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Design and Implementation of a TOGAF and UX-Driven Decision Support Service System for Academic Libraries: A Case Study of Shanghai Maritime University Library

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Abstract

A Decision Support Service System (DSSS) for academic libraries is proposed by combining the TOGAF business architecture with User Experience (UX) design principles. The proposed framework is organised into three interconnected layers: the business layer, which manages data integration and service workflows; the information layer, which supports data governance and application interoperability; and the technology layer, which incorporates system components and security features. These layers are structured in accordance with Garrett's UX framework. The implementation of automated tools for handling real-time user requests at Shanghai Maritime University Library demonstrated improvements in both operational efficiency and user satisfaction. By integrating modular TOGAF components with role-oriented interface customisation, the framework establishes effective collaboration between library administrators, acting as solution seekers, and stakeholders serving as solution providers. Achieving sustained service enhancement depends on modernised digital service policies, effective leadership practices, and the adoption of analytical decision-support tools. Furthermore, the proposed architecture allows academic libraries to continuously adapt their collections and services to changing educational demands while ensuring scalability, security, and ongoing refinement through continuous feedback.

Keywords: Enterprise Architecture (EA), TOGAF, User Experience (UX), Decision Support Service System (DSSS), Academic Library.

Introduction

Academic libraries hold significant advantages in the era of big data, particularly through their capabilities in data acquisition, integration, processing, and application. Sustaining their relevance and influence within modern higher education requires these institutions to capitalise on such strengths to enhance both research support and evidence-based decision-making (Rafi et al., 2020; Tiwari and Madalli, 2021). By drawing upon extensive literature collections and diverse data resources, university libraries deliver decision support services that assist institutional operational agencies.

Librarians utilise their professional knowledge, analytical expertise, and specialised tools to identify relevant information, synthesise research evidence, conduct scientific investigations, and consolidate

data from multiple sources. This integrated approach provides administrators with comprehensive and actionable intelligence, enabling more informed and timely decisions while improving organisational performance (Li et al., 2017). At the same time, the evolving landscape of higher education requires academic libraries to continually transform their services, ensuring they respond more efficiently and effectively to the expanding and increasingly diverse demands of research and teaching activities (Tammaro et al., 2019).

Libraries continually refine their service models in response to advances in information technology, shaped by evolving user expectations and the ongoing exploration of innovative service approaches and delivery models (Chen et al., 2024). To ensure that services remain aligned with user requirements, libraries must place users' needs at the centre of service development while maintaining effective communication channels to evaluate satisfaction and improve service quality (Obinyan, 2021; Pangestu and Setyawan, 2024). Concurrently, decision-support services in libraries have become increasingly dependent on advanced technologies and large-scale data analytics. Accordingly, libraries should actively track technological progress and integrate emerging innovations to enhance the precision and effectiveness of decision-support functions (Han, 2023). Achieving these objectives also requires a robust technical architecture capable of supporting reliable data acquisition, management, and analysis (Iqbal and Wali, 2022).

Existing research on subject-oriented decision-support services in academic libraries indicates a gradual shift towards more diversified service provision. Nevertheless, comprehensive evaluations and systematic methodologies for designing such service systems remain insufficiently explored. To address this limitation, the present study investigates the decision-support services implemented at Shanghai Maritime University Library (SMUL). Semi-structured interviews were conducted with 13 stakeholders representing multiple decision-making levels, including research teams, departmental managers, functional departments, and senior executives. Thematic analysis was employed to identify their requirements relating to disciplinary development, institutional collaboration, and competitive advantage. Based on these findings, the study integrates TOGAF (The Open Group Architecture Framework) with UX design principles to develop a customised decision-support service architecture for academic libraries. The proposed framework provides practical guidance for institutions and practitioners seeking to establish comparable decision-support systems.

Literature Review

Library Decision Support Services

Liu (2024) highlights the importance of incorporating innovative service models and emerging technologies to strengthen the quality and effectiveness of library services. Within this context, bibliometrics has emerged as a key component of academic library decision-support services. Corrall et al. (2013) identify bibliometric analysis as one of the most extensively adopted forms of researcher support, encompassing services such as bibliometric training, research impact assessment, citation analysis, discipline-specific trend evaluation, h-index calculation, recruitment evaluation, promotion and tenure assessment, and support for grant applications. Building on this foundation, Smolinsky and Lercher (2020), Goksu et al. (2022), Sidiq et al. (2020), Garg et al. (2020), Griffin (2020), and Aytac and Tran (2021) have contributed specialised studies that further advance bibliometric analysis within library and research contexts.

Research Data Management (RDM) represents a structured approach to managing research data throughout its entire lifecycle. According to Ashiq et al. (2020), RDM comprises activities including data planning, design, utilisation, curation, preservation, and subsequent reuse. Cox et al. (2019) argue that research libraries should establish RDM as a core service to safeguard data quality, integrity, and long-term accessibility. Likewise, Kennan et al. (2014) underscore the critical role of RDM services in enhancing institutional research support. Extending this perspective, Duan and Wang (2021) examine the application of data mining techniques within academic library services and propose an association rule mining approach designed to address the distinctive requirements of academic collection management systems.

Library Services Based on User Experience

User Experience (UX) has become a fundamental consideration in the design and delivery of systems and services. Originally introduced by

Donald Norman during the mid-1990s, the concept emphasises the quality of users' interactions with products, services, and systems (Norman, 1999). In line with this perspective, the international standard ISO 9241-210 on the ergonomics of human-system interaction defines UX as "the individual's subjective experience when using or evaluating a product, system, or service." This widely accepted definition encompasses users' emotions, expectations, attitudes, perceptions, physiological and psychological responses, behaviours, and resulting outcomes across every stage of interaction, including the periods before, during, and after use (Berni and Borgianni, 2021).

Within academic libraries, user behaviour and evolving expectations are central to the design and continuous improvement of library services. Konopik et al. (2022) emphasises that user-centred design principles and personalised service frameworks are essential for responding effectively to the changing requirements of library patrons in the digital era. Similarly, Connaway et al. (2011) enhances the understanding of library service development by systematically examining users' information-seeking behaviours, thereby redirecting research attention from broad institutional perspectives towards more detailed analyses of individual user interactions. Tipton (2014) advocates content-focused engagement strategies capable of addressing the diverse needs of readers while encouraging universities to continually improve service quality through ongoing technological and methodological advancements.

Through a comprehensive case study of the University of Winnipeg Library, Luo and Buer (2015) illustrates that discipline-oriented library services contribute to higher levels of user satisfaction, reinforce institutional reputation, and facilitate effective stakeholder feedback mechanisms. Complementing these findings, Pant (2015) investigate students' interactions with academic library mobile platforms and provide evidence-based recommendations for improving the usability and accessibility of mobile interfaces.

Empirical Research

Islam et al. (2021) examines quantitative data collected from 211 academic librarians working in Pakistani universities to assess library performance. The study demonstrates that the adoption of big data analytics significantly improves operational efficiency, optimises resource allocation, and increases user satisfaction. Likewise, the Library of the Technical University of Munich contributes actively to institutional self-evaluation and academic recruitment by engaging with university leadership through biannual roundtable meetings, where evidence-based strategies are developed to strengthen the institution's global ranking performance (Lazarev and Yurik, 2022).

A similar approach is adopted by the University of Gothenburg Library, which has provided continuous decision-support services to the university's administrative division since 2008 through tailored bibliometric analyses for faculties, departments, and individual researchers (Åström and Hansson, 2013). Silva et al. (2016) conduct a systematic assessment of services across three Australian universities and identify a broad portfolio of research support activities, including research consultation, technical writing assistance, computational support, milestone planning, language services, and guidance on research commercialisation. In Pakistan, more than half of university libraries reportedly deliver research support throughout the entire postgraduate journey, extending from student enrolment to career development after graduation (Hussain and Rafiq, 2025). In addition, numerous institutions ranked among the top 100 universities in the 2021 QS World University Rankings have incorporated data visualisation technologies into their library services, demonstrating a strategic commitment to strengthening advanced research infrastructure (Zakaria, 2021).

Materials and Methods

Expert Interviews

A comprehensive understanding of decision-makers' requirements is fundamental to the development of effective decision-support services. In the context of academic libraries, this study identifies five principal categories of decision-makers: university research teams, faculty leaders, departmental administrators, senior policymakers, and industry partners. To obtain primary empirical evidence, semi-structured interviews were conducted with 13 participants who regularly utilised decision-support services. All interview data were transcribed and systematically coded to identify the factors shaping users' experiences. Table 1 presents an overview of the participants' roles, information needs, and functional requirements.

Table 1: Key Decision-Making Information Needs of Respondents.

Role	Content	Timing	Interaction	Function
Member of the Research Team	Identifying academic research collaborators	On-demand	Online platform inquiry and contact	Partner matching and recommendation
Dean, School of Information Engineering	Computer science discipline development and competitive advantage analysis	Irregular (timely alerts)	Visualized reports; interactive data analysis	Comparative analysis tools; trend prediction models
Research Team Leader	Latest research trends and hotspots	Monthly updates + real-time alerts	Customized email reports	Research trend tracking and hotspot analysis
Director, Information Department (Port)	Domestic/international port construction and data dynamics	Monthly updates	Website information services; email report delivery	Data visualization; port benchmarking
Director, Development Planning Office	Disciplinary planning; university data analysis	Annual statistics + real-time data	Customized reports via email/platform	Disciplinary data forecasting
Director, Human Resources Department	Talent recruitment performance and assessment	Irregular	Online evaluation reports; achievement inquiries	Performance assessment models; talent matching; publication statistics
Director, Science and Technology Dept.	Academic competitive advantage analysis	Regular updates + real-time alerts	Online statistical reports	Competitive advantage models; subject rankings; publication analytics
Vice-President (University)	Disciplinary development and strategic planning	Periodic	Thematic reports via email/platform	Strategic planning tools
Staff, Information Dept (Shipping Co.)	Latest shipping industry news	Real-time market trends	Mobile app/online platform access	Market trend analysis; ship data queries
Director, Logistics Institute	Hot topics in logistics papers/patents	Annual update	Academic annual reports	Paper/patent trend analysis; technology hotspot identification
Dean, School of Science	Emerging ESI discipline trends	Bimonthly updates	Thematic reports via email/platform	Disciplinary potential assessment; trend forecasting
Dean, School of Transport & Communications	Competitive advantages in transport engineering	Irregular	Thematic reports via email/platform	Discipline potential evaluation
Vice-President (University)	Benchmarking university trends	Real-time updates	Thematic reports via email/platform	Benchmarking analysis; collaboration opportunity recommendations

Through interviews with different categories of decision-makers, this study identified that academic libraries encounter a wide range of diverse and complex requirements when delivering decision-support services. The detailed findings are presented in Table 2.

Table 2: Decision-Making User Needs and Prioritization.

User Category	Key Requirements	Urgency	Significance	Feasibility	Priority
Senior Policymakers	• University discipline development strategy and planning • Benchmarking university dynamics • Industry collaboration opportunities	High	High	High (with adequate resources)	1
Functional Departmental Decision-Makers	• University discipline development strategy and planning • Domestic/international university data • Talent recruitment performance • Academic competitive advantage analysis	Medium	High	High	2
Faculty Decision-Makers	• Scholarly paper statistics • Benchmarking analysis • Competitive advantage analysis • ESI potential discipline trends	Low	Medium	High	4
Research Teams	• Identifying academic collaborators • Tracking research trends and hotspots	High	Medium	High	2
Industry-Based Decision-Makers	• Data dynamics, research hotspots, and patent trends in ports, shipping, and logistics fields	Medium	Low	Medium	5

- Urgency: User needs are evaluated according to both their immediacy and their operational significance. High urgency denotes requirements that demand immediate attention because of

their critical nature. Medium urgency refers to needs that should be addressed within an appropriate timeframe while still requiring prompt action. Low urgency represents requirements that can be postponed without causing substantial consequences.

- Importance: The importance of each need is determined by its influence on the decision-making process. High importance indicates a critical contribution to decision-making outcomes. Medium importance reflects a moderate level of influence that warrants consideration but not immediate intervention. Low importance denotes needs that have only a limited effect on decision-making.
- Feasibility: Feasibility is assessed by considering the availability of organisational resources and operational capabilities needed to satisfy each requirement. High feasibility indicates that existing resources are sufficient for implementation without substantial additional effort. Medium feasibility suggests that meeting the requirement will require a moderate investment of resources or organisational support. Low feasibility indicates that current capabilities are inadequate and that significant additional resources or external assistance would be necessary.
- Priority: Priorities are established by jointly considering urgency, importance, and feasibility. Lower numerical values represent higher implementation priorities. Developing a systematic and standardised decision-support system is therefore essential for addressing these diverse user requirements in a more effective and coordinated manner.

UX Design Model

Traditionally, academic libraries concentrated primarily on managing and delivering information resources, often giving limited attention to user-centred experiences and emotional engagement. With the emergence of the knowledge economy, however, library service philosophies have undergone a substantial transformation, placing greater emphasis on personalised interactions, emotional connection, and service adaptability. These dimensions have become fundamental to the evolution of library information services, driving the transition towards user-centred service models that better reflect contemporary user expectations (Young et al., 2020).

Jesse James Garrett's framework, introduced in The Elements of User Experience, provides a widely recognised conceptual model for understanding UX. The framework is organised into five hierarchical layers: strategy, scope, structure, skeleton, and surface (Garrett, 2011) (see Figure 1). From a vertical perspective, each layer builds upon the one beneath it, progressing from abstract strategic concepts to increasingly concrete implementation details. Horizontally, every layer incorporates both conceptual principles and practical information elements. Collectively, these layers encompass two complementary dimensions: task-oriented systems, which emphasise functional processes and workflows, and information-centric systems, which focus on the effective organisation and delivery of contextual knowledge.

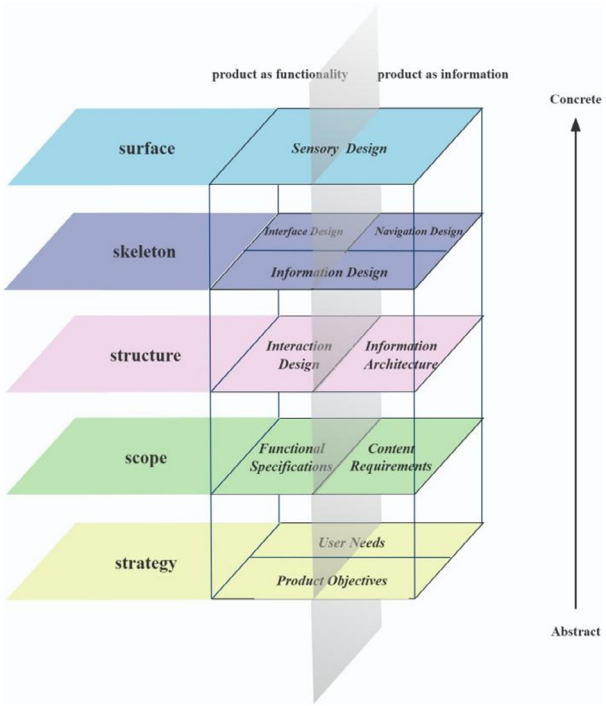

Figure 1: Jesse James Garrett's 5 Elements of UX.

TOGAF

Enterprise Architecture (EA) provides organisations with a structured approach for managing organisational complexity, aligning strategic objectives, and improving adaptability through systematic governance mechanisms (van de Wetering et al., 2021). During periods of organisational transformation, EA facilitates informed decision-making while increasing operational flexibility and organisational responsiveness (Niemi and

Pekkola, 2020). First introduced in 1995, The Open Group Architecture Framework (TOGAF) offers a comprehensive methodology for the design, implementation, and governance of enterprise information architectures (The Open Group, n.d.). Its central component, the Architecture Development Method (ADM), consists of a nine-phase iterative process that supports architecture development and lifecycle management (see Figure 2). Each phase addresses essential aspects of enterprise architecture, including business and information technology alignment, data interoperability, and technological scalability (Darkel et al., 2023).

TOGAF organises enterprise architecture into four interrelated domains: Business Architecture, Data Architecture, Application Architecture, and Technology Architecture. Within this framework, the Data and Application Architectures are integrated to form the Information Architecture, thereby promoting effective data governance and seamless interoperability across enterprise systems (Bastidas et al., 2023). Owing to its methodological flexibility and scalable design, TOGAF has become a preferred framework within higher education institutions, enabling universities to align information technology infrastructure with both academic priorities and administrative objectives (Hindarto, 2023; Subagja et al., 2022).

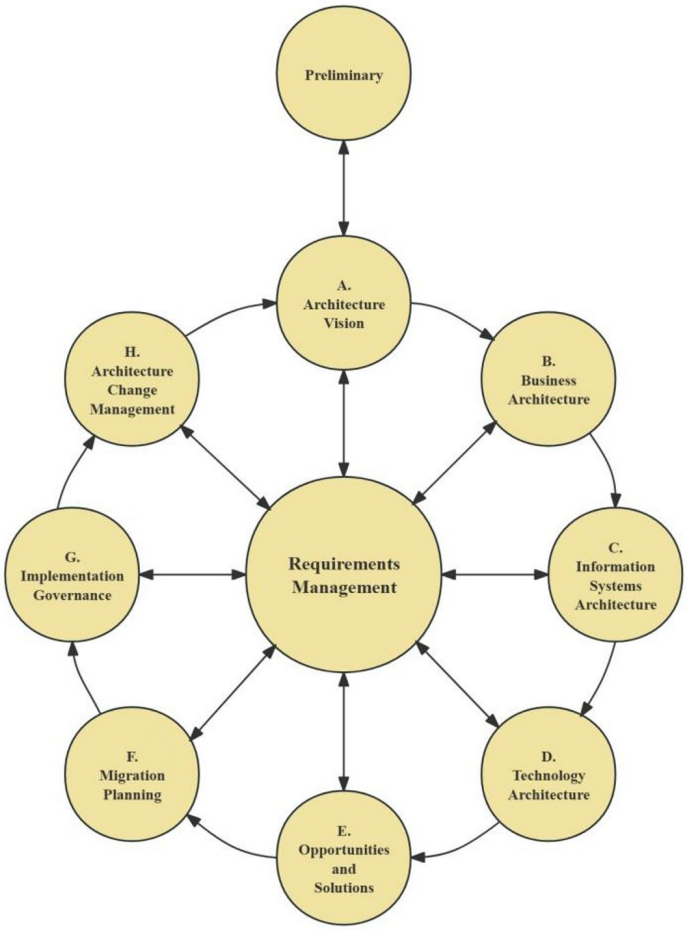

Figure 2: TOGAF ADM.

Figure 2 presents the three principal architecture domains adopted in the TOGAF ADM: Business, Information, and Technology (Kurniawan, 2013). In this study, these domains are integrated with the UX design model to develop a comprehensive decision-support service system. This integrated approach ensures that user-centred principles are embedded throughout the entire system development lifecycle, from requirements analysis and architectural design to implementation and ongoing maintenance, thereby

delivering an enhanced and consistently high-quality user experience.

Results

The development of a TOGAF-based architecture begins with the clear definition of system objectives. At SMUL, the DSSS is designed to achieve three principal objectives. First, it aims to improve the efficiency of library management. Second, it seeks to strengthen collaboration and communication between internal departments and external organisations. Third, it is intended to address the operational and technological challenges associated with the digital era. A key mechanism for achieving these objectives is the integration of decision-making data from multiple sources. By consolidating heterogeneous data within a unified environment, the system establishes a comprehensive decision-support platform while enabling the delivery of decision-support products tailored to the specific requirements of different user groups.

As illustrated in Figure 3, the study aligns the strategy and scope layers of the UX framework with TOGAF's Business Architecture to ensure consistency between user-centred design principles and organisational business processes. The structure and information design components of the UX skeleton layer are integrated with TOGAF's Information Architecture, supporting effective data governance and seamless interoperability among applications. In addition, the interface design and navigation design elements within the UX skeleton and surface layers are incorporated into TOGAF's Technology Architecture. This integrated architectural approach not only enhances the operational stability and reliability of the DSSS but also improves usability and user satisfaction through intuitive interfaces, efficient workflows, and adaptive interaction mechanisms.

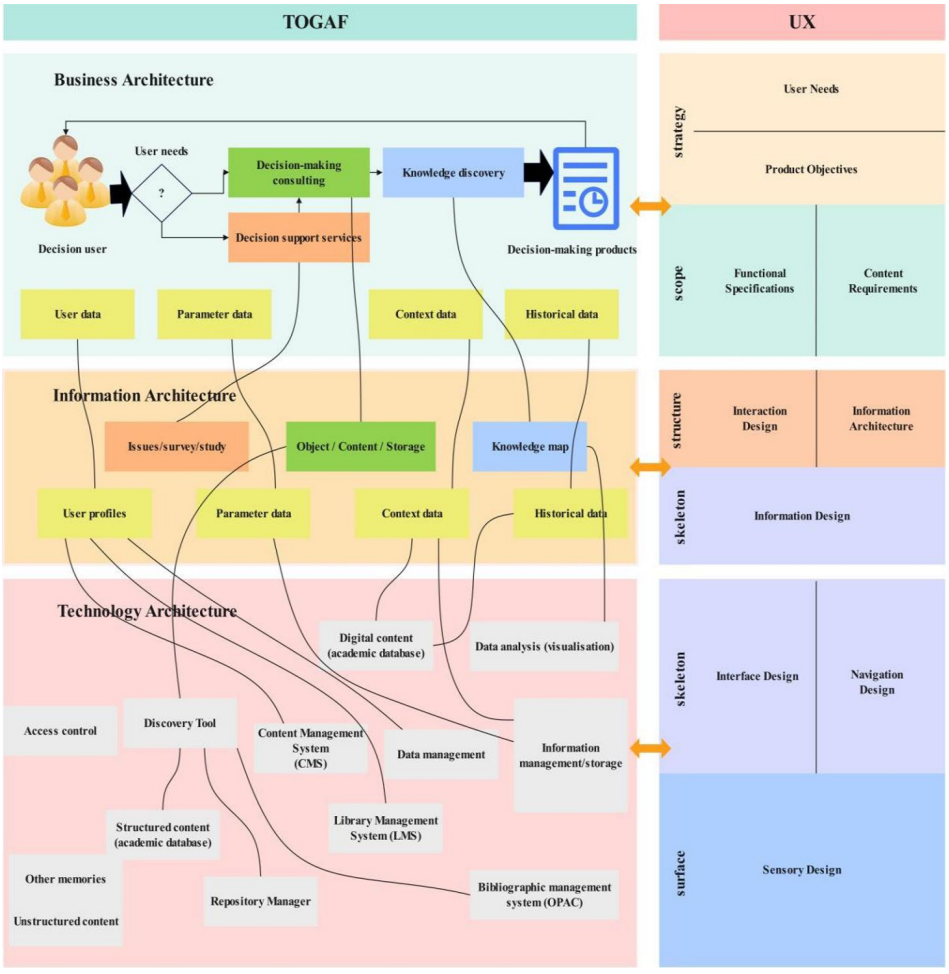

Figure 3: Overall Architecture.

Business Architecture

Business architecture serves two primary functions: (1) optimizing cross-departmental collaboration through standardized communication protocols, and (2) streamlining critical workflows such as data acquisition, analysis, and insight generation. By systematically refining these processes, it translates raw data into actionable intelligence, empowering users with personalized decision-support services. Figure 4 illustrates the functional model of business architecture.

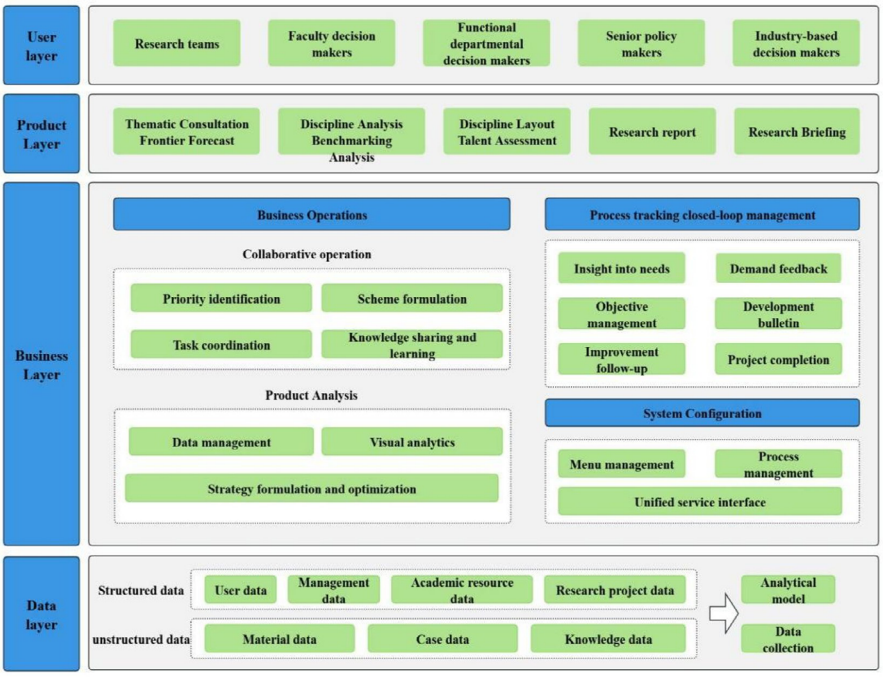

Figure 4: Business Architecture.

Data Layer

This layer is responsible for integrating and processing both structured and unstructured data using domain-specific analytical models that support the decision-making process. By consolidating information from multiple sources, it provides a reliable data foundation for subsequent analytical and decision-support activities.

Business Layer

- Business Operations: At SMUL, the Subject Service Department and the Science & Technology Intelligence Department work collaboratively with internal units, such as the Development Planning Division, and external organisations, including the China Federation of Logistics & Purchasing and Shanghai Port. Together, they identify user requirements, determine priority issues, formulate strategic plans, and assign responsibilities and implementation schedules to support coordinated cross-functional initiatives.
- Product Analysis: Serving as a core component of the data-driven business layer, this module manages both structured and unstructured datasets received from the data layer while maintaining data quality, security, and controlled accessibility. It applies data visualisation techniques to present analytical results and generates customised views that address the specific requirements of different categories of users.

Product Layer

- For Research Teams: SMUL collaborates closely with research groups by providing specialised decision-support services, including personalised research consultation, frontier technology forecasting, and patent intelligence analysis.
- For Faculty Decision-Makers: Faculty members receive intelligence support through services such

as benchmarking reports, frontier trend analysis, and comprehensive disciplinary evaluations to facilitate academic planning and decision-making.

- For Functional Departmental Decision-Makers: Decision-support services are centred on discipline mapping, strategic planning, and talent mapping, providing evidence-based analyses that support departmental management and institutional development.
- For Senior Policymakers: SMUL supports senior institutional decision-makers by conducting comprehensive analyses of both internal and external environments and producing periodic reports, such as the Academic Dynamics Report in Shipping. Through bibliometric analysis and data visualisation, the library evaluates disciplinary performance and provides evidence to inform strategic planning across multiple organisational levels, ensuring consistency with institutional missions and long-term objectives.
- For Industry-Based Decision-Makers: SMUL delivers specialised intelligence products tailored to industry stakeholders, including the China Logistics Technology Development Report and the Port-and-Shipping Market Information Briefing, providing timely insights to support strategic and operational decision-making within the logistics and maritime sectors.

Information Architecture

The Information Architecture phase constitutes a core component of the TOGAF framework, focusing on the systematic governance and management of organisational data and information assets. Its primary objective is to ensure that data are logically structured, readily accessible, and closely aligned with both operational processes and strategic objectives. To accomplish this, the Information Architecture comprises two closely integrated components: Data Architecture and Application Architecture.

Data Architecture

- Data Entity/Data Component Catalogue: Establishing a consensus-driven Data Entity/Data Component Catalogue is fundamental to the effective implementation of information management and data governance practices. The catalogue provides a standardised framework for defining data entities and components, thereby promoting consistent data management, efficient information sharing, and data reuse across the organisation. Its principal elements are presented in Table 3.

Table 3: Data Entity/Data Component Catalogue.

Data Entity	Description	Logical Components	Physical Components	Data Fields
Academic Achievement Data	Scholarly outputs (e.g., papers, patents, publications)	Academic achievement records	Oracle Database	Title, author, publication year, journal, patent number/type
Research Projects Data	Project lifecycle phases (application, initiation, progress, completion)	Project management records	MySQL	Project name, principal investigator, start-end dates, project type
Disciplinary Development Data	Discipline evolution trends, rankings, and competitiveness	Discipline analysis records	Microsoft SQL	Discipline name, trend indicators, ranking, competitiveness index
User Behaviour Data	User interaction logs on digital platforms	User behaviour logs	PostgreSQL	User ID, behaviour type, timestamp, interaction object
Industry Dynamic Data	Real-time industry news, policies (shipping, ports, logistics)	Industry intelligence records	MongoDB	Industry sector, news title, release date, policy summary, market trends
Talent Assessment Data	Talent recruitment, evaluation, and performance metrics	Talent management records	IBM Db2	Name, recruitment date, evaluation tier, performance KPIs
University Planning Data	Institutional development plans and strategic objectives	Strategic planning records	Amazon RDS	Plan name, timeframe, strategic goals, key milestones
User Feedback Data	User feedback on service quality and platform usability	Service feedback records	Azure SQL Database	User ID, feedback timestamp, content, resolution status

- Data Life Cycle Model: This model defines the complete lifecycle of data within the Data Architecture by specifying the processes governing data management from creation to final disposition. It ensures that data are effectively managed throughout every stage of their lifecycle, including creation, storage, utilisation, maintenance, archiving, and secure disposal (Bossaller and Million, 2023), as illustrated in Figure 5.

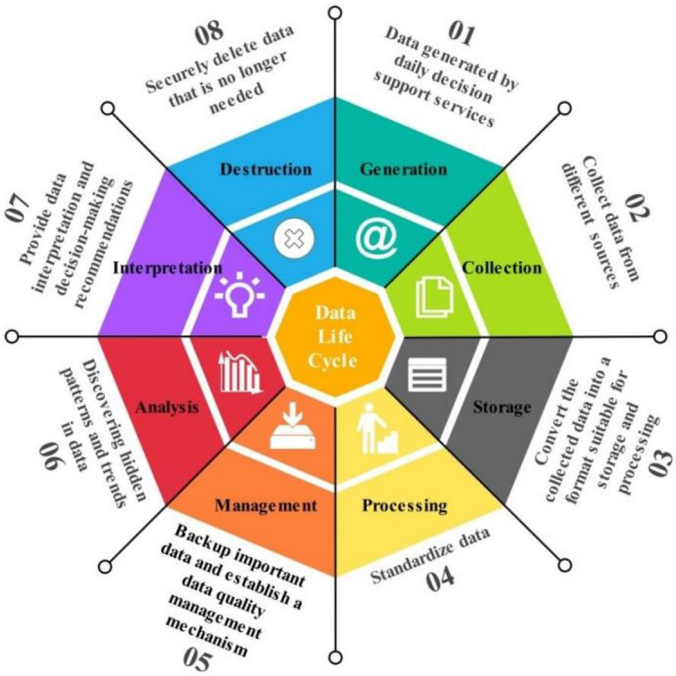

Figure 5: Data Life Cycle Model.

Figure 6 illustrates the overall framework of the Data Architecture, depicting the relationships among its constituent components and demonstrating their respective functional roles within the overall system.

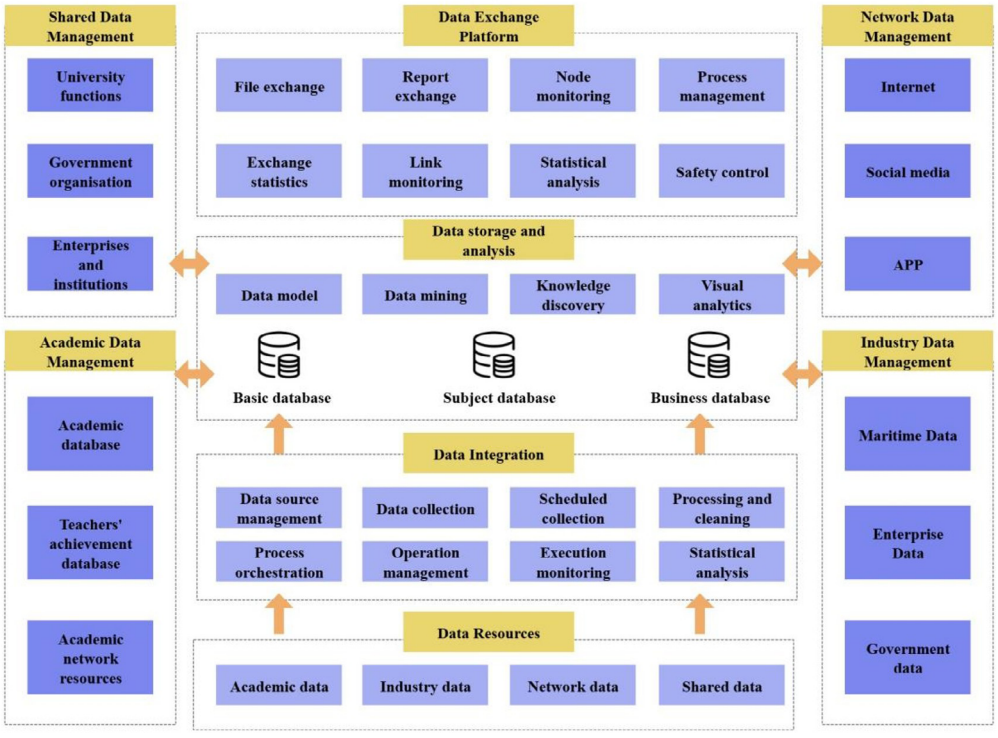

Figure 6: Data Architecture.

Application Architecture

The Application Architecture coordinates the integration of applications with underlying data resources, technological infrastructure, and business processes. This alignment supports systematic data governance by ensuring that applications effectively manage data throughout its lifecycle, including its creation, retrieval, modification, and storage.

- Application Directory: This directory functions as a central repository for all applications within the system. It comprises three primary components: information system services, application logic components, and physical components, as presented in Table 4.

Table 4: Application Catalogue.

Information System Services	Application Logic Component	Application Physical Component
Data Integration Services	Data Extraction and Conversion Module	ETL Tools (e.g., Informatica)
Decision Support Systems	Data Analysis Module, Report Generation Module	Python/R Scripting, Reporting Tools (e.g., Tableau)
User Interface	Front-End Presentation and Interaction Modules	HTML, CSS, JavaScript, Front-End Frameworks (e.g., React)
System Security Services	Authentication and Access Control Module	Security Servers, Authentication Middleware, Firewalls
Service Optimization and Iteration	User Feedback Collection Module, Version Iteration Module	Version Control Systems (e.g., Git), CI/CD Tools

- Application/Data Matrix: This matrix depicts the relationships between application components and the data entities they access and manage, as presented in Table 5. It specifies how each application interacts with individual data entities, thereby supporting effective data governance, maintaining data consistency, and improving coordination across business processes.

Table 5: Application/Data Matrix.

Name of Data Entity	Academic Achievement Database	Shared Data Systems	Data Analysis Platform	Data Publishing Platform	User Feedback Platform
Academic Achievement Data	CRUD	R	R	RU	R
Research Project Data	CRUD	R	R	RU	-
Discipline Development Data	RU	R	R	RU	-
User Behaviour Data	-	R	R	-	CRUD
Industry Dynamic Data	-	R	R	R	-
Talent Assessment Data	RU	R	R	-	-
University Planning Data	-	R	R	-	-
User Feedback Data	-	-	-	-	CRUD

This matrix illustrates the interactions between applications and data entities using CRUD (Create, Read, Update, Delete) operations. It specifies the operational permissions assigned to each application for individual data entities, thereby providing clear definitions of data access and management responsibilities. This structured approach enhances data governance, improves data integrity, and facilitates more efficient cross-functional workflows.

Technology Architecture

The Technology Architecture specifies the fundamental components required for the development, deployment, and operation of the academic library DSSS. By integrating hardware, software, networking, and cybersecurity technologies within a unified framework, it ensures reliable, secure, and high-performance system operation, as illustrated in Figure 7.

1. Infrastructure Layer: This layer provides the physical and virtual infrastructure supporting business applications and platform services. It comprises servers, network infrastructure, cybersecurity mechanisms, and other essential hardware resources that underpin system operations.
2. Service Support Layer: Following the principle of open service sharing, this layer establishes a multi-level service architecture consisting of platform services, support services, and application services.
   - Platform Services: These provide the technological foundation of the architecture by delivering core infrastructure capabilities, including cloud computing, virtualisation, service governance, and security management.
   - Support Services: These offer reusable

modular services, such as identity authentication, authorisation management, audit logging, and communication protocols, facilitating scalable integration across complex application environments.

- Application Services: These implement the business logic required for decision-support operations by utilising platform and support services to perform information retrieval, data processing, and user interaction functions.

3. Gateway: The gateway layer manages communication between internal and external systems. Hardware gateways comprise physical network devices, including firewalls and routers, whereas software gateways, such as Nginx and Kong, are deployed on servers to manage service requests. Cloud-based gateway services, including AWS API Gateway and Azure API Management, further support the delivery and management of application services.
4. Presentation Layer: This layer serves as the primary interface through which users interact with the DSSS. It presents information, captures user input, and delivers system responses.
   - Interface Design: Emphasising simplicity, consistency, and visual clarity, the interface improves readability and user comfort. Key functions, including form submission, information retrieval, and report generation, are designed to reduce operational complexity, streamline workflows, and minimise user effort.
   - Navigation Design: The navigation structure adopts a logical hierarchical organisation with clearly defined labels, enabling users to locate content intuitively and retrieve information efficiently.
   - Multi-Channel Access: To accommodate diverse user requirements, SMUL provides access to the DSSS through multiple digital platforms, including ① Shanghai Maritime University Repository; ② Subject Service Platform, which supports subject consultation, lecture coordination, and literature retrieval services; ③ Global Shipping Science & Technology Industry Patent Navigation Platform; and ④ International Maritime Information Website (www.simic.net.cn), which delivers maritime intelligence services in support of the Shanghai International Shipping Centre. In addition, users can access the system through the library website and social media platforms, including WeChat and Weibo.

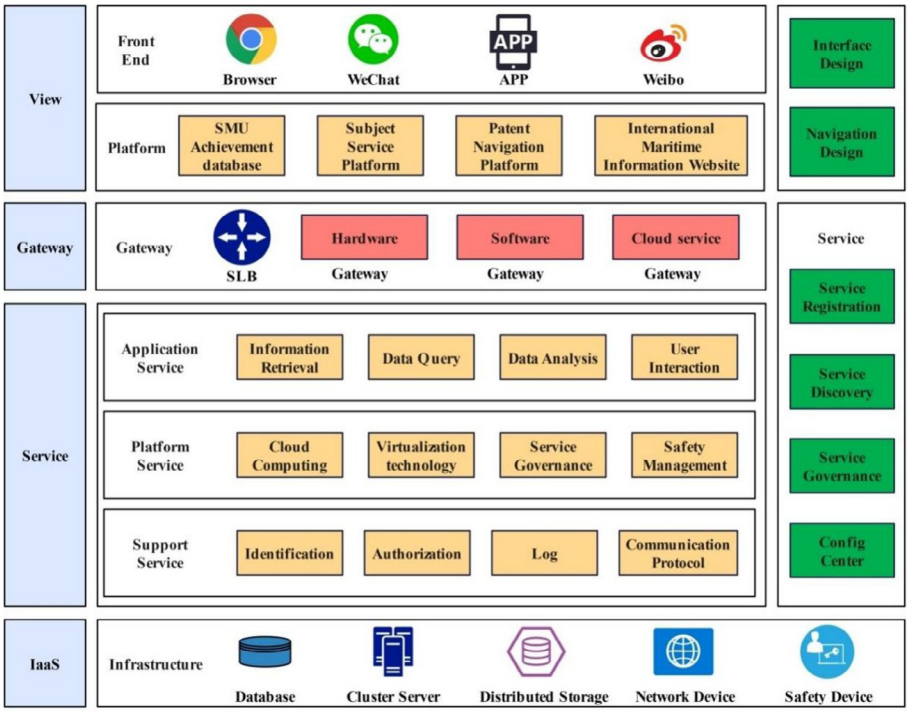

Figure 7: Technology Architecture.

Discussion

Using SMUL as the case study, this research adopts TOGAF as the core enterprise architecture methodology and incorporates UX principles to develop a comprehensive DSSS that addresses the evolving requirements of researchers and institutional managers.

The findings are generally consistent with previous research while offering several important distinctions. The adoption of EA, particularly TOGAF, facilitates the digital transformation of library management. This supports the observations of Anam et al. (2021), who identified TOGAF as providing greater architectural precision than alternative frameworks. TOGAF was selected because of its flexibility, open-source availability, and comprehensive approach to enterprise architecture and information system development. This selection is further supported by Darkel et al. (2023), who reported that TOGAF's ADM effectively accommodates multiple modelling techniques while adapting to changing organisational requirements.

Likewise, Rachmadi et al. (2023) argued that TOGAF is especially appropriate for organisations with underdeveloped Business, Data, Application, and Technology (BDAT) architectures, enabling a more streamlined EA implementation process. Collectively, these findings confirm the suitability of TOGAF for academic library environments while highlighting the importance of structured architectural training in advancing contemporary digital literacy.

Unlike recent studies that examine individual dimensions of decision-support services, the DSSS proposed in this research adopts an integrated architecture encompassing business, information, and technology layers. Lee and Kwon (2023), for example, demonstrated that academic libraries can utilise both structured data, such as databases, and unstructured data obtained through web crawling, combining visualisation techniques with statistical analysis to support institutional decision-making. Song et al. (2024) introduced a metadata-driven resource service platform aimed at improving data transparency, while Pitrawati et al. (2023) proposed a comparable framework for enhancing library information services. In contrast, the present study unifies these architectural dimensions within a single enterprise framework.

Another distinguishing contribution of this study is the incorporation of UX principles into the design of the DSSS. As an essential indicator of library service quality, UX requires continuous refinement through innovative service approaches, including knowledge dissemination, subject-based navigation, and research consultation services (Luo et al., 2023). The findings provide several practical implications for strengthening management practices within academic libraries. First, libraries can improve decision-support services by categorising decision-making user groups and integrating behavioural analytics with continuous feedback mechanisms. Analysing users' historical interactions and service preferences enables libraries to identify successful services, recognise areas requiring improvement, and deliver more personalised support (Amalia et al., 2024; An, 2023).

Second, effective integration of UX within the DSSS requires libraries to align emerging technologies, including mobile applications and virtual consultation platforms, with user expectations. Combining these digital technologies with innovative service models and UX-driven design enhances user interaction, engagement, and service efficiency (Facunla and Encarnacion, 2024; Yuan et al., 2024). Finally, the proposed DSSS enables libraries to collect valuable operational evidence through user behaviour analysis, feedback surveys, and usability testing. These data provide managers with objective evidence for informed decision-making, reducing reliance on subjective judgement while improving operational responsiveness and service effectiveness (Gao, 2023).

This study is subject to two limitations. First, because the investigation focuses exclusively on SMUL, the findings reflect the characteristics of a specific institutional environment. Consequently, the transferability of the proposed architecture may be constrained, as other academic libraries may differ in terms of organisational resources, governance structures, technological capabilities, or research priorities. Second, although the study introduces a decision-support framework integrating TOGAF and UX principles, it does not comprehensively assess the system's long-term operational performance following implementation. Consequently, evidence regarding sustained effectiveness, evolving user perceptions, and continuous system refinement remains limited.

Future research should extend the present work by conducting longitudinal evaluations of

the implemented system. Systematic collection of user feedback and operational data would enable researchers to examine its long-term influence on information management efficiency, research support services, and user satisfaction, thereby providing stronger evidence of its practical effectiveness and long-term sustainability.

Conclusion

In conclusion, TOGAF provides academic libraries with a robust technological foundation by supporting data standardisation, facilitating seamless system integration, strengthening security mechanisms, enabling scalable system development, and improving user interface design. These capabilities allow academic libraries to respond effectively to changing user requirements and emerging technological developments while establishing a sustainable infrastructure for delivering data-driven decision-support services.

Ethical Issue

All procedures in studies involving human participants were performed in accordance with the ethical standards of the Ethics Committee of Shanghai Maritime University and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study protocol was approved by the Ethics Committee of Shanghai Maritime University. Informed consent was obtained from all individual participants included in the study.

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