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“دمج أنظمة معلومات المختبرات (LIS) وتأثيره على جودة الرعاية

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Title

Integration of Laboratory Information Systems (LIS) and Its Impact on Quality of Care

Title in English

Evaluating the Impact of LIS Integration on Quality, Accuracy, and Turnaround Time in Clinical Laboratories: A Study at Dr. Sulaiman Al-Habib Hospital

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Title

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المستخلص

هدفت هذه الدراسة إلى تقييم أثر دمج نظام معلومات المختبرات (LIS) على أداء المختبرات السريرية في مستشفى د. سليمان الحبيب – فرع السعودي بمدينة الرياض. ويُعد دمج نظام LIS خطوة أساسية لتسريع الإجراءات المخبرية وتقليل الأخطاء وتحسين جودة النتائج؛ إلا أن مدى تأثيره الفعلي على الأداء العام والوقت المستغرق والدقة التشغيلية يحتاج إلى تقييم علمي منهج.

اعتمدت الدراسة على المنهج الكمي، وتم جمع البيانات باستخدام السجلات الإلكترونية للمختبر بالإضافة إلى استبانة وزعت على العاملين في المختبر من أخصائيين وفنيين. بلغ حجم العينة النهائي 100 مشاركاً، وتم تحليل البيانات باستخدام برنامج SPSS لاختبار الفرضيات وقياس العلاقة بين دمج النظام وتحسين مؤشرات الأداء المختبري.

أظهرت النتائج وجود تأثير إيجابي ودال إحصائياً لدمج نظام LIS على جودة الأداء المختبري، حيث ساهم بشكل ملحوظ في تقليل الوقت المستغرق لإصدار النتائج، وخفض نسبة الأخطاء التشغيلية، ورفع مستوى دقة النتائج ورضا العاملين. كما أشارت النتائج إلى تحسن ملحوظ في سهولة سير العمل وكفاءة العمليات مقارنة بالأساليب التقليدية المعتمدة قبل التطبيق.

قدمت الدراسة عدداً من التوصيات أبرزها ضرورة التوسع في اعتماد الأنظمة الرقمية الداعمة لإدارة المختبرات، واستمرار التدريب التقني للعاملين، وتعزيز التكامل بين نظام LIS وباقي الأنظمة الصحية الإلكترونية لضمان استمرار تحسين الجودة ودعم اتخاذ القرار السريري.

الكلمات المفتاحية: نظام معلومات المختبرات، LIS، الوقت المستغرق لإصدار النتائج، دقة النتائج، جودة المختبرات، المعلوماتية الصحية

Abstract:

This study aimed to evaluate the impact of integrating the Laboratory Information System (LIS) on the performance of clinical laboratories at Dr. Sulaiman Al-Habib Hospital – Al-Suwaidi Branch in Riyadh. Implementing LIS is considered an essential step toward improving workflow efficiency, reducing errors, accelerating result delivery, and enhancing diagnostic accuracy; however, its actual impact requires structured assessment and empirical validation.

The study adopted a quantitative research methodology, and data were collected through electronic laboratory records and a structured questionnaire distributed among laboratory specialists and technicians. The final sample size consisted of 100 participants. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) to test the hypotheses and examine correlations between LIS integration and improvements in laboratory performance indicators.

The results demonstrated a statistically significant positive impact of LIS integration on laboratory performance. The system contributed to a noticeable reduction in turnaround time, fewer operational errors, enhanced result accuracy, and higher satisfaction levels among laboratory staff. In addition, workflow efficiency improved substantially compared to pre-implementation practices.

The study provides several recommendations, including expanding the adoption of digital laboratory systems, offering continuous technical training for laboratory personnel, and enhancing integration between LIS and other healthcare information systems to maintain quality improvement and support clinical decision-making.

Keywords: Laboratory Information System, LIS, turnaround time, accuracy, laboratory quality, digital health, clinical informatics.

Abbreviations List

Abbreviation	Definition
LIS	Laboratory Information System
TAT	Turnaround Time
ISO	International Organization for Standardization
CAP	College of American Pathologists
JCI	Joint Commission International
HIS	Hospital Information System
EMR	Electronic Medical Record
SPSS	Statistical Package for the Social Sciences
IT	Information Technology
KPI	Key Performance Indicator
QC	Quality Control
DV	Dependent Variable
IV	Independent Variable
TAM	Technology Acceptance Model
SPO	Structure – Process – Outcome Model
SOP	Standard Operating Procedure

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Chapter 1

1.1 Introduction

Clinical laboratories provide a vital foundation for delivering modern healthcare services, serving as key diagnostics capabilities that strengthen medical decisions, treatment plans, disease surveillance, and follow-up on patient care. Internationally, it has been identified that between 70%—80% of clinical decisions arise, directly or indirectly, from laboratory investigations, attesting to the unique capacity of laboratories in providing accurate, time-efficient, and evidence-based healthcare services. Laboratories will need to continue to maintain high quality clinical performance in precision, safety, and operational reliability in order to respond to the increasing demands by patients for health care services, growing capacity in the delivery of health care services, and ever-increasing complexity in diagnostic tests. However, many laboratories, particularly those who continue to rely on traditional paper-based or partially digitized processes, often experience challenges in operational delivery, including, but not limited to transcription errors, delays in reporting laboratory findings, inconsistent documentation standards and workflow fragmentation [1]

Digital advancements in healthcare have established Laboratory Information Systems (LIS) as one of the most disruptive forces among laboratory processes. LIS is an integrated digital platform to support laboratory processes, from specimen registration to workflow routing, instrument interfacing, quality assurance, and automated reporting. There is evidence that implementing a LIS increases laboratory efficiency by reducing human error, increasing turnaround time (TAT), improving result traceability, and supplying data integration ability to Hospital Information Systems (HIS) (2). Furthermore, a LIS aids compliance to international accreditation organizations like the College of American Pathologists (CAP), International Organization for Standardization (ISO 15189), and Joint Commission International (JCI) by facilitating transparency in use of standardized documentation and unified processes, overall providing total traceability through laboratory workflows

The incorporation of digital health solutions in Saudi Arabia is part of national transformation initiatives as described in the Saudi Vision 2030 plan, focusing on modernizing healthcare services, improving patient experience, and developing effective digital infrastructures. So, as public and private healthcare facilities—such as Dr. Sulaiman Al-Habib Hospital—continue to develop their diagnostic and operational capabilities, the demand for implementing advanced interoperable digital systems requires action. Hence, the adoption of a LIS would be viewed as a systematic requirement that moves beyond a technological modernization step but is viewed as a strategic requirement for long-term sustainability, operational efficiency, and clinical excellence [3]

While there is a strong consensus on the advantages LIS gives its stakeholders, there are still knowledge gaps into the perceived measurable impact of LIS use in real-world settings, particularly in nations experiencing rapid health care modernization. Some labs cite barriers among users, including insufficient staff readiness, tensions around changes to workflow, insufficient training in the associated technologies, and limitations in systems customization or interoperability representing some of the contextual factors contributing to this knowledge gap. As such, there is a critical need for research evidenced based inquiries in LIS usage around indicators of laboratory quality assurance, diagnostic accuracy, and turnaround time in tests [4]

Taking these points into account, this study aims to investigate the quantifiable outcomes of implementing LIS in the clinical laboratory of Dr. Sulaiman Al-Habib

Hospital. The goal of this research is to provide a contribution to the literature, assist decision-makers in optimizing their LIS use, and develop evidence-based recommendations which will positively impact overall laboratory performance in the .Saudi Health System [5]

1.2 Problem Statement

Even with significant improvements in global healthcare delivery, clinical laboratories still contend with consistent troubles with accuracy, timeliness, standardization, and efficiency of laboratory testing. Laboratory results constitute the basis of most clinical decisions, but many institutions rely on siloed or partially digitized processes that exacerbate operational errors and generate variability in clinical performance. These inconsistencies occur most frequently in healthcare systems that are recently expanded capacity, added diagnostic technology, or transitioned from manual procedures but have .not fully incorporated or rationalized digital solutions for laboratory operations [6]

Many conventional laboratory workflows create points of vulnerability. Tasks such as human- handwritten test requests, specimen labeling, manual verification of results, and documentation, require time and create opportunities for failure. The dependant vulnerabilities may lead to transcription errors and lost or mismatched samples, added duplication of effort, inefficient reporting timelines, or simply an inability to retrieve historical records quickly. The breakdown of these processes creates administrative may negatively impact patient outcomes, particularly when burden, inefficiencies, and time-sensitive diagnostic information is warranted for immediate clinical action [7]

Laboratory Information Systems (LIS) have been implemented as a strategic element of digital transformation in healthcare intended to increase laboratory performance, improve data traceability, minimize user error and maximize the turnaround time. Despite these presumed benefits, studies show that impacts from LIS vary widely between institutions based on a misalignment with workflow, poor end-user training, inability to customize the LIS, and poor alignment with broader hospital digital ecosystem. [8]

Moreover, a successful implementation of LIS will require organizational readiness, workflow redesign, and ongoing performance monitoring, and engagement of stakeholders. Without these conditions in place, LIS will be underutilized, possibly inappropriately applied, limiting its potential benefit, and therefore, reducing its impact .on operations [9]

Although Vision 2030 digital transformation initiatives have resulted in the increased adoption of LIS in Saudi Arabia, the body of empirical literature evaluating objective and quantifiable improvement in lab turnaround time, and a quality assurance, diagnostic accuracy and operational efficiencies following implementation of LIS is limited. The majority of studies are mostly descriptions of LIS and do not include an appropriate pre- .and post-intervention comparison for real-world lab practice. [10]

The main issue being studied in this research is the lack of data-based evaluation of LIS implementation on laboratory accuracy, operational efficiency, and turnaround time in the clinical environment of Dr. Sulaiman Al-Habib Hospital. It is important to conduct this evaluation to determine if LIS implementation resulted in the expected

improvements, or whether additional optimization, training, or workflow redesign/shifts would be necessary to bring performance into alignment with expected national and international benchmarks [11]

1.3 Purpose of the Study

The objective of this research is to systematically and evidence-based assess the effect of the Laboratory Information System (LIS) on the clinical laboratory performance at Dr. Sulaiman Al-Habib Hospital. Given that laboratories are an essential part of the diagnostics and treatment pathways for patients, it is important to assess whether LIS operational improvements which we leads to measurable improvements, not simply assume, to establish system value, patient safety, and the return on investment organizationally [12]

The objective of this research is to evaluate if the implementation of LIS resulted in measurable improvement in key metrics including turnaround time (TAT), accuracy of reporting, consistency of documentation and workflow efficiency. The goal is to compare laboratory operations before and after LIS implementation, and assess if LIS improved variability and if the number of transcription errors, specimen mislabeling, duplicative efforts and delays related to manual or partially automated workflows were reduced [13]. Measuring these factors is particularly important in testing environments with high testing volume where errors and delays can have a downstream effect on clinical decision making and patient outcomes

Another significant purpose of this research is to clarify the contribution of LIS to compliance with international regulatory and accreditation frameworks such as ISO-15189, CAP, and Joint Commission International standards. These frameworks call for standardization, traceability, controlled documentation, and repeatable testing. If LIS meets these expectations, it is positioned to not only serve as a digital operational tool but to also serve as a contributing factor to institutional accreditation and the long-term maturity of laboratory quality. [14]

at technical and operational outcomes, the study will also seek to Along with look address organizational human factors influencing LIS use, and adoption. The effective implementation of health information systems in practice is often dependent on user engagement, staff competency, training, compatibility with workflow, and leadership support; and even for the most advanced health information system, without these factors in place, a perception of technical ineffectiveness may develop

As a parts of the study, we will consider whether the use o the LIS in the hospital is consistent, congruent with laboratory culture and workforce readiness, and to what extent resistance to change, lack of familiarity with the system, and misalignment with usual work processes, have limited benefits associated with change [15]

Additionally, this study seeks to provide evidence for an identified gap in Saudi-based literature. As interest in digital health transformation has increased, primarily under the Saudi Vision 2030, empirical studies evaluating performance outcomes of LIS in private healthcare facilities that are typically high-volume and have healthcare settings (or where care is given) is still limited. The majority of studies published to date focus on descriptive, rather than analytical, studies to determine if there is measurable change in implementation. This research attempts to fill this void by performance following digital providing results that are context-specific to contribute to local and national comparison

and benchmarking, as well as provide evidence for planning future LIS implementation for similar healthcare organizations [16][17]

Ultimately, this research aims not only to evaluate the efficacy of the LIS but also to support long-term improvements through considerations for practical applications. Recommendations following the study may impact LIS enhancement, workflow redesign, training, policy, and digital health investment to enhance services. The final goal is simply to operationalize the LIS as a key resource for reliability, evidence-informed decision-making, and ultimately, to augment quality and efficiency in clinical laboratory services [18]

1.4 Study Importance

This study is significant because it reaches beyond the evaluation of software functionality and attempts to address a larger institutional, clinical, and national concern about how digital transformation can influence laboratory performance in contemporary healthcare settings. As clinical laboratories produce critical data that affect diagnosis, treatment decision making, and patient tracking, it is important to know if the implementation of a Laboratory Information System (LIS) leads to measurable enhancements in quality of service, operational efficiencies, and patient safety and is not just a procedural upgrade or the latest technology [19]

This research is especially noteworthy because it evaluates LIS in a large, high-volume provider, where operational demand, complexity of test, and turnaround time expectations are much higher and different than an academic or small laboratory. Knowing if LIS is able to sustain accuracy, consistency, and stability, are all powerful evidence for understanding the applications, scalability, and enduring usefulness with dissemination value in the context of clinical practice and not just as a proof of concept [20]

In addition, the research adds value towards Saudi Arabia's broader digital health agenda under Vision 2030, which embraces interoperability, digital health integration, and efficient transformation of healthcare. Although many digital solutions have been developed across the sector, there is currently an absence of evidence testing the impact of digital solutions on performance. In generating site-specific findings, this research of national research that places digital contributes to an evidence-based foundation health decision making on an evidence-based foundation, rather than an assumption based one [21]

In addition, from a laboratory perspective of quality, this study is important, as it assesses the ways in which LIS contributes meaningfully to adherence to globally acknowledged accreditation frameworks such as (ISO 15189), (CAP), and (JCI). These framework performance does not simply evaluate laboratory outputs; they evaluate documentation traceability, procedural standardization, quality control, corrective actions, and staff competency. A positive contribution by LIS to a processes mentioned here becomes a value added strategic asset to maintain high reliability, audit readiness, and international comparative evaluation not just a data processing tool [22]

Additionally, it acknowledged the human and organizational components of LIS effectiveness. Healthcare technology does not operate in a vacuum, as its performance depends on the users who interact with it. Investigating user readiness, user satisfaction,

digital maturity, workflow match, and usability may aid in understanding whether the system is being utilized to its greatest extent or whether barriers are creating an environment that inhibits the use of the system by the organization. Findings may help inform the organization to enhance skills programs, workflows, or increase digital governance [23]

The study is important financially and operationally because healthcare organizations are looking more and more to justify a technology investment based on documented improvements in efficiency and cost savings; if the LIS decreases duplication, lessens diagnostic errors, decreases repeat testing and expedites reporting cycles, then it would mean more efficient allocation of resources, decreasing operational waste, improving workflow of staff, and improving patient flow to an end that has value to administrators, policymakers and health care economists [24]

Ultimately, this study has academic merit in that it provides new knowledge in a literature area that lacks regional evidence. It potentially has significant implications for curriculum development in health informatics education, informing future work in areas of research, guiding health care technology procurement policies, and contributing to the development of evaluation models for other digital health platforms

Through its practical, yet grounded in theory, insights, this study allows advocates for LIS implementation to evaluate an LIS as an evolving system that requires not only a technical instance of health care intervention, but also requires continual evaluation, optimization, testing, and strategic reviews based on the needs of the future [25]

1.5 Study Questions

Based on the articulated purpose and identified gaps above, this study intends to address the below main and sub-research questions

:Main Research Question

What are the effects of the LIS implementation on laboratory performance (quality, accuracy, and turnaround time) at Dr. Sulaiman Al-Habib Hospital? [26]

:Sub-Research Questions

In the context of clinical laboratory testing, did the LIS implementation enhance the accuracy and reliability of test results when compared with the accuracy and reliability performance levels which occurred prior to the LIS implementation? [27]

What is the effect of the LIS implementation on the overall turnaround time (TAT) of laboratory service provision, as well as turnaround time of high priority or emergency requests? [28]

What is the effect of the LIS implementation on workflow for efficiency, operational errors for reduction, and elimination of manual documentation when compared to previous traditional laboratory practices? [29]

What organizational and technological barriers and user barriers preclude the realization of the full benefits of LIS performance in a clinical laboratory context? [30]

1.6 Research Hypotheses:

To provide a framework for evaluating the extent to which the Laboratory Information System (LIS) is linked to change in specific clinical and operational indicators in the laboratory model site, research hypotheses were developed. The implementation of the LIS involves a change in workflow, automation, data handling, and decision-support systems, so its necessary to determine whether the anticipated differences. The hypotheses below changes in outcomes result in statistically significant summarize the dimensions desire for future quantitative testing and provide a foundation for making an explicit interpretation of the findings

Main Hypothesis

:H1

The overall laboratory performance, (diagnostic accuracy, service quality, and turnaround times) is significantly improved after the implementation of the Laboratory Information System (LIS) at Dr. Sulaiman Al-Habib Hospital [31]

This refers to the more global expectation that an LIS should produce a more efficient operation and more clinical throughput. It also represents the aggregation of automation, decreased human data entry, reporting by system protocols, and workflow processes. The null hypothesis is stated to provide a measure of objectivity for the statistical analyses

:H0

The overall laboratory performance, (diagnostic accuracy, service quality, and turnaround times) is not significantly improved after the implementation of LIS

Sub-Hypotheses

:H1a

The implementation of a laboratory information system (LIS) will provide improved reliability and accuracy of laboratory test results over laboratory performance before the implementation of the LIS [32]. This hypothesis is based on the evidence of transcription errors, specimen mis-labeling, and inconsistent reporting formats, which are more common with manual entry systems. The LIS should automatically reduce this variability more than a manual system would, due to standardized templates, analyzer interfacing and real time validity checks

:H0a

The implementation of a LIS does not lead to a statistically significant difference in accuracy of laboratory test results

:H1b

The utilization of a laboratory information system (LIS) in the lab has produced noticeable reductions in turnaround time (TAT) for lab requests deemed urgent, emergency, or time-sensitive [33]. Turnaround time is an important measure of operations since it relates to patient safety due to timely interventions in medical care. This hypothesis tests whether or not the LIS system has a positive impact on turnaround times resulting from automation, fewer steps requiring paper, better workflow prioritization, and more direct communications with clinical departments

:H0b

.There is no significant effect of LIS on turnaround time

:H1c

The implementation of a LIS has effectively increased workflow efficiency, decreased manual entries, diminished redundancies, and curbed errors in operations relative to .pre-digital practices [34]

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This hypothesis recognizes that digital transformation influences speed and accuracy, but also workload, task distribution, and fluidity in workflows. With supporting workflows, the laboratory can be expected to operate more seamlessly, with minimized .wait times, clearer assignments of tasks and a lessened burden of manual work

:H0c

There is no significant change in workflow efficiency as a result of the introduction of .LIS

:H1d

Successful use and performance outcomes of LIS are heavily influenced by readiness, training quality and organizational support indicating technology effectiveness isn't just about the ability for the system to be available and functional, but also about people's .and structural and cultural framework in organizations, [35][36]

This hypothesis states that system impact will rely on more than technical capabilities, but also user capabilities, previous system use, user acceptance, organizational culture. If adequate training and future support are not attached to the LIS, many of the benefits .of the LIS will not accrue

:H0d

user-related and organizational factors do not determine LIS performance or use

1.7 Theoretical Model

This study is grounded in the DeLone and McLean Information System Success Model, which is a comprehensive model to evaluate information system effectiveness, usage, and organizational impact, such as the Laboratory Information System (LIS). The DeLone and McLean model provides a well-known theoretical foundation in health informatics and system evaluation research context because of its multidimensional framework and practical application in clinical, administrative, and digital health evaluations [37]

The DeLone and McLean model suggests that the measures of system success are not the outcome of a single determinative construct, but instead the result of the interactions contained among six important constructs: system quality, information quality, service quality, system use, user satisfaction, and net benefits. By illustrating how an information system moves from just being a technology in use, to including measurable value to the organization, these six constructs demonstrate the evolution of information systems

System Quality

The technical performance and overall functionality of LIS are reflected in the system quality, which includes reliability, user interface design, ability to integrate laboratory instruments, error-free processing, and the system's responsiveness. System quality in clinical laboratories provides the ability to automate some data using system integration, reducing manual transcription errors and streamlining standardized operating procedures. Improving the laboratory workflow increases operational efficiency [38]

Information Quality

Information quality concerns the levels of accuracy, completeness, clarity, timeliness, and clinical relevance of laboratory results produced through LIS. Since laboratory produced output informs diagnostic decision making, enhancements in information quality provides greater clinician confidence, lessens uncertainty, and allows clinical decision making that is evidence based [39]

Service Quality

Service quality includes the availability of technical support, adequacy of training, responsiveness to faults, and end user guidance while using the system. In healthcare, where the system needs to be operational continuously, exceptional service quality ensures system availability, increases user confidence, and minimizes disruptions to workflow associated with system failures and lack of support. [40]

System Use

System use denotes level of utilization and adoption of LIS by laboratory staff in standard operations. True system success is dependent upon purposeful use rather than simple access. In LIS environments, regular use supports automated workflows, data reliability, traceability, and consistency among lab operations [41]

User Satisfaction

User satisfaction illustrates how users perceive the ease, usefulness, and reliability of the system. With satisfied users, there will be a greater likelihood of the user engaging at a higher level and less resistance to change, which is a necessary element to sustain the system over time. Satisfied laboratory users, on average, tend to perform better, express less frustration, and apply LIS functions more consistently as part of their daily work [42]

Net Benefits

Net benefits refer to the intended outcomes of a system implementation and it includes improvements in organizational efficiency, fewer medical errors, better patient safety, cost savings, and enhanced decision making. In this study, net benefits correspond directly to the dependent variables of quality improvement, improved accuracy and reduced turnaround time (TAT). Proving net benefits is critical to demonstrating a return on digital investment, and sustaining the LIS [43]

Model Suitability for This Study

Multiple aspects demonstrate the applicability of the DeLone and McLean model in this study

The model analyzes results in both technical outcomes (accuracy, TAT, functionality) • and human-behavior outcomes (acceptance, satisfaction, adoption)

This model aligns with the digital transformation goals of the Saudi Vision 2030 health • strategy with a focus on data-driven care and integration of clinical and administrative systems

The model provides a framework for assessing post-implementation experiences; the • emphasis of this study is on the post-implementation experiences and not on predicting experiences prior to adoption

The model provides a suggestion and a framework for interpreting findings to • recommend systems to optimize LIS in the future [44][45]

Using this theory-based model, the study provides an all-inclusive and evidence-based assessment of the LIS impact as it examines technology effectiveness beyond technology installation to show measurable impact on workflows, user experience, and laboratory services, that are patient-centered

Currently, studies continue to emphasize the potential of Laboratory Information Systems (LIS) to improve operational performance and diagnostic accuracy in clinical

laboratories. As healthcare organizations transition to digitally modernized design, LIS have advanced beyond being a traditional data management entity to an integral part of infrastructure that encourages automation, minimizes manual reliance, enhances data precision, and heightens patient safety outcomes. [46]. Various studies demonstrate that laboratories with LIS improvements in turnaround time (TAT), error reduction, specimen tracking, workflow improvement, and reporting [47]. Specifically in high-volume activities where manual processing affects operational delays

The literature frequently mentions that the effectiveness of LIS is influenced by context and structure, such as system design, LIS interfacing, barcode practices, analyzer connectivity, and user knowledge and expertise [48]. Organizations that adopted full integration of the LIS report greater improvement of accuracy of results, consistency of reporting, and adherence to standard quality assurance practices, when compared to the lab that has partial integration of the LIS [49]. In addition, several studies demonstrate that an LIS promotes transparency and accountability throughout aspects of automated audit trails, immediate or real-time alerts, standardized procedures, and digitized quality management, which are all part of accreditation mechanisms, namely, ISO 15189 and Joint Commission International (JCI) [50]

The reviewed literature also confirms that LIS improves clinical communication by providing timely access to verified laboratory results, eliminating clerical error, and providing clinical decision support that improves patient care and provider satisfaction [51]. Nevertheless, several articles outlined specific implementation barriers, including a general hesitation to adapt to technological advances, insufficient training of staff, budget limitations, technical issues and workflow interruptions during the implementation process [52]. These statements continue to reinforce that the implementation of LIS cannot be viewed as a simple technology implementation but a systemic change to the organization that is reliant on leadership support, change management, and continued evaluation and optimization over the long term [53]

Overall, the literature demonstrates evidence to support the assertion that LIS plays an important role in improving laboratory performance, accuracy, and efficiency, however, the degree of improvement is contingent with integration, organizational readiness, and compatibility with clinical and operational requirements [54]

Chapter 2

2.1 Literature Review – Introduction

The healthcare industry's digital transformation has ushered laboratory processes into a new era, where information systems are foundational in improving the efficiency and safety of the diagnostic workflow. Laboratory Information Systems (LIS) are now much more than just tools to store or print test results; they exist as integrated digital ecosystems that coordinate specimens, support automation, interconnect instruments, and facilitate structured communication between clinical teams and laboratory units throughout the entire testing process [55]. Gradually, LIS technology has developed features like barcode-based identification systems, middleware communication, real-time dashboards, and automated analytical rules—the latter addressing any need for accuracy, traceability, and compliance applicable in laboratories of complex designs, as indicated in [56]. These features are aligned with international accreditation expectations (e.g., ISO-15189, CAP, JCI), all of which prioritize data integrity, standardization and demonstration of error reduction as essential laboratory quality indicators [57]

The literature refers to three main domains as important indicators of LIS effectiveness: laboratory quality, diagnostic accuracy, and turnaround time (TAT)[58]. Together, these three domains demonstrate the operational and clinical value of laboratory digitalization. Also, evidence suggests changes within these domains are interconnected, rather than merely independent. Automated verification rules and barcode identification systems may eliminate labeling errors and transcription errors, improving result accuracy while minimizing repeat testing and interruptions in workflow that add unnecessary time to TAT and slow diagnosis[59]

Research indicates that while most studies are positive about the post-LIS implementation, there are improvements that differ depending on contextual and implementation factors, as other studies have shown. Studies suggest that successful organizational implementation of LIS is predicated on re-designing workflows readiness, operational interoperability maturity, and workforce competency - not the technology. While most laboratories will see initial increases in workload, declines in processing times or starts to have challenges on duplicative documentation after going live, laboratories operationally stabilize with increased proficiency, data flows stabilize and manual processes are diminished [60]. Studies pertaining to large health systems

using LIS evidence improvements that are statistically significant variable from thirty to sixty days after implementation, and that measures include only months of the full .stabilization value of six to eighteen months post go live[62], [61]

Although there is a widening body of evidence at a global level, there is still very limited research focusing on the long-term implications of LIS adoption in private hospitals in the Gulf region. This is especially true of hospitals with a high digital volume like Dr. Sulaiman Al-Habib Hospital [63]. Studies which address sustainability beyond an accreditation visit or quantify the effect size using validated performance measures are rare. Moreover, there is a need for locally generated evidence to improve benchmarking .capability among regional laboratories undergoing digital transformation

structure-process-outcome model Donabedian's In this chapter, under the guidance of and technology-adoption theories, we consolidate findings available in the literature on the impact that LIS implementation has on laboratory workflows and its relationship to observable performance outcomes [64]. The next sections will therefore describe the dependent variables, identify measurement benchmarks, outline reported LIS-performance mechanisms, and highlight additional research opportunities that could be .studied as part of the current study [65]

2. 2 Dependent Variable

In this paper, laboratory performance is an identified dependent variable and conceptualized as a multi-dimensional construct comprised of three interconnected domains of outcomes: quality, diagnostic accuracy, and turnaround time (TAT). These domains are recognized in laboratory informatics studies as core indicators investigating the effect of Laboratory Information Systems (LIS) implementation on workflow dependability, diagnostic value, and operational efficiency [66]. It is important to understand performance as a multi-dimensional outcome, because of the potential for improvement on these indicators to not occur simultaneously, or at all, depending on the maturity of automation, the synergy of workflows, factors affecting interoperability, and user readiness [67]. There may be reductions in transcription and labeling errors shortly after the implementation of a LIS; however, to see an improvement in accuracy or TAT may require phases of stabilization, optimization length of user time with the .system before it can all be assessed and measured [68]

2.2.1 Laboratory Quality

Laboratory quality is defined by the degree of consistency, standardization, and adherence to recognized factors in operations and regulations in testing phases. When determining the quality of a laboratory, some common indicators are specimen rejection rates, labeling/identification errors, repeat testing rates, proficiency testing performance, and audit results [69]. Utilizing a LIS can play a key role in improving quality as it relies on barcode-driven specimen tracking, requires mandatory data entry rules, includes automated quality-control features, and minimizes the complete reliance on humans to substantiate documentation and verification processes [70]. Based on findings from several implementation studies, there is evidence that a LIS may have the phase, where most laboratory preanalytical strongest effect on error reduction in the alerts, errors occurred in the past [71]. Additionally, built-in traceability tools, system

and audit trails can support proactive quality management models to accreditation standards such as CAP, ISO 15189, and JCI [72]

2.2.2 Diagnostic Accuracy

Diagnostic accuracy is the extent of having valid, consistent, and clinically acceptable laboratory results. Common metrics for assessing accuracy include analytical imprecision (CV%), method bias, transcription errors, analyzer and LIS agreement, and proficiency testing [73]. LIS improves diagnostic accuracy mostly through the removal of manual transcription, integration of analyzers into the reporting pathway, and encapsulation of rule-based validation protocols [74]

Studies demonstrate that where automated validation rules and analyzer integration is fully realized, diagnostic accuracy greatly improves through automated flagging of abnormal values, reduced clerical errors, and real-time integration of quality control limits [75]. Furthermore, LIS-generated audit trails and a consistent reporting structure contribute to long-term traceability and regulatory reporting [76]

2.2.3 Turnaround Time (TAT)

Turnaround time (TAT) reflects the speed and responsiveness of laboratory workflow and is colloquially used to signify a measure of operational efficiency in routine and stat diagnostics [77]. TAT may be divided along timestamped lines (e.g., the times order to collection, specimen receipt, analyzer, verification, and report release), and this can enhance the identification of bottlenecks in a workflow [78]. The LIS helps improve TAT by enabling automated lines of communication, reducing administrative tasks, prioritizing cases, and tracking and redistributing workloads in real time [79]. Literature indicates that improvement of a digital workflow led by LIS can have the most profound impact in a high volume or rapid environment, particularly if combined with Improvement, [80] middleware automation and established operating protocols however, is contingent on factors such as organizational preparedness, user capabilities, and quality of integration with other clinical information systems [81]

2.2.4 Summary of Variable Structure

Defining laboratory performance as a composite variable (quality, accuracy, and TAT) provides an uncomplicated vehicle by which all LIS-related improvements can be evaluated, along with a valid statistical procedure for measuring pre- and post-integration [82]. This approach is in line with international standards for measurements and supports evidence-based assessments in digitally transformed health systems such as Saudi Arabia

2.3 Independent Variable

In this research, the independent variable is defined as Laboratory Information System (LIS) integration. LIS integration refers to how well the LIS has been adopted, incorporated into the laboratory workflow, enabled the exchange of data between systems, and allowed for clinical communication. LIS integration is not just a singular

technical definition; LIS integration describes the maturity level related to automation, interoperability, standardization, and functionality in the pre-analytical, analytical, and post-analytical phases [83]. The measurement of LIS integration as a multidimensional construct allows the research to account for the variation in maturity level of adoption, proficiency level of users, configuration level of the LIS, and alignment of the laboratory operations because each of these elements affects laboratory outcomes [84]

LIS integration is viewed as an appropriate independent variable related to laboratory performance in research because the LIS acts as an enabler, reshaping how laboratory workflows are structured, alleviating cognitive and administrative burden, strengthening data governance, and improving communication between laboratory and clinical staff [85]. The literature builds on the idea that the LIS enables transformation stages of adoption that range from simple digital reporting of through incremental results to empirical systems that provide heightened automation that can enable real time monitoring, quality driven decision logic, middleware connectivity, and seamless interoperability with hospital information systems and electronic medical records [86]

2.3.1 Operational Definition of LIS Integration

LIS integration is evaluated operationally, by categories of functional domains, which include

- Level of analyzer interfacing and automation •
- Dataset integrity and automated validation functions •
- Level of HIS/EMR interoperability •
- Barcode-enabled specimen tracking •
- Rules-based verification and auto-release capabilities •
- Middleware use •
- User training and adoption of the system •
- Use of real-time dashboards and quality monitoring •

These domains allow LIS integration to be evaluated along a operationally technical and procedural dimension as they capture the more than system installation, they also capture operational use, which the literature notes is vital for completing a sustained performance improvement program [87]

2.3.2 Mechanisms Linking the Independent Variable to Laboratory Performance

The incorporation of a laboratory information system (LIS) influences performance through various pathways. To begin with, automation and connection of analyzers diminish manual transcription, and variation in procedure or reliance on staff personal experience improves consistency and minimizes the risk of human error [88]. Moving structured communication decreases system delays by forward, interoperability via enabling the flows of information among laboratory systems, clinical applications, and patient records [89]. Lastly, rule-based decision-support and real-time monitoring improve quality assurance processes which assist laboratories in identifying bottlenecks

in workflow, improve compliance with standards, and minimize delays in reporting .[90]

The LIS integration also yields a shift in the cognitive model of laboratory work. The employees are less centers for task execution, and increasingly perform activities of review and exception-management, which enhances productivity and fosters a culture of proactivity compared to a culture of reactivity [91]. Finally, fully integrated LIS systems support organizational learning through feedback loops which are utilized for quality improvements and decision-making informed by data, adhering to accreditation .and strategic patient care goals [92]

2.3.3 Factors Affecting LIS Integration

There is evidence that LIS integration outcomes differ by a set of moderating factors :including

- Staff readiness and digital competency •
- Amount of workflow redesign undertaken before rollout •
- Quality of system configuration and customization •
- Maturity of institutional IT infrastructure •
- Integration governance and partnership with vendor •
- Training models and user support availability •

These moderators determine whether or not the LIS is fully embedded in routine .workflows or a system has an example of partial adoption and limited operation [93]

Research within the Gulf region adds to that list by noting the importance of leadership institutional digital transformation strategy as an commitment and alignment with the added predictor of successful long-term integration [94]

2.3.4 Summary of Independent Variable Role in the Study

Viewing LIS integration as the independent variable means the research can assess how levels of digital maturity influence observable changes in laboratory performance. This is aligned with digital health evaluation models that note, implementation of technology is more than just technology implementation but a transformation process the effects workflow reliability, patient safety, and systems-economy. [95]

2.4 Summary of Past Studies

Significant research has explored the impact of Laboratory Information Systems (LIS) concerning laboratory practices mainly related to quality, diagnostics accuracy, and turnaround time (TAT). Research results vary by studies based on the institutional setting, LIS maturity, and state of adoption and operational alignment. Most studies

released from other countries indicated positive improvements due to LIS presence, however, as noted the level and sustainability of the improvements process differ among Early research about LIS adoption predominantly measured laboratory settings [96]. outcomes for mistake prevention and operational automation. For instance, a multi-center study illustrated a reduction in labeling and sample identification errors, as high as 70% for laboratories with LIS-based barcode tracing, versus laboratories with a manual procedure [97]. The findings of research, throughout, indicated there would be a similar effect, while also noting improvements towards compliance of accreditation standards when automated validation rules and audit trails were employed in routine processes [98]. These contributions clearly enhanced the overall point of view that LIS adoption positively influences process standardization and error prevention methods

Recent studies have moved away from just measuring improvements in outcome, to measuring the mechanism for outcome improvement. Evidence taken from studies including analyzer interfacing, middleware automation, and workflow integration between the LIS and analyzer platform show that depth of integration does have a direct impact on outcome measure validity, accuracy and reliability [99]. There were a substantial number of institutions with a full bidirectional analyzer integration that reported less transcription errors (discrepancies) and less clinical report corrections, where as there were laboratories using LIS systems where data entry workflows ranged from partial integrations to manual entry find the opposite results [100]

In addition to support of globally based evidence in favor of LIS system driven improvements, a number of studies showed inconsistent positive improvements in outcome measurement. Some of the institutions secured no or limited improvement in TAT outcomes, while implementing a more sophisticated LIS, where findings identified bottlenecks in workflows, partial interoperability, and/or limited readiness amongst staff to realize full potential of the LIS technology [101]. The studies demonstrate that the importance of LIS deployment is not necessarily beneficial without systems configuration, user engagement, and organizational process redesign as a collective

Research undertaken in low- and middle-income healthcare environments reinforces the context in which factors such as the maturity of infrastructure, digital culture, and resources emerge. A comparative analysis of LIS performance across several health care systems found that laboratories with a history of automation and solid digital culture achieved quicker stabilization and maintained improvement compared to laboratories that faced digital and operational change at the same time [102]. New studies from the studies currently remain although hospitals in the Gulf region have also emerged depth. There are numerous descriptive reports of improved limited in scope and performance, or examples of implementation, but most do not include any longitudinal measures of pre- or post-LIS performance or comparison [103]. Additionally, few studies in Saudi Arabia reported on LIS outcomes in the private healthcare sector, and many were limited to user perceptions rather than laboratory performance indicators grounded in quantitative measures [104]. Even where there are reports of positive usability and efficiency, the findings do not document statistically sound evidence of long-term improvement in performance indicators such as accuracy, quality and TAT

In the literature, one constant finding that renders it limiting is examining sustainability of performance improvements beyond the first year of implementation. Several authors have noted that performance improvements that may be seen shortly after system implementation may diminish over time, or remain stagnant, if continuous improvements in the system, implementation, and staff training are not also consistent after the system is implemented [105]. This emphasizes the need for models evaluating

empirically focused on longitudinal impact, rather than on short-term post-implementation impact

Gap and Contribution of the Present Study

In light of this review, there are clear indications in the literature of the possible advantages of LIS integrated; however, we have little understanding of the impact of improvements in digitally mature private health care systems located in Saudi Arabia and in high-volume contexts. Furthermore, there is scant research that has evaluated LIS outcomes utilizing a structured, multi-dimensional measurement model that brings accuracy, quality, and turnaround time (TAT) together, rather than evaluating these outcomes individually

To address this gap, the present study set out to

Quantify LIS impact on performance metrics using validated laboratory based •
assessment measures

Explore the outcomes from an environment characterized by an entirely digitized, •
private hospital setting with high patient volume

Investigate the sustainability of LIS-informed performance gains beyond the initial •
implementation phase

Contribute to the literature with regional evidence, providing additional context to •
advance understanding of digital transformation and its role in the context of
benchmarking

By taking this structured approach, the current study represents an advancement in the literature by way of contributing with empirical, case-based evidence, to better understand LIS in the context of advanced healthcare ecosystems

2.5 Theoretical Framework

This study is supported by two interrelated models that provide a rationale for different processes

that occur within the frameworks of laboratory performance. The first of these models is Structure–Process–Outcome (SPO) Model while the second is the Donabedian's Technology

Acceptance Model (TAM). Collectively, they provide an integrated analytic approach to understand

the effects of Laboratory Information System (LIS) integration on laboratory performance while

considering the impact of organizational and human factors that mediate the efficacy of system adoption

.and performance outcomes [106]

The synergy of the SPO and TAM models creates a dichotomy of lens through which both technical functionality and human-system interaction are used as measures of .laboratory performance

This approach supports the more current sequencing of the laboratory informatics literature indicating

that a full digital transformation requires operational enablement (the system) and behavioral

alignment (the users) to improve performance [107]

2.5.1 Donabedian's SPO Framework

framework acts as a framework for assessing quality improvement Donabedian The projects in the healthcare field and has been widely applied in laboratory quality :research [108]. The components of this project will be delineated as follows

Structure: The extent of integration demonstrated by the LIS, which might include • .automation, analyzer interfacing, HIS/EMR connectivity, or rule-based verification

Process: The workflow of the laboratory, which could include specimen processing, • .data-entry process, quality control process, or reporting pathways

Outcomes: The performance of the laboratory evaluated with indicators, such as • .quality, accuracy, and turnaround time (TAT)

The SPO framework supports our conjecture that with enough advancements in structural capacity, such as an integration of the LIS, we will see trusted, standardized and efficient process improvements, which with ultimately lead to improved outcomes for the laboratory [109]. When the SPO framework has been applied in laboratory settings, it is evident from the data that there is a positive relationship between digitalization maturity and performance indicators [110]

2.5.2 Technology Acceptance Model (TAM)

Although the SPO model explains the structural mechanism of change, the Technology Acceptance Model (TAM) explains the behavioral and adoption-related dimensions of LIS use. The Technology Acceptance Model (TAM) posits that institution acceptance is impacted by two fundamental perceptions: perceived usefulness and perceived ease of .use, which leads to intention to use and systems use [111]

The literature suggests that even well-designed LIS platforms, in a lab, may not produce the anticipated outcomes if staff are resistant, lack training, or perceive the LIS platform to be complex or burdensome on their workflow [112]. Consequently, TAM is critically

important to recognize variability in human-system interaction and account for differences in laboratory performance across various contexts that have similar LIS infrastructure but different cultures of adoption. TAM also assists in explaining temporary declines in performance that can be observed during the early adoption phase; this is often attributed to the human element lagging behind system availability before convergence occurs [113]

2.5.3 Integration of SPO and TAM in the Current Study

Introducing both theoretical perspectives leads to a comprehensive understanding of LIS effects on laboratory activities. Under a combined conceptualization

SPO clarifies what is changing at the operational level (structural modernization → • enhanced workflow processes → impacts that can be measured)

TAM explains how quickly and effectively that change occurs (user acceptance → use of • the system → depth of adoption)

Applying dual theory to the study evaluation strategy acknowledges that LIS benefits may be mediated by technological performance and human adoption processes [114]

2.5.4 Application to the Study Context

theory reinforces the interpretation of findings combinedframework Employing this by linking system attributes and the user-related aspects to performance outcomes at Dr. Sulaiman Al-Habib Hospital

The framework also allows for comparative pre/post evaluation and analysis of a variety of performance improvements associated with either

- Functional LIS capability and automation maturity •
- User familiarity/training and perceived system value •
- Or a hybrid of both operational and behavior adaptation •

By employing this theoretical framework, the present research offers not just empirical results, but also conceptual clarity on how and why LIS-driven improvements are occurring in a digitally mature practice environment [115]

Chapter 3

Research Methodology

3.1 Introduction

In this chapter, the procedures to study the impact of integrated Laboratory Information Systems (LIS) on laboratory performance indicators of quality, diagnostic accuracy and turnaround time (TAT) are reviewed. A comprehensive methodology provides clarity to the work, and ensures scientific rigor and commitment to a research product that is credible, legitimate and applicable for research in a healthcare environment.

A comprehensive methodology is important, particularly with clinical laboratories having varying degrees of workflow standardization, system interoperability, and personnel competency [116]. Therefore, a comprehensive methodology must describe a clear plan for the research, which considers the research purpose, descriptive method, study population and sampling, ethical principles, and analytical techniques. This chapter will discuss research design, study population and sampling characteristics, data collection methods, instrument development, pilot study results, ethics, statistical plans, and limitations.

3.2 Research Design

In this study a quantitative descriptive, cross-sectional research design was implemented. A cross-sectional design permits the gathering of information at one point in time without impacting or changing operational workflows within the laboratory setting [117]. A cross-sectional design was appropriate given the current study's focus on measuring perceptions and practices the laboratory staff currently held about LIS use.

3.2.1 Justification for the Selected Design

The choice of this design was informed by several factors:

- It enables the collection of data from a large number of participants efficiently [118].
- It minimizes operational disruption in a healthcare environment where continuous workflow is critical.
- It allows the examination of associations between LIS integration and dependent variables (quality, accuracy, TAT) without manipulating work conditions.

3.2.2 Comparison of Alternative Designs

To demonstrate methodological validity, alternative research designs were evaluated. The comparison is shown below:

Design Type	Strengths	Limitations	Applicability in This Study
Experimental	Identifies causation	Requires intervention and randomization	☐ Not appropriate in clinical workflows
Longitudinal	Tracks change over time	Requires long-term follow-up	☐ Not feasible for timeframe
Qualitative	Rich insights	Limited generalizability	☐ Not suitable for statistical testing
Cross-sectional (selected)	Efficient, measurable, generalizable	Cannot establish causation	✓ Best fit

This comparison supports the selected design as the most practical, ethical, and scientifically aligned approach.

3.3 Study Population

The study population was comprised of clinical laboratory employees who had been employed at Dr. Sulaiman Al-Habib Hospital, Al-Suwaidi Branch at the time of data collection. These included:

- Laboratory technicians and technologists
- Clinical pathologists (consultants and specialists)
- Microbiology, hematology, and biochemistry staff
- Quality officers and LIS administrators

Work shifts included morning, evening and night duty rotation so that all staff who interact with the LIS during times of low and high workload are represented [119].

The laboratory is accredited through Joint Commission International (JCI) and the College of American Pathologists (CAP), meaning that documentation, error reporting, and transformation of workflow into digital format are all part of daily work habits.

3.4 Sample Characteristics

Table 3. Sampling Framework

Step	Description	Notes
Target Population	All laboratory staff	N = 140
Inclusion Criteria	Active LIS users with ≥ 6 months experience	Ensures familiarity
Exclusion Criteria	Administrative staff not using LIS, incomplete responses	Applied during screening
Distributed Surveys	sent electronically ¹¹²	—
Valid Responses	included in analysis ¹⁰⁰	Response rate = 71%
Calculation Formula Used	Cochran's Sample Size Formula	

3.4.1 Sampling Method

A purposive sampling technique was selected because participants needed to meet specific criteria—namely, LIS users with a minimum of six months' experience. This enhances the relevance and validity of responses [120].

3.4.2 Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
LIS users with ≥ 6 months experience	Non-LIS administrative staff
Active employment during data collection	Staff on extended leave
Voluntary participation	Incomplete survey responses

3.4.3 Final Sample Overview

A total of 112 responses were received. After applying exclusion criteria and quality checks, 100 responses were retained for analysis, representing a 71% response rate, which is considered strong in healthcare operational surveys [121].

A summary of demographic variables is provided below:

Table 3.1 Demographic Distribution of Respondents

Variable	Category	Percentage (%)
Gender	Male / Female	52 / 48
Age	<30 / 30–39 / ≥40	26 / 44 / 30
Years of Experience	<3 / 3–5 / 6–10 / >10	18 / 24 / 32 / 26
Education Level	Diploma / Bachelor / Master+	22 / 58 / 20

3.5 Sample Size Determination

The necessary sample size was determined using a standard formula for populations based on proportion, at a 95% confidence level and 5% error magnitude. With the total population (N=140), the recommended sample was approximately 103 respondents [118]. In this analysis, a sample of 100 respondents was deemed to be adequate, with the sample being only nominally less than the ideal sample requirement.

3.6 Instrument Development and Validation

Table 1. Structure of the Questionnaire

Section	Description	Number of Items	Response Format	Variable Linked
Section 1	Demographic Information (gender, age, experience, education, department)	6	Multiple choice	—
Section 2	LIS Integration (system usability, analyzer connectivity, automation, reliability, barcoding)	10	LikertScale (1 = Strongly Disagree → 5 = Strongly Agree)	Independent Variable
Section 3	Laboratory Quality and Accuracy (error reduction, documentation, workflow standardization, reporting accuracy)	12	LikertScale Point-5	& Dependent Variable 1 2
Section 4	Turnaround Time (ordering, specimen processing, reporting speed, delays, workflow efficiency)	8	LikertScale Point-5	Dependent Variable 3

3.6.1 Structure of the Questionnaire

The questionnaire contained four sections and used a mix of closed-ended items and a five-point Likert scale for perception-based questions [122]:

Section	Content
Section 1	Demographics
Section 2	LIS Integration Level
Section 3	Quality and Accuracy Indicators
Section 4	Turnaround Time (TAT) Indicators

3.6.2 Example of Survey Items

Variable	Sample Item	Scale
LIS Integration	“The LIS is fully integrated with analyzers.”	Likert 1–5
Quality	“Barcode scanning reduces specimen labeling errors.”	Likert 1–5
TAT	“Result release time has improved after LIS integration.”	Likert 1–5

3.7 Pilot Testing and Reliability

A pilot test was conducted with 15 participants from another hospital branch. Feedback confirmed that the survey language, item structure, and content were clear.

Cronbach’s alpha values showed high reliability:

Table 2. Reliability Coefficients

Scale	Cronbach’s Alpha
LIS Integration	0.88
Quality & Accuracy	0.90
Turnaround Time (TAT)	0.79
Total Scale	0.93

Values above 0.70 are considered statistically acceptable, confirming strong internal consistency [123].

3.8 Data Collection Procedure

Data collection occurred over four weeks using an electronic Google Form distributed through official communication channels. Two reminders were issued to increase participation. Raw data were exported to Excel for cleaning and transferred to SPSS Version 26 for analysis.

No personal identifiers were collected, supporting anonymity.

3.9 Ethical Considerations

The study complied with ethical guidelines for human research. Participation was voluntary, confidentiality was maintained, and there were no risks to participants. Administrative approval was secured before data collection [124].

Key ethical protections included:

- No identifiable information collected
- Secure encrypted storage
- Right to withdraw at any stage

Table 3.2: Sampling Framework

3.10 Statistical Analysis

Table 2. Statistical Analysis Mapping

Analysis Type	Purpose	Variables Used	Research Question Addressed
Descriptive Statistics	Summarize demographic characteristics and variable distribution	All variables	RQ1
Reliability Test (CronbachAlpha)	Assess internal consistency of the instrument	LIS, Quality, Accuracy, TAT	RQ2
Pearson Correlation	Examine relationships between variables	LIS vs Quality, Accuracy, TAT	RQ3
Multiple Regression	Identify predictive influence of LIS on outcomes	LIS (IV), Quality/Accuracy/TAT (DV)	RQ4

Data analysis was conducted using SPSS Version 26.

Analytical Step	Purpose
Descriptive Statistics	Summarizing demographic and variable distributions
Reliability Testing	Confirming internal consistency
Pearson Correlation	Examining relationships between variables
Regression Analysis	Assessing predictive value of LIS on outcomes

Statistical significance was set at $p < 0.05$, consistent with health science research standards [125].

3.11 Methodological Limitations

There are limitations with the methodology:

- Cross-sectional design restricts causal inference
- Self-reported perceptions
- Sampling from one site, limiting generalizability
- Minor discrepancy between calculation of sample size
- Moderate reliability for the TAT scale

That said, it is still warranted for operational assessment studies in health and social service organizations.

Chapter 4

4.1 Data Analysis (Final Correct Referenced Format)

IBM SPSS (Version 26), a prominent statistical software that is often used for statistical analysis and data management in health and behavioral sciences research [126], was the tool employed to analyze the data. Prior to analysis, data were screened for missing or incomplete responses to ensure overall integrity and trustworthiness of the results [127]. Incomplete responses were deleted or excluded, which was a strategy that fell into line with recommendations for quantitative research in health care [128].

Descriptive statistics, including frequencies, means, and standard deviations were employed to include aggregate descriptive information about the demographic characteristics and response patterns related to the study variables. This provided a first-level description of how respondents might best be described and general trends regarding LIS integration, laboratory quality, accuracy, and turnaround time.

Cronbach's Alpha was used to test the reliability of the assessment, and the results were greater than the smallest acceptable value of 0.70, establishing to our satisfaction that the questionnaire had good internal consistency and stability of measurement [130].

Next, Pearson correlation analysis was performed to assess the strength and direction of any relationships between study variables, which included LIS integration indicator, quality and accuracy indicators, and turnaround time. Pearson was the correct method to use because the study's variables were based on continuous scale variables [131].

The data were then assessed using multiple regression analysis to examine if LIS integration detected statistically significant predictions for laboratory performance outcomes. Regression analysis allowed us to quantify the amount of variance in performance indicators attributed to LIS, while controlling for demographics (e.g., years of experience, education level) [132]. Statistically significant was set at $p < 0.05$, consistent with standard research conventions in applied clinical and other quantitative research [133].

4.2 Research Findings and Discussion

This section provides a summary of the main findings of the study and discusses their implications in the context of previous studies. The relationships between laboratory information system (LIS) integration and laboratory performance indicators—quality, accuracy, and turnaround time (TAT)—were discussed using results from descriptive analysis, correlation analysis, and regression modeling. Results are addressed in the context of existing literature to confirm or refute the findings currently available.

4.2.1 Findings Related to LIS Integration and Laboratory Quality

The study results showed a moderate to strong positive correlation between LIS integration and laboratory quality and accuracy outcomes. This indicates that study participants reported expected improvements in workflow standardization, error reduction, and traceability following the implementation of LIS. This finding is consistent with earlier studies, which have stated that LIS can reduce pre-analytical and reporting errors due to features, such as enforcement of barcode identification, automated rule validation, and structured workflows [136].

The regression analysis further established that LIS integration could be considered a statistically significant predictor of laboratory quality and accuracy. This suggests that the overall usage of the system, and familiarity with the system features among the staff is an important factor to consider when measuring operational reliability. Similar findings have been reported from studies conducted in both Saudi Arabian and international settings, where the implementations of LIS were associated with measurable improvements in quality compliance and the processes of verifying test results [137][138].

4.2.2 Findings Related to LIS Integration and Turnaround Time (TAT)

Even though the integration of the LIS had an effect on TAT outcomes, its effect size was weaker compared to both quality and accuracy measures. Because regression showed that the LIS did predict TAT performance (even if at a moderate effect size) it is reasonable to conclude that TAT is still subject to other operational factors including workload intensity, whether specimens are transported efficiently or just too slowly, and staffing levels for the testing modality.

Consistent with previous research, the LIS will do its part to add automaticity and expedite result processing, but it does not operate independently of operational external flow components, in other words, things like specimen routing, clinician ordering behaviors, and analyzing capacity affect the balance of TAT outcomes (139). There is also literature available from a high-volume laboratory context with strong evidence indicating that technology alone cannot reduce turnaround time without at least adherence to workflow redesign, appropriate training, and continuous monitoring (140).

4.2.3 Interpretation of the Findings

All . . . findings point to a positive association between LIS and laboratory performance, especially in relation to precision and reducing mistakes. This is consistent with the literature that supports the importance of digital integration across clinical laboratories as critical for safe patient care delivery, accurate documentation, and improved clinical compliance and transparency [137][139].

Nonetheless, the moderate effect on TAT provides evidence that achieving full performance effects requires more than just implemented systems. This aligns with evidence to suggest that effectively implementing a LIS relies on effectively harnessing the maturity of interoperability, systems optimization, and user acceptance [140][141]. Therefore, these findings indicate that ongoing education, even monitoring, and working to align workflows are necessary components to achieve maximum utility of LIS.

4.2.4 Comparison Summary

Research Outcome	Result in This Study	Alignment With Previous Studies
Quality & Accuracy	Strong improvement and statistically significant effect	Fully aligned with literature supporting LIS error reduction
Turnaround Time	Moderate improvement; still influenced by operational factors	Partially aligned; similar findings emphasize external workflow dependencies
Overall LIS Impact	Positive but requires complementary process improvement	Consistent with global digital transformation literature

Table 4.5: Summary of Findings Compared With Literature.

4.2.5 Conclusion of the Discussion

The findings demonstrate that LIS integration contributes meaningfully to enhancing laboratory performance, particularly in quality and accuracy dimensions, while TAT improvements require additional workflow optimization efforts. The results reinforce evidence suggesting that LIS serves as a foundational component of modern laboratory automation but must be paired with human factors and system-level adjustments to achieve optimal outcomes.

4.3 Research Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the effectiveness of Laboratory Information System (LIS) integration and improve laboratory performance outcomes, including quality, accuracy, and turnaround time (TAT). The recommendations are directed toward laboratory administration, system developers, quality units, and policymakers within the healthcare institution.

4.3.1 System Optimization and Technical Improvements

- Continuous assessment and refinement of LIS functionalities should be implemented to ensure that system features align with current laboratory workflows and testing demands.
- Enhancing interoperability between LIS and other digital platforms, including instrument middleware and hospital information systems (HIS), is recommended to reduce manual steps and support seamless data flow.
- Automated alert systems for incomplete orders, delayed samples, or validation bottlenecks should be expanded to support proactive monitoring and timely interventions.

4.3.2 Staff Training and User Support

- Regular scheduled training programs should be provided for both new and experienced laboratory staff to ensure consistent and efficient system use.
- Ongoing competency assessments are recommended to identify learning gaps related to LIS functionalities and digital documentation standards.
- Establishing a dedicated technical support channel or “LIS champion team” within the laboratory may help resolve user challenges more efficiently and improve system adoption.

4.3.3 Workflow Redesign and Process Integration

- Laboratory leadership should evaluate existing operational workflows to identify non-technical barriers affecting turnaround time and accuracy.
- Redesigning specimen routing, prioritization rules, and workload balancing across shifts may help maximize the benefits of LIS automation.
- Integrating barcode tracking at all workflow points—not only at accessioning—may help further reduce pre-analytical errors and improve traceability.

4.3.4 Quality and Performance Monitoring

- Performance metrics such as error rates, repeat testing due to discrepancies, instrument-to-LIS mismatches, and TAT compliance rates should be monitored continuously.
- Developing dashboards or monthly KPI reports may support data-driven decision-making and strengthen continuous quality improvement (CQI) initiatives.
- Benchmarking performance against internal historical data and external reference laboratories is recommended to evaluate progress and identify improvement areas.

4.3.5 Policy and Governance Development

- The institution should establish or update policies related to LIS usage, digital documentation, data access, and audit tracking to ensure standardization and accountability.
- Policies supporting continuous digital transformation should prioritize investments in LIS upgrades, cybersecurity, and long-term sustainability of laboratory automation.

4.3.6 Recommendations for Future Research

- Future studies may include multi-site comparisons across different hospital branches to enhance generalizability and validate findings in larger operational environments.
 - Combining quantitative data with qualitative interviews or observational studies may provide deeper insights into human and organizational factors influencing LIS adoption.
 - Evaluating the impact of LIS on patient safety and clinician satisfaction may add value in assessing broader healthcare system outcomes.
-

Chapter 5

Conclusion of Recommendations

These recommendations emphasize system refinement, workforce development, workflow redesign, and continued performance monitoring. By implementing these actions, healthcare institutions can further optimize LIS benefits, strengthen laboratory quality and accuracy, and achieve sustainable improvements in turnaround time and overall service delivery.

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QUESTIONNAIRE BOOKLET

Research Title:

Evaluating the Impact of LIS Integration on Quality, Accuracy, and Turnaround Time in Clinical Laboratories:

A Study at Dr. Sulaiman Al-Habib Hospital – Al-Suwaidi Branch

Dear Respondent,

I am conducting a study as part of my Master's degree research titled:

“Evaluating the Impact of LIS Integration on Quality, Accuracy, and Turnaround Time in Clinical Laboratories.”

This study aims to assess how the Laboratory Information System (LIS) has influenced laboratory workflow, accuracy of results, quality, and reporting turnaround time.

Your participation is highly appreciated. Your responses will remain confidential and used only for academic purposes.

Researcher Name: _____

Email: _____

Phone: _____

Supervisor Name: _____

Email: _____

Section A: Demographic Characteristics

Please tick (✓) the appropriate choice:

1. Gender:

☐ Male ☐ Female

2. Age:

☐ 20–29 ☐ 30–39 ☐ 40–49 ☐ 50+

3. Job Position:

☐ Lab Technician ☐ Lab Technologist ☐ Specialist

☐ Supervisor ☐ IT Support ☐ Other: _____

4. Years of Experience:

☐ Less than 1 year ☐ 1–3 years ☐ 4–7 years ☐ More than 7 years

5. Have you used LIS before full implementation?

☐ Yes ☐ No

Section B: Questionnaire Statements

Scale:

5 = Strongly Agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly Disagree

I. Quality and Workflow Efficiency

Statement	5	4	3	2	1
LIS has improved workflow efficiency.	☐	☐	☐	☐	☐
LIS helps reduce duplicated work and delays.	☐	☐	☐	☐	☐

II. Accuracy and Error Reduction

Statement	5	4	3	2	1
LIS reduces manual data entry errors.	☐	☐	☐	☐	☐
LIS improves traceability and verification.	☐	☐	☐	☐	☐

III. Turnaround Time (TAT)

Statement	5	4	3	2	1
LIS contributes to faster reporting time.	☐	☐	☐	☐	☐
LIS improves sample tracking and reporting speed.	☐	☐	☐	☐	☐

IV. User Experience & Support

Statement	5	4	3	2	1
LIS is easy to use and user-friendly.	☐	☐	☐	☐	☐
Training and technical support for LIS are sufficient.	☐	☐	☐	☐	☐

Section C: Open-Ended Questions

C1. What is the most helpful feature of LIS in your daily work?

C2. What challenges or improvements would you recommend?

✓ **Thank you for your participation.**