

Analysis of Study Visa Applicants' Survey Responses Using Data Modeling: A Case Study of Educational Immigration Agencies

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ABSTRACT

Background and Objective: Academic Application Service Management Systems (AASMSs) support educational application processes but may face challenges related to infrastructure, user experience, interface design, and data management. This study aims to identify weaknesses in AASMSs based on applicant feedback and system evaluation and to develop data modeling-based approaches for improving service efficiency and user experience.

Methods: This mixed-methods study was conducted in Tehran in March 2023. Application-service-related websites of 80 international universities were evaluated, from which 30 universities were selected. A performance index based on global ranking, user return rate, and page views was calculated, and 10 universities were selected for in-depth analysis. Survey data were collected from 30 study visa applicants using a researcher-developed questionnaire. Data modeling was conducted using Entity–Relationship (ER) diagrams, while quantitative data were analyzed using SPSS version 25 and the chi-square test.

Results: The average user satisfaction with the evaluated systems was 79.95%. The main challenges identified were insufficient guidance, difficulties in document submission and verification, limitations in online support tools, data security concerns, and unfriendly interfaces. In addition, 57.89% of respondents rated chatbot-based support as good or excellent. Data modeling identified opportunities for automated data validation, intelligent document processing, real-time feedback, and database integration to address identified bottlenecks and improve system performance.

Conclusion: Data modeling provides a structured approach for identifying weaknesses in AASMSs and developing evidence-based improvement strategies. The findings highlight the potential value of interactive guidance, intelligent document review, and centralized data structures in improving service quality, applicant satisfaction, and the efficiency of academic application processes.

Keywords: Academic application service management systems; Study visa applicants; Data modeling; User experience; Educational immigration agencies

INTRODUCTION

International student mobility refers to the movement of students from their home countries to foreign educational systems for the purpose of pursuing academic studies. This process involves multiple stages, including destination selection, university admission, legal entry procedures, and adaptation to a new educational environment (1,2). From an analytical perspective, international student mobility is influenced by the interaction between structural conditions and individual agency, including push factors in the home country, such as educational, employment, and institutional limitations, and pull factors in the destination country, including

educational quality, academic reputation, research opportunities, career prospects, and potential pathways for residence (2,3). While educational migration may contribute to human capital development, intercultural experiences, and improved career opportunities at the individual level, its broader consequences may vary across individuals, institutions, and countries and may also influence the distribution of human capital and knowledge (5,6). The increasing complexity of educational migration processes has consequently created a greater need for efficient systems that support information management, applicant communication, and academic application procedures.

Educational immigration agencies serve as intermediaries between applicants, universities, and destination-country admission processes by providing services such as destination selection guidance, document preparation, communication management, and application support (7,8). The expansion of these agencies has been influenced by the increasing demand for international education, the complexity of admission regulations, and the growth of cross-border higher education services (1,7,8). However, variations in service quality, limited regulatory oversight, and dependence on individual consultants' expertise may result in administrative errors, applicant confusion, increased processing time and costs, and reduced trust in educational immigration services (7,8). Therefore, systematic analysis of agency performance and the information generated through academic application services can support the identification of process limitations, evaluation of service quality, and development of strategies for improving applicant experience and operational efficiency (9,10).

Data mining and data analysis are widely used to extract meaningful patterns, actionable knowledge, and decision-support insights from large and heterogeneous datasets (4,9,10). As digital systems generate increasing volumes of textual, behavioral, and survey data, appropriate data organization and logical structuring become essential for supporting reliable analysis and evidence-based decision-making (9,11,12). In this context, data modeling provides a structured approach to defining relationships among entities, organizing information, and establishing a suitable foundation for data storage and analysis (11,12). However, poor data quality, incomplete or inconsistent information, and inappropriate data structures can compromise the reliability of analytical results. Therefore, appropriate data modeling frameworks, accurate data preprocessing, and systematic evaluation of the resulting structures are necessary for obtaining reliable and usable analytical outcomes (9,11,12).

Data-driven analysis transforms raw data into meaningful information that can support evidence-based decision-making through processes such as data collection, processing, analysis, and modeling (9,10,14). With the expansion of digital systems, this approach has gained increasing relevance in educational, managerial, and service-oriented research, where decisions increasingly rely on systematically collected evidence (10,14). However, the effectiveness of data-driven analysis depends on data quality, sample representativeness, and appropriate validation procedures. Traditional analytical approaches may also face limitations when dealing with complex and multidimensional datasets, highlighting the need for rigorous analytical frameworks and reliable validation methods to obtain meaningful and trustworthy results (9,10,11).

Recent studies indicate that the choice of an international study destination is not solely an individual decision but is shaped by the interaction of educational, institutional, informational, and economic factors (2,13). Perceived quality, institutional reputation, and access to transparent information have been identified as important factors influencing international students' decision-making (15,16,17). Educational reputation, individual opportunities, and career prospects may also influence students' preferences regarding their academic pathways (6,18). These findings suggest that applicants' survey responses can provide valuable evidence for examining decision-related patterns and understanding the factors associated with their educational choices. Accordingly, data-driven analysis of such responses may support evidence-based decision-making and provide practical insights for improving the services offered by educational immigration agencies (9,10,15,19).

However, recent studies provide a more critical perspective on these processes. Feng and Horta (7) show that the activities of education agents and intermediary mechanisms do not necessarily improve transparency and efficiency and may, in some contexts, involve opaque practices or dependence on intermediaries. Similarly, empirical studies indicate that greater access to information or educational options does not necessarily lead to more informed decisions, as student choices may remain influenced by uncertainty and information heterogeneity (15,17). Qualitative research has also suggested that international student mobility may, in some

circumstances, reproduce existing inequalities and generate adverse structural consequences (6). These findings highlight that data-driven analytical approaches alone cannot ensure reliable outcomes; their effectiveness depends on data quality, appropriate preprocessing, model validation, and the institutional context in which data are generated and interpreted (9,10,11).

The continued growth in international student mobility and the expanding role of educational intermediaries have increased the importance of effective information and service management within academic application processes (1,2,7,8). Educational immigration agencies generate and handle substantial applicant- and process-related information, the systematic analysis of which can support the identification of service bottlenecks, performance evaluation, and service improvement (7,8,9,13,14). Despite advances in research on international student mobility, education agents, and data analytics, relatively limited attention has been given to the systematic integration of data-driven analysis of applicant responses with data modeling for evaluating academic application service systems and the organizations that operate them (9,10,11,12). This gap highlights the need for approaches that connect applicant-level evidence with the underlying information structures of application services.

Accordingly, this study analyzes applicants' questionnaire responses and models the structure of related data to identify weaknesses in academic application service systems and educational immigration services and to develop practical strategies for improving service quality and applicant satisfaction. The study further aims to provide an evidence-based basis for performance monitoring, decision-making, and optimization of service processes.

International student mobility is a multidimensional process influenced by educational, institutional, economic, informational, and individual factors (1,2,13). Previous studies emphasize the role of individual agency alongside structural conditions in shaping students' mobility decisions and experiences (3,20). Research has also identified information availability, institutional quality, educational capital, financial considerations, and career-related factors as important determinants of destination choice (15–18). At the same time, international mobility may generate different outcomes across individuals and contexts, including educational and professional benefits as well as broader inequalities in access and opportunity (5,6).

Educational immigration agencies and education agents act as intermediaries between applicants and higher education institutions by supporting information provision, documentation, communication, and application procedures (7,8). Existing research has highlighted their importance in international student recruitment while also identifying concerns related to transparency, regulation, accountability, and dependence on intermediaries (7,8). However, relatively limited attention has been given to the information structures and service-management systems that support these intermediary processes.

The increasing availability of educational and administrative data has encouraged the use of data mining, learning analytics, and other data-driven approaches to support evidence-based decision-making (4,9,10,14). These approaches can identify patterns and provide actionable insights from large or heterogeneous datasets. Nevertheless, the reliability of analytical outcomes depends on data quality, appropriate processing, and the structure of the underlying information (9,10). Applicant questionnaire data can therefore provide useful evidence for evaluating service experiences when systematically organized and analyzed.

Data modeling provides a structured means of representing information, entities, relationships, and data requirements within information systems (11,12). Previous research has examined data modeling approaches for organizing and managing data in different information environments (11,12). In academic application services, such modeling can represent interconnected entities such as applicants, institutions, applications, documents, and service processes, thereby providing a structured basis for examining information organization and potential process limitations.

Overall, previous studies have separately examined international student mobility and decision-making, educational intermediaries, data-driven analysis, and data modeling. However, the integration of applicant-level evidence with data modeling for evaluating academic application service systems and educational immigration services remains comparatively underexplored. This gap provides the basis for the present study.

Despite extensive research on international student mobility, educational intermediaries, and data analytics, limited attention has been given to integrating applicant-level evidence with data modeling for evaluating academic application service systems. This study addresses this gap by analyzing applicants' questionnaire responses and modeling the related service data structure to identify service weaknesses and propose practical improvements.

METHODOLOGY

Research Ethics

Ethical principles were observed throughout the study. Participation in the questionnaire was voluntary, and the purpose of the research was explained to participants before data collection. No personally identifiable information was collected or reported, and the collected data were used solely for academic and research purposes.

Research Design

This study was applied in terms of its purpose and descriptive-analytical in terms of its research design, using a quantitative–qualitative approach. The quantitative component involved analyzing questionnaire responses from academic applicants to assess user satisfaction and identify challenges associated with Academic Application Service Management Systems (AASMS). The qualitative component involved data modeling and analysis of information structures to examine process weaknesses, system bottlenecks, and potential areas for improvement.

Study Population and Sample

The quantitative study population consisted of applicants to international universities and users of educational management centers in Tehran who had experience with Academic Application Service Management Systems (AASMS). A sample of 30 applicants was selected using simple random sampling, and the required data were collected through an online questionnaire. In addition, the websites of 80 international universities from eight countries—the United States, Canada, Spain, Italy, Germany, Australia, Türkiye, and the United Kingdom—were examined. A composite performance index based on selected indicators, including global ranking, user return rate, and pages viewed per visit, was calculated to rank the universities. The 10 universities with the highest scores were subsequently selected for more detailed analysis.

Questionnaire Instrument

The primary data collection instrument was a researcher-developed online questionnaire designed to evaluate user experience, identify problems in Academic Application Service Management Systems, and assess applicants' satisfaction. The questionnaire consisted of two sections. The first section collected demographic and background information, including age, gender, educational level, place of residence, and employment status. The second section evaluated aspects of system performance and user experience, including interface quality, ease of use, clarity of application procedures, document uploading and review, online support, information security, and overall user satisfaction. The initial questionnaire consisted of 25 items. Following content review, repetitive, irrelevant, and ambiguous items were removed, resulting in a final questionnaire comprising 12 main questions. Responses were recorded using a six-category scale: Very Poor, Poor, Average, Good, Excellent, and Do Not Know.

Instrument Validation

Content validity was addressed by developing the initial questionnaire based on relevant literature concerning international student mobility, educational information systems, user experience, and data analysis. The items were reviewed for relevance, clarity, and content appropriateness, and ambiguous items were revised or removed following expert feedback. To promote consistency in measurement, the final questionnaire used standardized wording and a consistent response scale for all participants. The removal of ambiguous and overly complex items was also intended to reduce measurement error and improve response consistency.

Data Analysis and Evaluation

The collected data were analyzed using descriptive and inferential statistical methods. Frequencies, percentages, and mean responses were used to summarize the questionnaire data and assess user satisfaction and reported service-related challenges. The Chi-square test was used to examine associations among the study variables.

In addition, data modeling was used to examine the information structure of academic application services. Relevant entities, relationships, and information flows were represented using an Entity–Relationship (ER) Diagram. The model was used to identify structural limitations, potential data redundancy, processing bottlenecks, automation requirements, opportunities for automated data validation, and potential improvements in interactions among system components.

The composite performance index was also used as an initial ranking mechanism for selecting the university cases subjected to detailed analysis.

Statistical and Modeling Tools

All statistical analyses were performed using SPSS Version 25. The data structures and relationships among entities were designed and represented using Entity–Relationship (ER) modeling and related data-modeling tools.

RESULTS

Performance Ranking of the Selected Educational Immigration Agencies

To compare the performance of the educational immigration agencies included in the study, the final composite performance index was calculated for the selected cases. The 10 agencies with the highest index values were subsequently identified for detailed analysis. Figure 1 presents the distribution of the final composite performance index across the selected agencies.

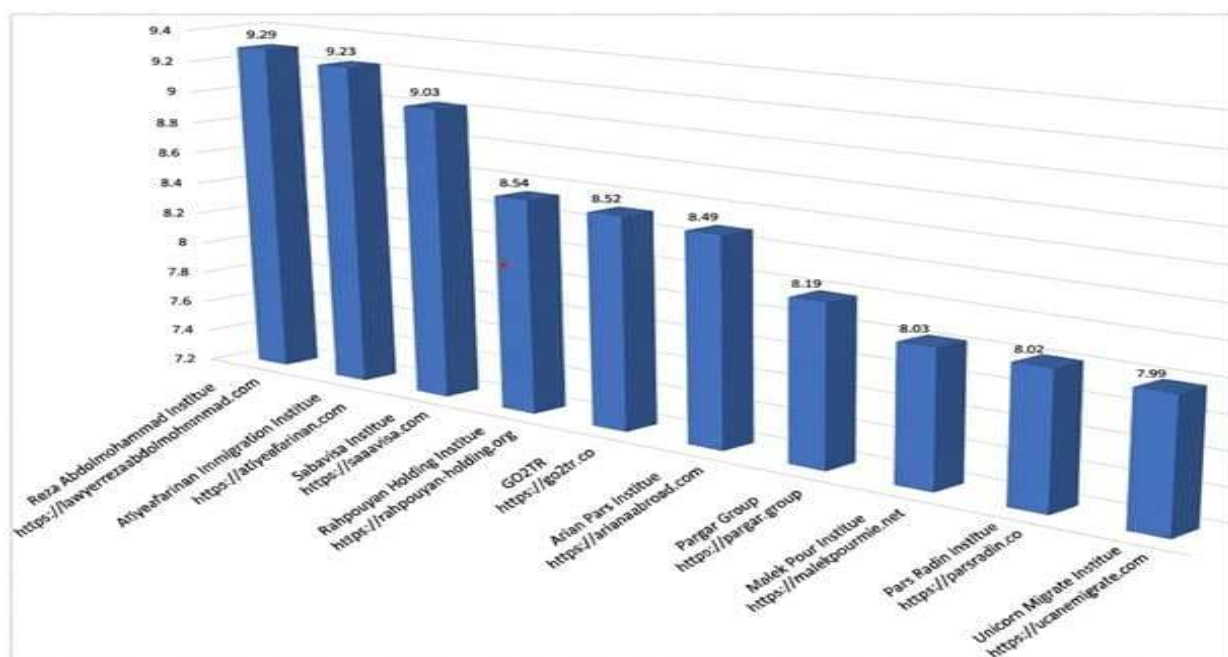


Figure 1. Final composite performance index of the 10 selected educational immigration agencies.

The mean final composite performance index among the 10 selected agencies was 8.53, while the median was 8.50. The close correspondence between these two values indicates relatively limited asymmetry in the distribution of the index values. The highest final index was recorded for Reza Abdolmohammad Institute (9.29), whereas the lowest value was observed for Unicorn Migrate Institute (7.99). Accordingly, the range of the final

index was 1.30 points. The standard deviation was 0.49, indicating relatively limited dispersion around the mean. Although differences were observed among the agencies, most index values remained within a relatively narrow range around the overall mean. The difference between the first- and second-ranked agencies was only 0.06 points, whereas the difference between the highest and lowest values reached 1.30 points. These results indicate that the selected agencies showed relatively limited but observable differences in the composite performance index. The ranking was subsequently used as an initial screening criterion for selecting cases for more detailed examination of academic application service systems.

Demographic Characteristics of Participants

The demographic characteristics of the study participants were analyzed to describe the composition of the research sample. The evaluated variables included age, gender, educational level, and employment status. The frequency and percentage distributions of these characteristics are presented in Figure 2.

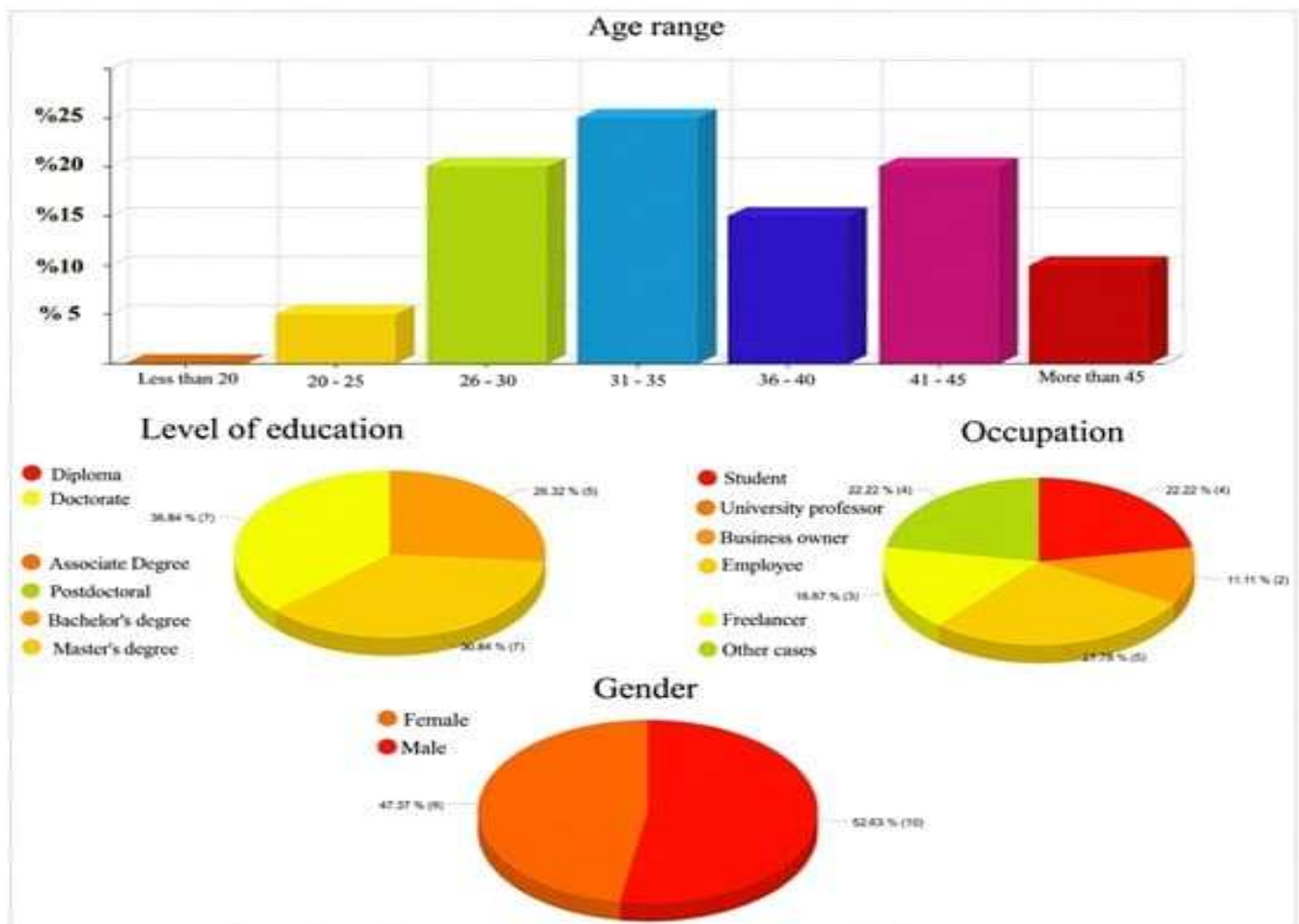


Figure 2. Demographic characteristics of the study participants.

Regarding age distribution, the highest frequency was observed in the 31–35 years age group. The 26–30 and 41–45 years groups represented the next largest categories, while the remaining age groups accounted for smaller proportions of the sample. In terms of educational level, participants with master's and doctoral degrees represented the largest groups, each accounting for 36.84% ($n = 7$) of the sample. Furthermore, 26.32% ($n = 5$) of participants held bachelor's degrees, while no participant with a diploma-level education was observed. Analysis of employment status showed that business owners represented the largest occupational group, accounting for 27.78% ($n = 5$) of participants. Students and participants categorized as other occupations each represented 22.22% ($n = 4$), followed by self-employed individuals with 16.67% ($n = 3$) and university professors with 11.11% ($n = 2$). Regarding gender distribution, 10 participants were male (52.63%) and 9 were female (47.37%), indicating a relatively balanced gender distribution within the sample.

Overall, the demographic analysis indicates that the sample consisted primarily of highly educated participants with diverse occupational and age characteristics.

Evaluation of the Document Submission and Review System

The document submission and review system was evaluated using two components: the availability of applicants' registered information and records on the institutional website, and the perceived accuracy of the information recorded on the website. The responses obtained for these two components are presented in Figure 3.

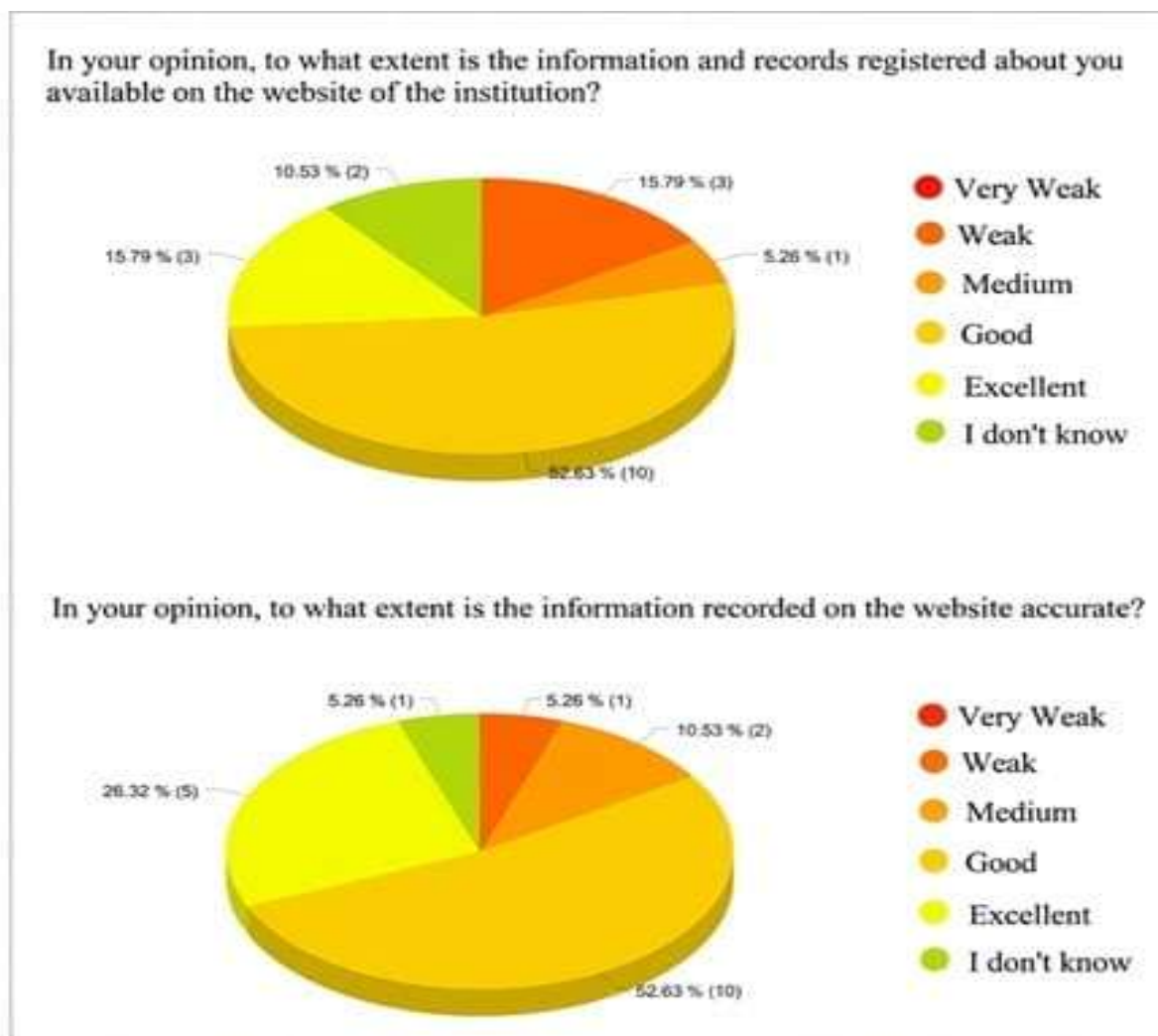


Figure 3. Results of the assessment of the document submission and review system.

Regarding the availability of registered information and records, the highest proportion of responses was Average, accounting for 52.63% (n = 10). The Weak and Excellent categories each accounted for 15.79% (n = 3), while 10.53% (n = 2) of respondents selected Do Not Know and 5.26% (n = 1) selected Very Weak. No respondent selected the Good category. For the perceived accuracy of the information recorded on the website, Average was again the most frequent response, accounting for 52.63% (n = 10). This was followed by Excellent, selected by 26.32% (n = 5) of respondents. The Weak category accounted for 10.53% (n = 2), while Very Weak and Do Not Know each accounted for 5.26% (n = 1). No respondent selected Good. A comparison of the two components indicates a more positive assessment of information accuracy than information availability. In particular, the proportion of Excellent responses was higher for information accuracy (26.32%) than for information availability (15.79%). Overall, both components were predominantly rated as Average. The results therefore indicate that information accessibility and the management of applicants' records remain areas that may warrant further improvement in academic application service systems.

Evaluation of Online Support and AI-Based Document Review

To assess users' perceptions of technology-oriented capabilities in academic application service systems, two components were evaluated: the quality of online support provided through chatbots or intelligent agents, and the potential use of artificial intelligence (AI) for reviewing documents and supporting application procedures. The results are presented in Figure 4.

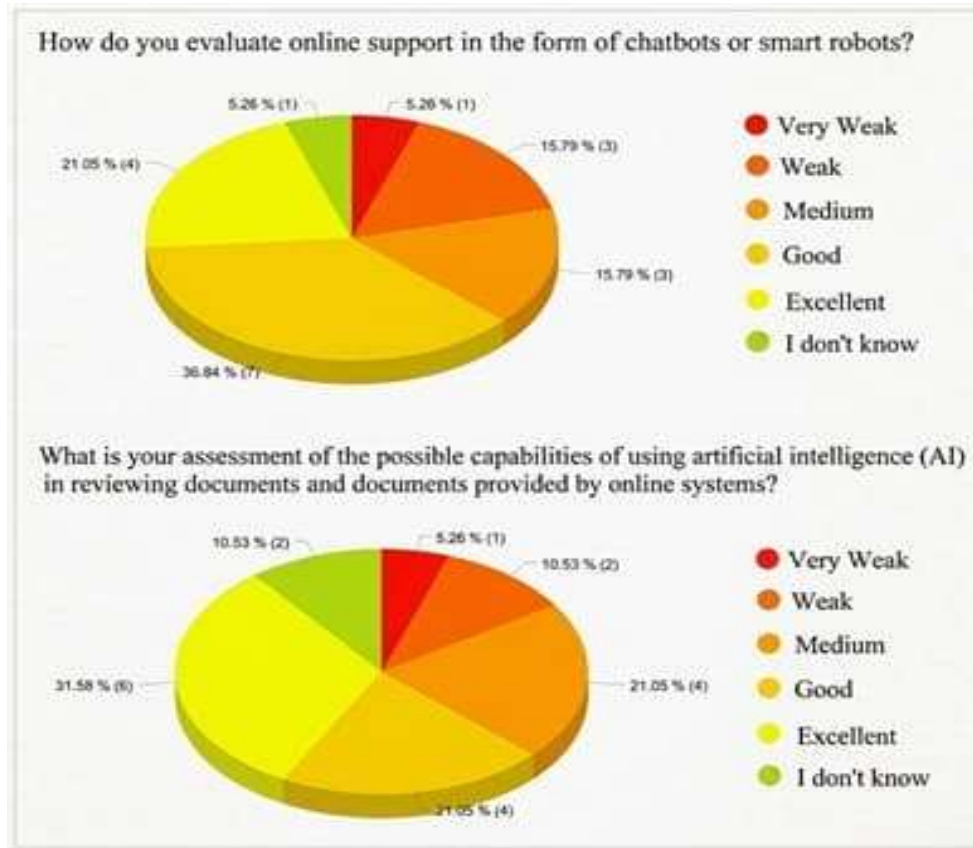


Figure 4. Results of the assessment of online support and the potential use of AI for document review.

Regarding online support, the highest proportion of responses was Good, accounting for 36.84% (n = 7). Excellent was selected by 21.05% (n = 4) of respondents, while Average and Poor each accounted for 15.79% (n = 3). The Very Poor and Do Not Know categories each represented 5.26% (n = 1). Overall, positive responses (Good and Excellent) accounted for 57.89% (n = 11), compared with 21.05% (n = 4) for the negative response categories (Poor and Very Poor). Regarding the potential use of AI for document review, Excellent was the most frequently selected category, accounting for 31.58% (n = 6). Good and Average each accounted for 21.05% (n = 4). In addition, 10.53% (n = 2) of respondents selected Poor, while Very Poor and Do Not Know each accounted for 5.26% (n = 1). Overall, positive responses (Excellent and Good) represented 52.63% (n = 10), whereas negative responses (Poor and Very Poor) represented 15.79% (n = 3). Overall, both components received a higher proportion of positive than negative responses, with the most frequent response for online support being Good and that for AI-assisted document review being Excellent.

Data Model results

By analyzing the data model diagram (Figure 5) and using the findings obtained from this research, it is possible to identify the weaknesses and opportunities for improvement in the AASMS platform. Implementing these improvements can lead to a more efficient, user-friendly, and effective application process for students and administrators of educational institutions.

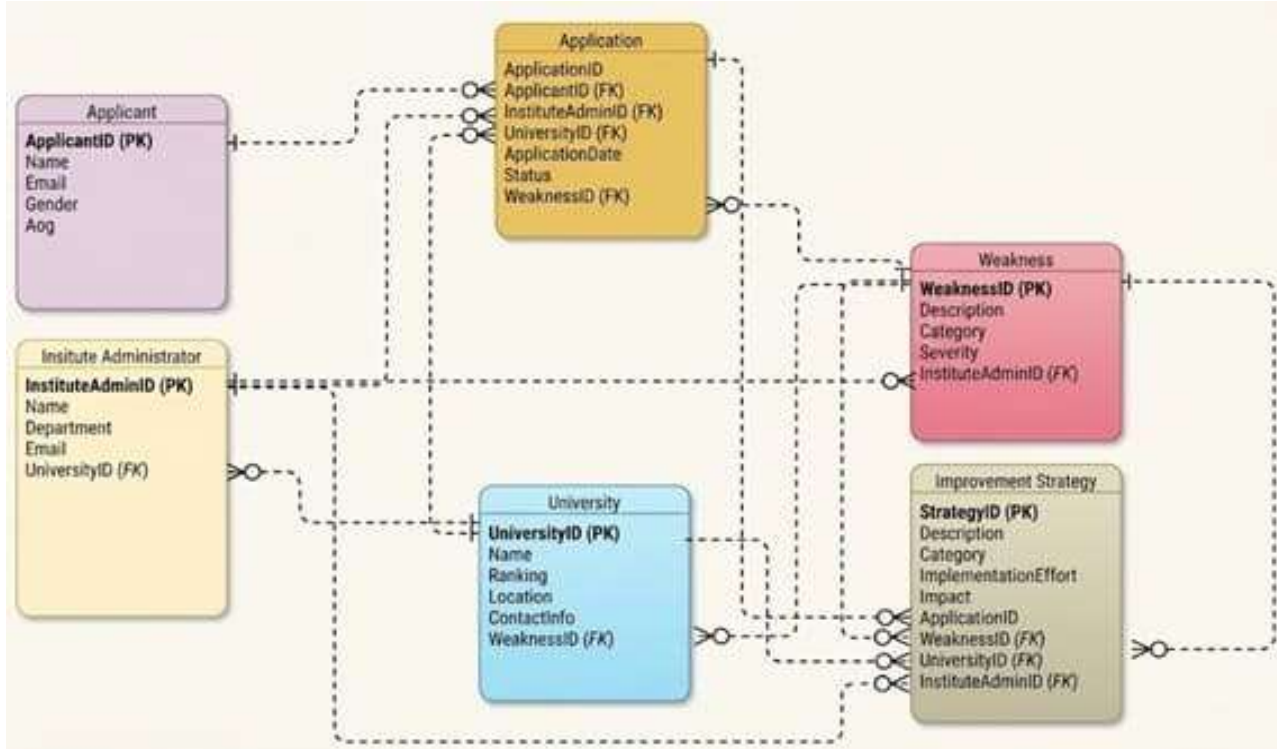


Figure 5. Data model ERD diagram.

Utilizing the ERD diagram derived from the entity-relational data model enables the identification of potential bottlenecks within the request process (21). A meticulous examination of the diagram reveals certain areas in the data flow where delays in processing Academic Apply Files occur, often attributed to sluggish or overwhelming requests. Addressing these bottlenecks becomes pivotal in streamlining the application process and enhancing overall efficiency.

Leveraging the ERD diagram facilitates the verification of data entry points and their interrelationships to ensure accuracy. Thoroughly scrutinize the diagram for inconsistencies or errors that could impact the application process. To fortify data integrity, the implementation of data validation checks is crucial (22). These checks ensure that only precise and valid information is accepted, minimizing the likelihood of erroneous application processing. The integration of an online data validation tool, employing artificial intelligence, further enhances the accuracy and reliability of the data.

In the extracted data model diagram, automation emerges as a potent tool to diminish manual operations, enhancing overall response time. Automation finds application in critical tasks, including updates on action file statuses, document verification, and reviews of Academic Apply Files. By implementing automation in these processes, efficiency is heightened (23), reducing the reliance on manual interventions and expediting the response time for essential actions.

Leveraging the extracted data model diagram enables the implementation of efficient mechanisms for tracking and reporting work progress. This initiative can pave the way for establishing a centralized workflow system. In the event of any disturbance or delay throughout the stages of the academic application process, from initiation to final admission to a foreign university, the system manager and the applicant will stay informed and prompt action can be taken. The integration of artificial intelligence-based algorithms proves particularly efficient in ensuring a seamless and proactive approach at this critical stage (24).

The extracted data model diagram serves as a foundation for designing and implementing effective feedback mechanisms involving both applicants and managers. Integrating feedback loops allows for the collection of valuable suggestions, facilitating continuous improvement and enhancing overall user satisfaction (Fig. 6)

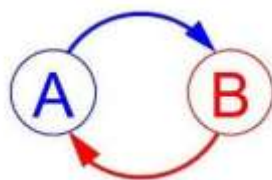


Figure 6. Diagram representing the system's positive feedback loops.

Integration with other systems: Examining and identifying the extracted data model diagram provides insights for enhancing the management of the academic application process, particularly in areas that involve the potential integration with other systems or databases, such as foreign universities. Seamless integration can pave the way for more efficient data sharing, minimizing redundancies and optimizing overall system performance (25). 3.3.7. Scalability: Utilizing the extracted data model diagram from this research enables the assessment of the platform's scalability. This approach allows for the evaluation of vulnerable points during the application process to accommodate an increasing number of applicants and universities. Planning for scalability ensures that the system can effectively manage a higher volume of requests, anticipating and adapting to potential increases in demand over time (26).

DISCUSSION

The findings of this study highlight several important challenges and improvement opportunities in Academic Application Service Management Systems (AASMS). The results indicate that although educational immigration agencies provide essential support for international applicants through academic application services, several limitations remain in information organization, document management, user support, and system design. These findings emphasize that improving academic application services requires not only better information provision but also structured data management and user-centered system development.

Transparency of Application Procedures and Information Guidance

One of the main findings of this study was the lack of clear, step-by-step guidance in academic application procedures. In complex processes such as international admission applications, accessibility of information alone is insufficient; information must be structured in a way that enables applicants to make effective decisions and complete required procedures accurately. This finding is consistent with previous studies indicating that international student mobility decisions are strongly influenced by information quality and clarity (2). Previous research has also emphasized the intermediary role of educational agents in reducing information asymmetry between applicants and higher education systems (7,8). However, existing evidence suggests that providing information does not necessarily guarantee better decision-making, as the effectiveness of information depends on its organization and contextual relevance (15,17). A possible explanation for this finding is that structured guidance reduces cognitive workload and uncertainty during the application process. Therefore, designing sequential workflows and transparent procedures can improve applicant experience and reduce errors.

Document Management and Processing Challenges

Another important finding was related to difficulties associated with document submission, management, and review processes. Since documents represent the core operational component of academic applications, inefficient document workflows can increase processing time, administrative errors, and applicant dissatisfaction. Previous studies have demonstrated that educational intermediary systems require standardized information management processes to reduce inconsistencies and improve service reliability (7,8). Furthermore, research in educational data management has emphasized the importance of structured data architectures and information integration for improving administrative efficiency (9,10). The observed challenges may be explained by limitations in document workflow design, insufficient validation mechanisms, and weak relationships between stored information entities. Therefore, applying data modeling approaches and automated validation mechanisms may improve accuracy, reduce repetitive tasks, and enhance system performance.

Online Support and Intelligent Technologies

The findings regarding online support systems and artificial intelligence-based document review indicate a relatively positive attitude among users toward intelligent technologies; however, their implementation remains dependent on appropriate design and integration with existing processes. Previous studies have highlighted the importance of support mechanisms in facilitating international student mobility and improving interactions between applicants and service providers (3,7,8). Moreover, research in educational data mining and learning analytics suggests that intelligent tools provide value when they are supported by reliable data structures and user-centered design principles (4,9,10). The potential contribution of chatbots and AI-based tools lies in reducing response time, improving accessibility, and assisting applicants during complex procedures. Nevertheless, technological implementation alone does not guarantee effectiveness, and these systems must be integrated with structured knowledge bases and transparent workflows.

User Trust, Security, and Experience

The results also emphasize the importance of security, reliability, and user experience in academic application systems. Applicants provide sensitive personal, educational, and financial information during the admission process; therefore, perceived security and system reliability directly influence trust and continued engagement. Previous research has shown that perceived information quality and reliability are important factors affecting international education decisions (2,6). In addition, studies on digital educational environments indicate that usability and security should be considered interconnected components of system design rather than independent factors. A possible explanation is that well-designed and predictable systems reduce perceived risk and increase user confidence. Consequently, improving user experience and information security should be addressed through an integrated system architecture.

Data Modeling as a Framework for Process Improvement

A key contribution of this study is demonstrating the potential role of data modeling in improving academic application service systems. The findings suggest that modeling information structures, identifying relationships among entities, and reducing data redundancy can support more efficient processing and better system management. This observation is consistent with previous studies in educational data management, big data, and learning analytics, which emphasize the role of structured data approaches in supporting administrative decision-making and operational improvement (4,9,10). Previous research on database design has also shown that appropriate data modeling improves scalability, reliability, and information consistency (11,12). In this study, integrating data-driven analysis with data modeling provided a framework for moving beyond identifying problems toward proposing structural improvements for academic application services.

Limitations and Future Research

This study has several limitations. First, the questionnaire sample size was limited, which may restrict the generalizability of the findings to broader populations of academic applicants and educational service providers. Second, the collected data were based on participants' self-reported perceptions, which may introduce response bias. Third, the study was conducted within a specific geographical and contextual setting. Future studies are recommended to employ larger and more diverse samples, compare academic application systems across different countries or regions, and combine questionnaire-based data with actual behavioral data collected from digital platforms. Longitudinal studies and predictive analytical approaches may also provide deeper insights into changes in applicant experience and decision-making over time.

CONCLUSION

Overall, the findings of this study demonstrate that transparency of application procedures, step-by-step guidance, efficient document management, online support quality, perceived security, user trust, and data modeling are important factors affecting the performance of Academic Application Service Management Systems (AASMS). The results highlight that improving academic application services requires a process-oriented, user-centered, and data-driven approach rather than merely introducing additional digital tools.

From a practical perspective, the findings of this study can support the redesign of academic application systems through clearer procedural guidance, improved document validation mechanisms, enhanced intelligent support services, and integrated data structures. These improvements can contribute to increasing applicant satisfaction, reducing processing challenges, and improving the operational efficiency of educational immigration services.

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Competing interests

The authors declare that they have no competing interests.

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None.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of originality and AI use

The data and images presented in this study are entirely original and derived from our empirical research. AI-assisted software was employed exclusively to refine English language fluency and enhance the visual clarity/resolution of original figures and histopathological images. No content, data, or microscopic features were generated, altered, or fabricated by AI tools.

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

RESOURCES

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