital Campus Bio-Medico of Rome*.
- Archetti, C., Montanelli, A., Garrafa, E., Finazzi, D., & Caimi, L. (2017, April). Clinical Laboratory Automation: A Case Study. *Journal of Public Health Research*, 2017;6(1), 6(1), 31-36. doi:<https://doi.org/10.4081/jphr.2017.881>
- Balis, U. J., & Pantanowitz, L. (2012, January). Specimen tracking and identification systems. *Pathology informatics: theory and practice*, 283-304. doi:https://www.researchgate.net/publication/281168473_Specimen_tracking_and_identification_systems
- Bartlett, M. S. (1950). Tests of Significance in Factor Analysis. *British Journal of Statistical Psychology*, 3(2), 77-85.
- Chin, W., Cheah, J. H., Liu, Y., Ting, H., Lim, X. J., & Cham, T. H. (2020). Demystifying the role of causal-predictive modeling using partial least squares structural equation modeling in information systems research. *Industrial Management & Data Systems*, 2161-2209.
- Choi, A. (2012). Comprehensive Outlook on Global Laboratory Automation Market. *AZoRobotics*. doi:<https://www.azorobotics.com/News.aspx?newsID=2416>
- Creswell, J. W., & Creswell, J. D. (2017). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publications.
- Finstad, K. (2010). *Response Interpolation and Scale Sensitivity: Evidence Against 5-Point Scales* (Vol. 5). Not mentioned: Journal of User Experience. Retrieved from <https://uxpajournal.org/response-interpolation-and-scale-sensitivity-evidence-against-5-point-scales/>
- Fornell, C. G., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39-50.
- Genzen, J. R., Burnham, C.-A. D., Felder, R. A., Hawker, C. D., Lippi, G., & Palmer, O. M. (2018, February). Challenges and Opportunities in Implementing Total Laboratory Automation. *Clinical Chemistry*, 64(2), 259-264. doi:10.1373/clinchem.2017.274068

- Gurevitch, D. (2004). Economic Justification of Laboratory Automation. *Journal of Laboratory Automation*, 9(1), 33-43. doi:10.1016/s1535-5535-03-00086-8
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science*, 43, 115-135.
- Hertzog, M. A. (2008). Considerations in determining sample size for pilot studies. *Research in Nursing & Health*, 31(2), 180-191.
- Hinkin, T. R., Tracey, J. B., & Enz, C. A. (1997). Scale construction: Developing reliable and valid measurement instruments. *Journal of Hospitality & Tourism Research*, 21(1), 100-120.
- Ialongo, C., Porzio, O., Giambini, I., & Bernardini, S. (2016). Total Automation for the Core Laboratory. *Journal of Laboratory Automation*, 21(3), 451–458. doi:10.1177/2211068215581488
- Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, 39(1), 31-36.
- Kay, R. H., Ploetzener, H. D., & Gritter, R. J. (1975). Cost effectiveness of computerized laboratory automation. *Proceedings of the IEEE*, 63(10), 1495–1502. doi:10.1109/proc.1975.9979
- Kim, K., Lee, S.-G., Kim, T. H., & Lee, S. G. (2022). Economic Evaluation of Total Laboratory Automation in the Clinical Laboratory of a Tertiary Care Hospital. *Annals of Laboratory Medicine*, 42(1), 89–95. doi:https://doi.org/10.3343/alm.2022.42.1.89
- Lam, C. W., & Jacob, E. (2012). Implementing a Laboratory Automation System. *Journal of Laboratory Automation*, 17(1), 16–23. doi:https://doi.org/10.1177/2211068211430186
- Le, N. T., Thwe Chit, M. M., Truong, T. L., Siritantikorn, A., Kongruttanachok, N., Asdornwised, W., . . . W., B. (2023). Deployment of Smart Specimen Transport System Using RFID and NB-IoT Technologies for Hospital Laboratory. *Sensors*, 23(1). doi:https://doi.org/10.3390/s23010546
- Lippi, G., & Rin, G. D. (2019). Advantages and limitations of total laboratory automation: a personal overview. *Clinical Chemistry and Laboratory Medicine (CCLM)*, 57(6), 802-811. doi:https://doi.org/10.1515/cclm-2018-1323

- MacCallum, R. C., Widaman, K. F., Preacher, K. J., & Hong, S. (2001). Sample Size in Factor Analysis: The Role of Model Error. *Multivariate Behavioral Research*, 36(4), 611-637. doi:https://doi.org/10.1207/S15327906MBR3604_06
- Markin, R. S., & Whalen, S. A. (2000). Laboratory Automation: Trajectory, Technology, and Tactics. *Clinical Chemistry*, 46(5), 764–771. doi:<https://doi.org/10.1093/clinchem/46.5.764>
- Muriithi, W. (2020). Laboratory test tracking. *Conduct Science*. doi:<https://conductscience.com/laboratory-test-tracking/>
- Nam, T. K., & Ying, L. (2020). Pre-analytical pitfalls: Missing and mislabeled specimens. *Psnet.ahrq.gov*. doi:<https://psnet.ahrq.gov/web-mm/pre-analytical-pitfalls-missing-and-mislabeled-specimens>
- Nelson, M. (1969). Automation in the laboratory . *J. Clin. Path*, 1-10. doi:<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC473994/pdf/jclinpath00378-0007.pdf>
- Norgan, A. P., Simon, K. E., Feehan, B. A., Saari, L. L., Doppler, J. M., Welder, G. S., . . . Reichard, R. R. (2020). Radio-Frequency Identification Specimen Tracking to Improve Quality in Anatomic Pathology. *Archives of Pathology & Laboratory Medicine*, 144(2), 189–195. doi:<https://doi.org/10.5858/arpa.2019-0011-oa>
- Pilkington, B. (2022). Why Do We Need Lab Automation? . *AZoRobotics*. doi:<https://www.azorobotics.com/Article.aspx?ArticleID=542>
- Pollock, S. (2018). Benefits of Implementing a Specimen Tracking System (STS) in Anatomic Pathology. *Anatomic Pathology*. doi: www.leicabiosystems.com. <https://www.leicabiosystems.com/knowledge-pathway/benefits-of-implementing-a-specimen-tracking-system-sts-in-anatomic-pathology/>
- Rasanen, M. (2024). Specimen Tracking Systems: Tracking Samples Helps Reduce Misdiagnosis. *Leicabiosystems.com; Leica Biosystems*. doi:<https://www.leicabiosystems.com/knowledge-pathway/specimen-tracking-systems-tracking-samples-helps-reduce-misdiagnosis>
- Rupp, N., Ries, R., Wienbruch, R., & Zuchner, T. (2023). Can I benefit from laboratory automation? A decision aid for the successful introduction of laboratory automation.

Analytical and Bioanalytical Chemistry, 416(1), 5–19.

doi:<https://doi.org/10.1007/s00216-023-05038-2>

Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students. *Pearson Education Limited*.

Seaberg, R. S., Stallone, R. O., & Statland, B. E. (2000). The Role of Total Laboratory Automation in a Consolidated Laboratory Network. *Clinical Chemistry*, 46(5), 751–756. doi:<https://doi.org/10.1093/clinchem/46.5.751>

Uedufy. (2022, Jan 18). *How To Interpret Model Fit Results In AMOS*. Retrieved Jan 10, 2023, from Uedufy: <https://uedufy.com/how-to-interpret-model-fit-results-in-amos/>

Young, D. S. (2000). Laboratory Automation: Smart Strategies and Practical Applications. *Clinical Chemistry*, 46(5), 740–745. doi:<https://doi.org/10.1093/clinchem/46.5.740>

Yu, H.-Y. E., & Wilkerson, M. L. (2017). Employee Engagement Is Vital for the Successful Selection of a Total Laboratory Automation System. *Laboratory Medicine*, 48(4), e66–e74. doi:<https://doi.org/10.1093/labmed/lmx030>

Zachary, J., Tijerina, A., & Joligon, R. (2020). PMD20 Economic impact of specialized laboratory automation on the turnaround time (tat) mean and standard deviation. *Value in Health*, 23(S191). doi:10.1016/j.jval.2020.04.588

Zaninotto, M., & Plebani, M. (2010, May 12). The “hospital central laboratory”: automation, integration and clinical usefulness. *Clinical Chemistry and Laboratory Medicine*, 48(7), 911-917. doi:<https://doi.org/10.1515/cclm.2010.192>