

An Ontological Design Model for Integrating Notification, Appointment, and Queue in Healthcare Queue Systems

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Abstract—Healthcare queue systems frequently suffer from prolonged waiting times, overcrowding, and inefficient patient flow management. Although various Queue Management Systems (QMS) have been developed, most existing solutions treat notification, appointment scheduling, and queue management as independent components. This fragmented design limits semantic clarity, adaptability, and reusability. This study proposes an ontology-based design model, termed *OntoNAQ*, which integrates Notification, Appointment, and Queue (NAQ) into a unified conceptual framework for healthcare queue systems. The study adopts the Design Science Research Methodology (DSRM) to identify conceptual gaps, design the ontological model, and demonstrate its applicability through prototype mapping and qualitative evaluation. The findings indicate that *OntoNAQ* provides explicit semantic relationships among NAQ components and serves as a reusable and theoretically grounded conceptual foundation for healthcare queue system design.

Keywords—*Ontology-based design; queue management system; appointment scheduling; notification system; healthcare information systems; design science research*

I. INTRODUCTION

Healthcare service delivery systems continue to experience persistent challenges related to patient waiting time, congestion in waiting areas, and inefficient patient flow management. Despite the widespread adoption of digital Queue Management Systems (QMS), long waiting times remain a recurring issue, particularly in public hospitals and outpatient clinics where patient volumes are high, and service capacity is constrained [1-4].

To mitigate these issues, healthcare providers have increasingly adopted appointment-based scheduling systems, mobile notification services, and electronic queue displays. Appointment systems aim to regulate patient arrivals by allocating service time slots in advance, while notification systems are commonly used to remind patients of their scheduled visits or inform them of delays. Queue systems manage the sequencing of patients for service delivery based on predefined rules. Although widely implemented, these components are typically designed and deployed as independent system modules with limited conceptual integration [5-7].

Empirical evidence indicates that this fragmented approach contributes to operational inefficiencies rather than resolving

them. Notifications are often delivered without awareness of real-time queue conditions, while queue systems operate without explicit consideration of appointment semantics [8-9]. In this study, we argue that the underlying issue is conceptual rather than technological, motivating the need for a unified knowledge model integrating notification, appointment, and queue components.

This study proposes *OntoNAQ*, an ontology-based design model that addresses conceptual fragmentation by formalizing semantic relationships among notification, appointment, and queue components. Developed using the DSRM, *OntoNAQ* emphasizes semantic relationships and reusability rather than algorithmic optimization.

This research makes three main contributions. First, it provides a comprehensive comparative analysis of 30 prior studies to identify conceptual fragmentation in healthcare queue systems. Second, it proposes *OntoNAQ*, an ontology-based design model that explicitly integrates notification, appointment, and queue components at the knowledge level. Third, it demonstrates the applicability of the proposed model through prototype mapping and qualitative evaluation within a Design Science Research framework.

II. BACKGROUND AND RELATED WORK

A. Healthcare Queue Management Systems

Healthcare Queue Management Systems (QMS) have traditionally been designed to manage patient flow by determining the order of service delivery and estimating waiting times using established queueing mechanisms such as First-In-First-Out (FIFO), priority-based queues, or rule-driven scheduling. These approaches are effective for basic sequencing and operational control, particularly in environments with relatively stable arrival patterns and predictable service durations. Numerous studies have demonstrated that such mechanisms can improve transparency and fairness in service delivery by providing patients with clear expectations regarding their position in the queue and anticipated waiting time [10-12]. As a result, QMS have become a fundamental component in outpatient clinics and hospital service counters to mitigate overcrowding and administrative inefficiencies.

However, despite these advantages, conventional QMS exhibit limitations when patient arrival patterns are highly

variable and influenced by external factors such as appointment adherence, walk-in behavior, emergency cases, and operational disruptions. In many real-world healthcare settings, patient arrivals are not purely stochastic but are shaped by appointment schedules, notification effectiveness, and individual patient behavior. Advanced electronic QMS have been introduced to enhance visibility and real-time monitoring of queues; nevertheless, these systems often operate as standalone modules that are weakly coupled with appointment scheduling and notification services [11]. This fragmented implementation restricts the system's ability to adapt dynamically to changes in patient flow, leading to inefficiencies such as early arrivals, idle service capacity, or unanticipated congestion. Consequently, the effectiveness of QMS is constrained not by queuing algorithms alone, but by the lack of conceptual integration with other interdependent components of healthcare service delivery.

B. Appointment Scheduling Systems

Appointment scheduling systems are widely adopted in healthcare settings to regulate patient arrivals, optimize resource utilization, and reduce excessive waiting times by allocating predefined service slots. By assigning specific time windows to patients, these systems aim to balance service demand with available clinical capacity, thereby improving operational efficiency and patient experience. Prior studies have shown that structured appointment scheduling can reduce congestion in waiting areas, improve staff workload distribution, and enhance predictability in service delivery [7, 12]. As a result, appointment-based systems have become a core component of outpatient clinic management and are often regarded as a primary mechanism for controlling patient flow.

Nevertheless, the effectiveness of appointment scheduling is frequently undermined by real-world behavioral and operational factors such as early arrivals, late arrivals, no-shows, and unexpected service delays. When appointment systems operate independently from queue management mechanisms, deviations from scheduled arrival times can propagate downstream, causing queue instability and inefficient resource utilization. For instance, early arrivals may contribute to premature congestion, while no-shows and prolonged consultations can result in idle service capacity or cascading delays. Without explicit integration between appointment schedules and real-time queue dynamics, appointment systems lack the semantic awareness required to adapt to changing conditions [7, 12]. This limitation highlights that appointment scheduling alone is insufficient to manage patient flow effectively, reinforcing the need for an integrated conceptual framework that aligns appointment semantics with queue behavior.

C. Notification Systems

Notification systems in healthcare are primarily employed to communicate information such as appointment reminders, schedule confirmations, and delay alerts to patients. These systems are typically implemented using communication channels, including short message service (SMS), mobile applications, emails, or automated calls. Prior studies indicate that timely notifications can improve appointment adherence, reduce no-show rates, and provide patients with greater certainty regarding their visit schedules [5]. As such, notification systems are often positioned as supportive tools that enhance patient

engagement and operational efficiency within healthcare service delivery.

Despite their potential impact on patient arrival behavior, notification systems are frequently designed as standalone communication modules that operate independently from appointment scheduling and queue management processes. In many implementations, notifications are triggered based on static appointment data rather than real-time queue states or service progression. Consequently, patients may receive reminders or delay messages that do not accurately reflect current queue conditions, limiting the system's ability to regulate patient arrivals dynamically. The absence of semantic linkage between notification content, appointment status, and queue dynamics restricts the effectiveness of notifications as a control mechanism for patient flow [5]. This fragmentation underscores the need for a unified conceptual model in which notifications are context-aware and semantically integrated with appointment and queue components to support coordinated and adaptive healthcare queue management.

D. Ontology-Based Approaches in Healthcare

Ontology-based approaches have been increasingly adopted in healthcare information systems to enhance semantic interoperability, structured knowledge representation, and data integration across heterogeneous systems. By providing explicit definitions of domain concepts and their relationships, ontologies enable consistent interpretation of clinical data and support interoperability between disparate systems such as electronic health records, appointment platforms, and decision support tools [13]. Ontological models have also been applied in specialized healthcare domains, including health tourism, continuity of care, and personalized service configuration, demonstrating their effectiveness in formalizing complex domain knowledge and improving system extensibility [14]. These studies highlight the role of ontologies as foundational knowledge artefacts that facilitate reuse, reasoning, and long-term system evolution.

Despite these advances, the application of ontology-driven design in healthcare queue management systems remains relatively limited, particularly in terms of integrating notification, appointment, and queue components within a unified semantic framework. Existing ontology-based solutions tend to focus on specific aspects such as patient records, service workflows, or booking processes, while treating queue management and notification mechanisms as operational or implementation-level concerns. As a result, the semantic relationships among appointment scheduling, real-time queue states, and notification triggers are often not explicitly modeled. This limitation constrains the ability of healthcare QMS to achieve coordinated behavior and adaptive response to dynamic service conditions. The absence of a comprehensive ontological model that explicitly integrates notification, appointment, and queue concepts underscores a clear research gap, motivating the need for an ontology-based design model that addresses NAQ integration at the conceptual level.

E. Comparative Analysis and Research Gap

To systematically identify research gaps in existing healthcare queue system studies, a comparative analysis of 30

Prior works were conducted, focusing on their treatment of Notification (N), Appointment (A), and Queue (Q) aspects.

Table I summarizes the scope and focus of these studies, highlighting whether each aspect is explicitly addressed.

TABLE I. COMPARATIVE ANALYSIS OF 30 PRIOR STUDIES ON HEALTHCARE QUEUE SYSTEMS

No.	Author(s)	Title	Notification Aspect (N)	Appointment Aspect (A)	Queuing Aspect (Q)
1.	[15]	Strategic timing of arrivals to a queuing system with scheduled customers	×	✓	✓
2.	[16]	Education on Utilization of Online Queuing Application Based on Khanza Health Information System for Patients and Families	×	✓	✓
3.	[14]	An Ontology-Based Booking Application for Personalized Packages in the Health Tourism Industry	×	✓	✓
4.	[11]	Decision support system for appointment scheduling and overbooking under patient no-show behavior	×	✓	✓
5.	[17]	Robust Appointment Scheduling with Waiting Time Guarantees	×	✓	✓
6.	[12]	Asymptotically Optimal Appointment Scheduling in the Presence of Patient Unpunctuality	×	✓	✓
7.	[18]	A queuing-based approach for integrated routing and appointment scheduling	×	✓	✓
8.	[19]	A generalized petri net-based modeling framework for service reliability evaluation and management of cloud data centers	×	×	✓
9.	[20]	Semantic Web in Healthcare Systems	×	×	✓
10.	[10]	Machine Learning for Prediction of Wait Times in Outpatient Clinic	×	✓	✓
11.	[13]	FHIR Based ContSys Ontology to Enable Continuity of Care Data Interoperability	×	✓	×
12.	[4]	Queuing Theory: Contributions and Applications in the Field of Health Service Management - A Bibliometric Approach	×	×	✓
13.	[21]	Centralized and automated healthcare systems: A essential smart application post Covid-19	✓	×	✓
14.	[9]	Zero queue maintenance system using smart medicare application for Covid-19 pandemic situation	✓	✓	✓
15.	[22]	An optimized queue management system to improve patient flow in the absence of appointment system	×	×	✓
16.	[8]	Mobile-augmented smart queue management system for hospitals	✓	✓	×
17.	[23]	Queuing models for patient-flow dynamics in inpatient wards	×	×	✓
18.	[24]	Patient Queue Systems in Hospital Using Patient Treatment Time Prediction Algorithm	×	×	✓
19.	[25]	Queue Management in Non-Tertiary Hospitals for Improved Healthcare Service Delivery to Outpatients	✓	✓	×
20.	[26]	Healthcare Management System in Android – “meD4U” Application	✓	✓	×
21.	[27]	A central-limit-theorem version of the periodic Little’s law	×	×	✓
22.	[7]	Little's law based validation framework for load testing	×	×	✓
23.	[28]	Hospital queue control system using Quick Response Code (QR Code) as verification of patient's arrival	×	×	✓
24.	[29]	‘Walk - Away’ Queue Management System Using MySQL and Secure Mobile Application	✓	✓	×
25.	[5]	Patient Queue Management System	✓	✓	×
26.	[32]	Framework for patient service queue System For Decision Support System on Smart Health Care	×	✓	✓
27.	[31]	Pttp Algorithm and Its Benefits in Hospital Queuing Recommendation System	×	×	✓
28.	[30]	Hospital capacity management based on the queuing theory	×	×	✓
29.	[1]	Multiple Queue Management With Real Time Tracking For OPD Scheduling In Hospitals	✓	✓	✓
30.	[32]	Hospital service queue management system with wireless approach	×	×	✓

As shown in Table I, most prior studies focus heavily on queue optimization and appointment scheduling, with notification mechanisms often treated as secondary or supporting features. While several studies address more than one aspect concurrently, such integration is largely functional rather than conceptual. Notably, none of the reviewed studies proposes an ontology-based model that explicitly integrates notification,

appointment, and queue components within a unified knowledge framework. This finding highlights a clear conceptual gap in existing research and provides the primary motivation for the development of the OntoNAQ model.

The comparative analysis of prior studies indicates that existing research on healthcare queue management systems

largely adopts a fragmented perspective, with most works concentrating on queue optimization, appointment scheduling, or notification services as independent functional components. Studies focusing on queue management primarily emphasize sequencing mechanisms and waiting time reduction, while appointment scheduling research addresses resource allocation and arrival regulation without explicit consideration of real-time queue dynamics. Similarly, notification systems are commonly treated as auxiliary communication tools aimed at improving attendance or informing patients of delays, rather than as integral elements that actively influence queue behavior. Although several studies acknowledge interactions among these components at an operational level, such integration is typically implemented in an ad hoc or system-specific manner, lacking explicit semantic modeling of their interdependencies. Moreover, ontology-based approaches in healthcare have predominantly focused on data interoperability, clinical knowledge representation, or domain-specific applications, with limited attention given to the conceptual integration of notification, appointment, and queue components within healthcare QMS. Consequently, the underlying knowledge structure governing NAQ interactions remains implicit, hindering reusability, adaptability, and coherent system evolution. This analysis reveals a clear research gap, highlighting the absence of a unified ontological design model that explicitly formalizes the semantic relationships among notification, appointment, and queue components as an integrated conceptual framework.

III. METHODOLOGY

This study adopts the DSRM as it focuses on artefact construction and conceptual contribution rather than hypothesis testing. In the problem identification phase, a systematic literature review of 30 prior studies on healthcare queue systems was conducted to identify conceptual fragmentation between notification, appointment, and queue components. In the objective definition phase, the study formulated the design goal of establishing a unified conceptual model capable of semantically integrating these components. During the design and development phase, the OntoNAQ model was constructed by defining core domain entities, their attributes, and relationships based on ontology design principles. The demonstration phase involved mapping the OntoNAQ concepts to a prototype healthcare queue system architecture to illustrate how the ontology can guide system structuring. The evaluation phase was conducted qualitatively by assessing conceptual completeness, integration capability, reusability, and semantic clarity. Finally, the communication phase presents the artefact, evaluation outcomes, and research contributions to the academic community. The research follows six DSRM phases given by [33]: problem identification, objective definition, design and development, demonstration, evaluation, and communication, with OntoNAQ positioned as a conceptual design artefact that formalizes Notification-Appointment-Queue (NAQ) integration at the knowledge level. Fig. 1 illustrates the research process and highlights how problem identification, artefact design, demonstration, and evaluation are systematically aligned.

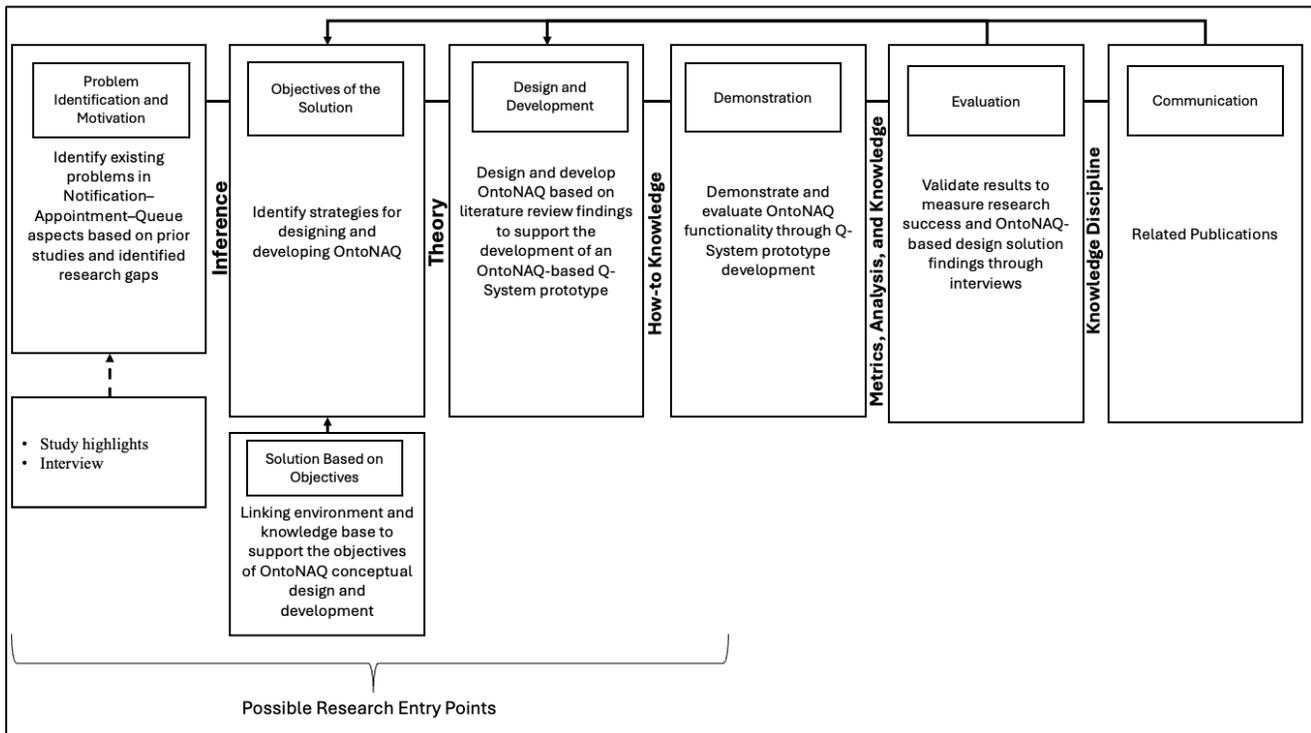


Fig. 1. Design science research process for OntoNAQ development.

The DSRM process ensures that OntoNAQ is grounded in identified research gaps, systematically developed, and evaluated as a conceptual design artefact rather than a system-specific implementation. In this work, DSRM-based Ontology

Development Methodology can be seen as another version of Ontology Development Methodology (ODM), where DSRM key phases are rooted for ontology design and development activities, as demonstrated in another research work by [34, 35].

IV. ONTONAQ DESIGN MODEL

OntoNAQ is an ontology-based design model that integrates notification, appointment, and queue components as interdependent knowledge elements. The model defines core concepts such as Patient, Appointment, Queue, Queue Status, Notification, and Notification Trigger, along with their semantic relationships. OntoNAQ explicitly models appointment-queue, queue-notification, and appointment-notification relationships, enabling coordinated workflows and reducing conceptual ambiguity. The model emphasizes reusability and extensibility by abstracting NAQ integration from implementation-specific details.

Although OntoNAQ is presented primarily as a conceptual ontology, the model can be formally represented using standard ontology representation languages such as the Web Ontology Language (OWL). In such a representation, entities such as Patient, Appointment, Queue, and Notification can be defined as ontology classes, while relationships such as hasAppointment, generatesQueueEntry, and triggersNotification can be represented as object properties. Ontological axioms may define constraints such as: 1) each Queue entry must be associated with exactly one Appointment instance, and 2) notification events may be triggered when queue status changes occur. These formal axioms enable reasoning engines to infer system states, such as identifying patients who should receive notifications based on queue progression. Future implementations may utilize ontology reasoning tools such as Protégé or OWL reasoners to validate ontology consistency and support intelligent queue management.

Fig. 2 presents the conceptual framework of OntoNAQ, illustrating the interaction among the three main components: Notification, Appointment, and Queue. These components are modeled as interdependent knowledge elements rather than independent system modules. Appointment scheduling regulates patient arrival patterns, queue management determines service sequencing, and notification mechanisms communicate system status to patients. The ontology defines explicit semantic relationships between these components, allowing events in one component to influence the behavior of others. For instance, queue status changes may trigger notifications, while appointment updates can dynamically modify queue entries.

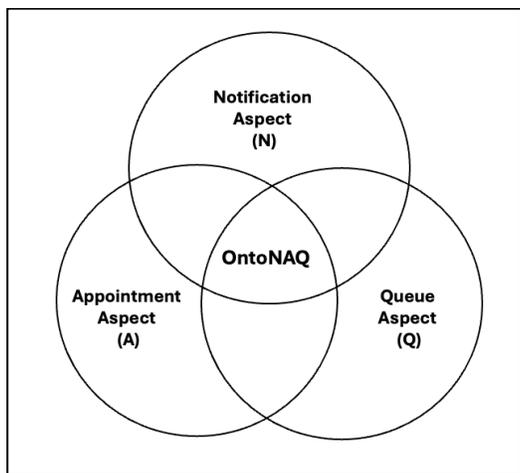


Fig. 2. Conceptual framework of the OntoNAQ model.

Appendix A further elaborates the semantic relationships among notification, appointment, and queue entities, highlighting how changes in one component propagate to others within the integrated NAQ framework.

Fig. 3 presents the core ontological structure of OntoNAQ, defining the key entities, attributes, and relationships that form the conceptual backbone of the proposed model. The Patient entity is associated with Appointment instances, which generate Queue entries when the patient arrives at the healthcare facility. Queue states represent the dynamic position of patients within the service process. Notification entities are triggered by changes in appointment status or queue conditions, ensuring that patients receive timely updates regarding their service progress.

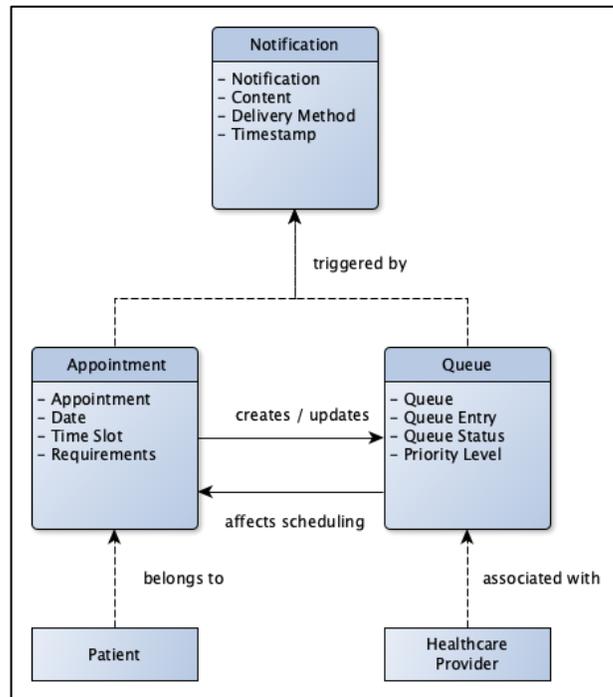


Fig. 3. Core Ontological Structure of OntoNAQ.

V. DEMONSTRATION

This section demonstrates the applicability of the proposed OntoNAQ design model and provides a qualitative evaluation of its usefulness as a conceptual artefact for healthcare queue system design. In accordance with the Design Science Research Methodology, the purpose of this phase is not to measure operational performance metrics, but to assess whether the artefact adequately addresses the identified research problem and fulfills its intended design objectives.

A. Demonstration Through Prototype Mapping

OntoNAQ was demonstrated through the development of a healthcare queue system prototype designed for outpatient settings. The prototype includes three core functional modules: appointment management, queue management, and notification management, which were structured based on the ontological relationships defined in OntoNAQ. Rather than serving as a full-scale system evaluation, the prototype acts as a proof-of-concept illustrating how the ontology guides system structuring and interaction flow.

The mapping between OntoNAQ concepts and system components demonstrates that appointment entities generate and update queue entries, queue status changes act as triggers for notifications, and notification delivery influences patient arrival behavior and scheduling dynamics. This mapping confirms that OntoNAQ can be operationalized as a design reference that informs system logic without prescribing specific technologies or algorithms.

B. Evaluation Criteria

To evaluate OntoNAQ as a design artefact, a qualitative assessment was conducted based on four evaluation dimensions commonly applied in ontology-based and design science research: conceptual completeness, integration capability, reusability, and design clarity (see Table II). These criteria focus on the artefact’s ability to address conceptual fragmentation rather than on quantitative system performance.

TABLE II. QUALITATIVE EVALUATION OF ONTONAQ AS A DESIGN ARTEFACT

Evaluation Aspect	Description	Observation
Conceptual Completeness	Ability to represent key entities and relationships related to notification, appointment, and queue	OntoNAQ explicitly models core NAQ entities and their dependencies
NAQ Integration Capability	Degree to which NAQ components are semantically integrated	Appointment, queue, and notification are modeled as interdependent concepts
Design Reusability	Applicability across different healthcare contexts	Ontology is independent of implementation and domain-specific technologies
Semantic Clarity	Clarity of relationships and system behavior	Explicit relationships reduce ambiguity in system design
Practical Applicability	Ability to inform real system development	Demonstrated through prototype mapping

The evaluation indicates that OntoNAQ sufficiently fulfills its role as a conceptual design artefact by addressing the research gap identified in prior studies. While the evaluation does not measure operational efficiency, it confirms that the ontology provides a coherent and reusable knowledge structure for healthcare queue system design.

To demonstrate how the proposed ontology informs practical system design, an abstract operational architecture is presented.

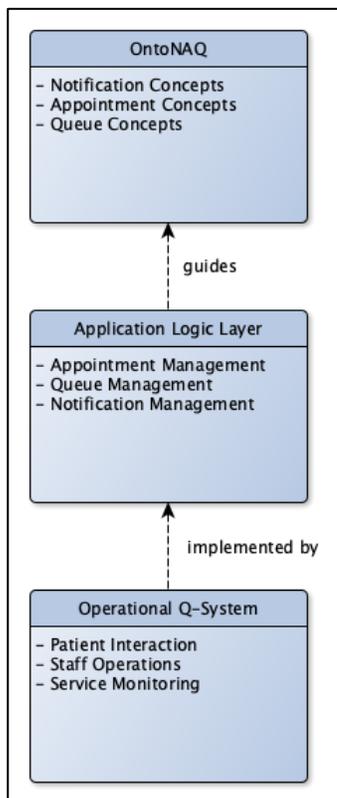


Fig. 4. Operational architecture of the Q-system based on OntoNAQ.

Fig. 4 illustrates how OntoNAQ provides semantic guidance to the application logic and operational layers without prescribing implementation-specific mechanisms or system workflows.

Although the prototype presented in this study primarily serves as a conceptual mapping exercise, the OntoNAQ model can be implemented within typical healthcare information system environments. For example, the ontology can be represented using ontology modeling languages such as OWL and integrated with hospital information systems through REST-based service architectures. Appointment data, queue states, and notification triggers can be linked to existing electronic medical record systems or appointment platforms. In practical deployments, notification services may be implemented through mobile applications or SMS gateways, while queue updates can be synchronized with real-time hospital operational databases. This illustrates how the ontology can guide system architecture even though the current study focuses on conceptual design rather than full-scale system implementation.

VI. DISCUSSION

This section discusses the significance of OntoNAQ in relation to existing healthcare queue system research, highlighting its conceptual contribution, design implications, and alignment with Design Science Research objectives. This further positions OntoNAQ as a foundational design contribution rather than an alternative optimization technique.

A. Addressing Conceptual Fragmentation in Prior Studies

The comparative analysis of 30 prior studies reveals that existing healthcare queue system research predominantly focuses on individual components, queue optimization, appointment scheduling, or notification delivery, often in isolation. Even studies that consider more than one component tend to emphasize functional integration rather than conceptual integration. As a result, system behavior remains fragmented, and design decisions are frequently implemented in an ad hoc manner.

OntoNAQ addresses this limitation by introducing a unified ontological structure that explicitly defines the semantic relationships among notification, appointment, and queue components. By elevating NAQ integration to the knowledge level, OntoNAQ provides a conceptual foundation that complements existing algorithmic and optimization-based approaches rather than competing with them.

B. OntoNAQ as a Design Science Artefact

From a Design Science perspective, OntoNAQ fulfills the characteristics of a valid artefact by providing a prescriptive solution to a clearly identified problem. The ontology is grounded in systematic literature analysis, constructed through explicit design principles, and demonstrated in a realistic application context. Unlike system-specific frameworks, OntoNAQ abstracts NAQ integration from implementation details, enabling long-term maintainability and adaptability.

This abstraction is particularly relevant in healthcare environments, where system requirements frequently evolve due to policy changes, patient volume fluctuations, and technological advancements. OntoNAQ supports such evolution by offering a stable conceptual backbone upon which system enhancements can be layered. By positioning ontology as a design artefact rather than an implementation mechanism, OntoNAQ complements existing optimization-driven studies and extends the design space of healthcare queue systems.

C. Implications for System Designers and Researchers

For system designers, OntoNAQ serves as a reference model that clarifies how appointment scheduling, queue management, and notification mechanisms should interact semantically. By making these relationships explicit at the knowledge level, the model reduces reliance on implicit assumptions and ad hoc design decisions, thereby improving consistency, maintainability, and system extensibility. For researchers, OntoNAQ provides a conceptual baseline that can support future studies involving predictive analytics, optimization algorithms, and empirical performance evaluation, particularly in complex and dynamic healthcare environments.

Beyond immediate design guidance, the integration of ontology with Artificial Intelligence (AI) presents important implications for the evolution of healthcare queue management systems. Traditional queue systems predominantly rely on static rules such as first-come-first-served or simple priority mechanisms, which are limited in their ability to respond to dynamic service conditions and heterogeneous patient behavior. AI-based queue management approaches enhance these capabilities by enabling real-time data analysis, predictive modeling, and dynamic decision-making that can adjust service delivery based on live operational conditions. In this context, ontologies provide a foundational semantic layer that enables AI components to interpret operational data meaningfully by capturing explicit relationships among patients, appointments, queue states, and notification triggers. Rather than competing with AI-driven optimization techniques, ontology-based design models such as OntoNAQ function as stable knowledge foundations that support intelligent, adaptive, and scalable queue management solutions, enabling more effective and personalized service experiences [36].

D. Limitations and Future Work

Despite its contributions, this study has several limitations. The evaluation presented is qualitative in nature and does not include quantitative performance measurements such as waiting time reduction or throughput improvement. Additionally, the demonstration is limited to a prototype implementation, which may not capture the full complexity of large-scale healthcare systems. Future research may extend OntoNAQ by integrating predictive and optimization techniques to assess operational impact quantitatively. Empirical studies across multiple healthcare institutions would further strengthen the generalizability and practical relevance of the proposed model.

VII. CONCLUSION

This study proposed OntoNAQ, an ontology-based design model that integrates notification, appointment, and queue components within healthcare queue management systems. Through a comparative analysis of 30 prior studies, the research identified a significant conceptual gap in existing approaches, where these components are typically treated as independent system modules. OntoNAQ addresses this gap by formalizing semantic relationships among key healthcare service entities, thereby providing a unified conceptual framework for system design.

The study contributes theoretically by introducing a reusable ontological structure that clarifies the interaction between appointment scheduling, queue dynamics, and notification mechanisms. This integration enhances semantic clarity and supports the development of more adaptive healthcare queue systems. The demonstration through prototype mapping further illustrates how OntoNAQ can guide system architecture and operational logic.

However, this study has several limitations. The evaluation remains qualitative and does not include quantitative performance analysis using real hospital datasets. Additionally, the prototype demonstration focuses on conceptual mapping rather than a full system implementation. Future research may extend this work by implementing the ontology in real healthcare environments, integrating predictive analytics and optimization algorithms, and conducting empirical evaluations using operational hospital data.

Overall, OntoNAQ provides a foundational knowledge framework that can support future research and system development in healthcare information systems, particularly in designing intelligent and semantically integrated queue management solutions.

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APPENDIX A

Integrated Ontological Relationships among Notification, Appointment, and Queue

