Investigating a Virtual Queueing System for Durban University of Technology: A Comprehensive Review Approach to Improve Efficiency

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***Abstract*—In response to the increasing demands placed on educational institutions, there is a clear need for technological advancements that can enhance the student experience while maintaining data security. This article describes the development of a Virtual Queueing System (VQS) specifically designed for the Durban University of Technology (DUT) to tackle these challenges strategically. The proposed system aims to minimize physical waiting times, ultimately enhancing the overall student experience. To ensure student information remains private and secure, the system incorporates a robust multi-layered security protocol. The goal of this research is to provide recommendations for enhancing service quality, ensuring data security, and reducing wait times across various industries that utilize virtual queuing systems. The findings from this research demonstrate the potential of digital solutions in positively transforming educational institutions.**

Keywords—Virtual Queuing, University, Realtime-Queueing, Scalability, Data Security.

I. Introduction

A virtual queue system is a digital solution that helps manage waitlists, enabling users to wait for a service without having to physically stand in line. Users receive electronic notifications regarding their turn or waiting status, which helps reduce physical waiting times and improves the overall user experience [1]. Virtual queue systems, also referred to as queueing systems, have brought about a transformation in the way waiting processes are managed across various industries. These digital solutions have eliminated the need for queues by enabling customers to join queues through their devices and even schedule appointments. This has resulted in enhanced efficiency and improved customer experiences [2]. Real-time queue monitoring refers to the ongoing and dynamic tracking and analysis of queue statuses and activities.

Real-time notifications and alerts keep customers well informed about their position in the queue while data analytics assist businesses in optimizing resource allocation [3]. Additionally, they gather feedback and data, for enhancements leading to higher customer satisfaction and reduced abandonment rates. As a result, waiting in line becomes more convenient and enjoyable overall [4].

With systems becoming more common in universities, it is important to make sure they deliver on their promise of reducing student wait times and improving service quality [5]. This means addressing challenges like allocating resources which involves assigning staff and resources to different queues in a smooth manner. Solving these problems is essential for universities to fully harness the benefits of queuing systems while providing a seamless and secure experience for their students.

Research Question

What strategies and technologies optimize online queues for enhanced efficiency, student experience, and secure scalability?

Effectively managing and optimizing queuing systems requires the implementation of advanced algorithms for resource allocation, mechanisms for dynamic scalability measures to ensure stringent data security user-friendly interfaces, and real-time analytics [8]. The authentication of users, communication with customers, and feedback mechanisms are crucial in enhancing the overall customer experience. Furthermore, continuous training for staff and customers alike along with system optimization ensures that these systems deliver on their promise of reducing wait times and improving service quality [7].

Additionally, insights will be gathered by intentionally selecting experienced stakeholders for participation [4]. To analyze the data, techniques and thematic coding will be applied to gain a comprehensive understanding of optimizing virtual queuing systems [3]. Throughout the study, strict adherence to guidelines will be maintained. The goal of this research is to provide recommendations for enhancing service quality, ensuring data security, and reducing wait times across various industries that utilize virtual queuing systems [11].

II. Literature Review

The context of this study is to investigate the virtual queuing system using a South African University as a case study. Durban University of Technology rough estimated student population is 33,000 [15]. Examples of student services where physical queues are used are in the Card protection department, and finance department, and waiting in lines has long been a problem, in both private sectors. It does affect students, staff, and customers. Also poses a challenge for service-oriented establishments. According to a study by [10] these lines often lead to frustration and exhaustion among customers, which significantly impacts their experience. In today's business landscape, where the quality of service and customer satisfaction are crucial service providers need to address this issue.

Traditionally businesses and organizations have used paper ticketing kiosks on site to manage customer arrivals and facilitate access to services. While these systems are somewhat effective, they are gradually being replaced by customer-

friendly alternatives [12]. One such innovation is the adoption of virtual queue management systems. These systems allow customers to join a queue without waiting in line, providing a convenient experience for everyone involved. These systems have been adopted by numerous sectors including the banking sector and reaching fast-food chains such as KFC and McDonalds.

The shift towards virtual queue management systems represents a development in how businesses approach customer service [8]. These systems use technology to streamline the waiting process, giving customers flexibility and control over their time while ensuring they are guided promptly toward their service points [13]. Moreover, these systems frequently incorporate functionalities, like notifications and timely updates regarding queue durations enabling customers to organize their schedules while waiting. As technology continues to advance, the integration of virtual queue management systems is likely to become more widespread across various industries [11]. This transition not only benefits customers by enhancing their overall experience but also enables businesses to optimize their operations, improve service efficiency, and gather valuable data for performance analysis and service improvement [14].

The groundbreaking study conducted in 2023 explores the idea of using a mobile application along with geofencing technologies to create an advanced and responsive smart queuing system [13]. This system aims to improve distancing practices. The research provides detailed insights into its various components.

The objective of the study is to dive into the intricacies of this novel system explaining how it works and highlighting its benefits. Physical tokens or paper tickets are typically used in queues this system introduces a digital ticketing approach. The main objective is to minimize contact and reduce the spread of germs, which is crucial, in our health-conscious world [14]. The authors explain how this ticketing system functions emphasizing its user-friendly features and seamless integration with a mobile app. Additionally, the research paper thoroughly examines the queuing model focusing on optimizing user experience. The development of a user-centric queuing model is a multifaceted process that demands careful consideration of various elements. Through this advancement, they aim to not only ensure a safer environment for individuals but also improve the overall efficiency and convenience of queuing processes.

Using real-time information to improve and customize the queuing experience. The goal is to create a system that reduces waiting times and makes users happier. The advantages of online queueing systems are that both students and instructors can gain from the systems. These systems offer accessibility ensuring that students can easily access resources and assistance they need. Furthermore, these systems introduce flexibility in terms of space utilization allowing for optimization of spaces for educational purposes.

Observed situations where people chose to bypass the queue disregarding the "come first serve" principle. This blatant disregard for the established order and priorities in a queue can have an impact on the fairness and efficiency of the queuing process [5]. Such actions pose a threat to maintaining integrity and effectiveness in queue systems.

The issue of individuals deviating from queuing etiquette has been acknowledged by [11]. In various contexts necessitating a reassessment of existing queuing mechanisms. These deviations do not cause frustration among those who abide by the rules but also introduce inefficiencies and biases into the system, ultimately affecting service quality [7].

Advanced systems have the potential to tackle the problem of people not following the established order by using methods to ensure that everyone respects the rules of the queue. This will not maintain efficiency and fairness [9].

Potential Gaps and Areas of Disagreement

The research conducted for this study emphasizes the benefits of using payment transactions and the importance of having a reliable queueing system. However, it is worth noting that previous studies have not extensively explored the potential of utilizing technology and fintech solutions to improve payment methods [4]. The main goal of the discussed queuing system is to manage and monitor an individual's position in the queue while they engage in transactions.

To address a gap, in the existing literature, this study's authors focused on integrating Online Cashiering with fintech technology as a payment method. Additionally, they developed a queueing system to enhance user's overall experience and provide insights related to previous research [11].

While many studies have thoroughly examined the operational aspects of queuing systems there remains research on how users perceive, react to, and are affected by their position, in an online queue estimated waiting times, and their overall experience [9]. Understanding these reactions, in-depth has the potential to open doors, for user-oriented designs for online queuing systems. Ultimately implementing enhancements can improve user satisfaction and foster loyalty. Contribute to the ongoing growth and success of online transaction systems.

In times there has been interest in studying online queue management systems focusing not only on their operational efficiency but also their broader economic and social impacts. [3] point out a gap in our understanding highlighting that while there is progress in optimizing queuing systems, research has largely overlooked their effects on sales, customer loyalty, and brand perception. These factors are crucial in determining the success of businesses utilizing queuing systems thus necessitating research to explore these interconnected aspects.

Furthermore, as the digital landscape evolves rapidly concerns regarding data privacy and cybersecurity have become more critical than before. Understanding how users perceive data protection while waiting in queues is vital since it can influence their trust levels and willingness to engage with systems [5]. This highlights the importance of finding a ground that allows for online queuing while also protecting the privacy of user's sensitive data.

Furthermore, when it comes to developing queue management systems it is important to consider accessibility and inclusivity. Prioritizing the user experience should be an objective even if it means sacrificing a bit of efficiency. It is not a concern but also a smart business move to create systems that are inclusive and accessible, for individuals with disabilities. Doing so expands the user base and it helps maintain a positive public image [6].

In this evolving field one of the points of contention revolves around data collection. While collecting user data can undoubtedly enhance both efficiency and user experience it raises concerns about privacy. Striking a balance between optimizing system performance and respecting user privacy poses a challenge that researchers and developers must tackle [9].

There is a lot of focus on how efficiently queuing systems operate, but there has not been much research done on their broader economic impacts [3]. For example, knowing how they

affect sales, customer loyalty, or even how people perceive a brand. Furthermore, given the growing concerns about data privacy and cyber threats these days, it is crucial to investigate the security measures in place for online queuing systems and understand what users think about data protection while they are waiting. Lastly, it is essential to consider the accessibility of these online systems for people with disabilities and figure out ways to make them more inclusive and better for everyone involved.

While there are differing opinions on the primary goal of an online queue management system, some argue that prioritizing user experience is crucial, even if it has a slight impact on efficiency [6]. Collecting user data can improve both efficiency and user experience, but it also raises privacy concerns. The extent and nature of data collection can be a topic of discussion. [7]. **Table 1: Challenges and approached used in a queueing system of various Universities in different countries.**

AUTHOR	PROBLEM / CHALLENGES	PROPOSED APPROACH	FINDINGS/ SOLUTIONS
[5]	Tasks queue to access limited processors in a computer system, leading to potential delays.	Use queuing theory to model task arrivals and processor service rates.	Adjust the number of processors and prioritize critical tasks to optimize wait times.
[8]	20% of customers are annoyed by waiting in queues, leading to discomfort and inefficiency, with some unaware of the reasons for their wait.	Review traditional queuing practices, as they often result in inefficiencies.	Implement improved queue management and provide individualized service to reduce waiting times and enhance customer satisfaction.
[6]	Neglecting queue management, especially in high-volume settings, can lead to severe issues, exemplified by the Walmart incident in 2008	Understanding the importance of queue management and the psychology behind waiting lines, which has been studied for over three decades.	Apply systematic methods and utilize resources to serve customers efficiently, prevent overcrowding, and enhance the experience of waiting in line.
[10]	Inadequate queuing management causes stress among customers and decreases employee job satisfaction.	Introduce a queue management system that organizes customers differently than the traditional FIFO method.	Implement a new system that uses algorithms to assess and adjust queues every 15 minutes, comparing and improving upon previous methods by identifying failures.

III. Research Methodology

This study adopted a mixed-methods research design, combining both qualitative and quantitative approaches to comprehensively investigate the optimization of virtual queuing systems in diverse industries [16, 17].

Data Collection:

Quantitative Data: Quantitative data was collected through surveys and system-generated data. Surveys were distributed to businesses and institutions employing virtual queuing systems to gather quantitative insights on system performance, wait times, and customer satisfaction. System-generated data was extracted for analysis, including resource allocation, queue data, and user interactions.

Qualitative Data: Customers, staff, and system administrators were interviewed and surveyed to gather qualitative data.

Data Analysis:

Quantitative Analysis: Quantitative data was analysed using statistical software to derive descriptive statistics, correlations, and regression analyses. A pattern, trend, and relationship were identified through this analysis.

Qualitative Analysis: Qualitative data from interviews and focus group discussions were transcribed, coded, and analysed using thematic analysis. This approach uncovered key themes, insights, and recommendations.

Ethical Considerations: Data protection, informed consent, and confidentiality were all adhered to during the study.

Limitations: Potential limitations include the representativeness of the sample, self-reporting biases in surveys, and generalizability of findings to all industries and contexts using virtual queuing systems.

The mixed methods approach was chosen because it enables a more thorough exploration of the research questions, enhances the credibility of the findings, and ensures that the study accounts for both quantitative metrics and qualitative insights.

By employing this mixed-methods research approach, the study seeks to offer a holistic perspective on optimizing virtual queuing systems, addressing challenges, and providing valuable insights for businesses and institutions across various sectors [12].

Survey Questions

**Below is the link for the survey that was generated with Microsoft Forms.

https://forms.office.com/Pages/ResponsePage.aspx?id=0TAZS_QStUC0jL2GEXQp2BVei8QpQGlNu-AfZJKMvNUQk85NzdaWkVCQUpNWEFQMTQ4NExLU0dHTi4u

The Bar Graph represents survey results on student satisfaction in Figure 2.

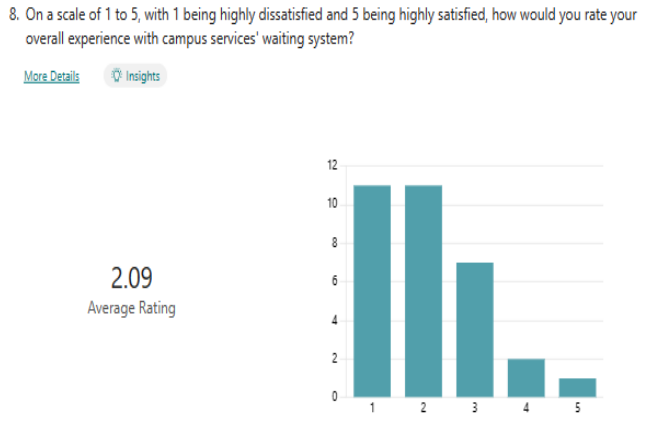

Figure 2: The Bar Graph represents survey results on student satisfaction.

The pie graph in Figure 3 below represents the departments with high waiting times. This graph emphasizes the extreme queueing times in these specific departments.

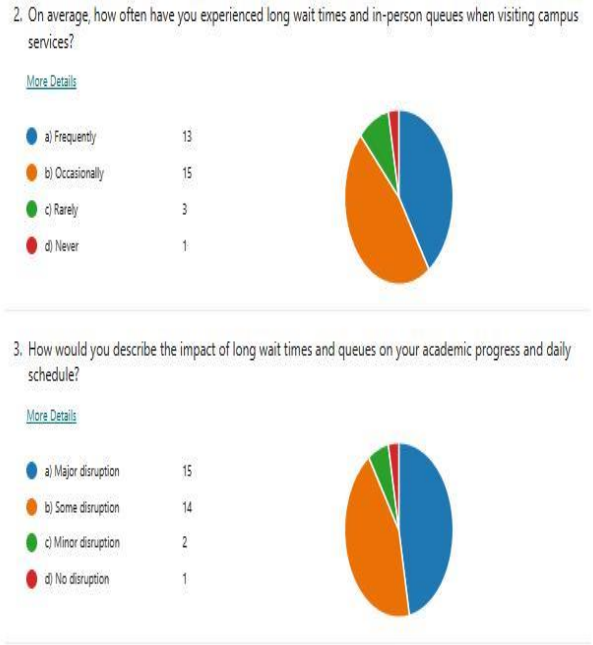

Figure 3: The departments with high waiting times.

1) Survey Results: Business

a) Business Profile: KFC Chatsworth Durban 4092

- **Industry:** Fast Food (Quick Service Restaurants)
- **Number of Self-Kiosks:** 2
- **Average Daily Transactions per Kiosk:** 70

b) System Performance Metrics:

1. **Average Wait Time for Customers:** 3 minutes
2. **System Uptime and Reliability:** 99%
3. **Number of Successful Transactions Processed Daily:** 250

c) Customer Satisfaction Metrics:

1. **Percentage of Customers Reporting a Positive Experience:** 80%
2. **Net Promoter Score (NPS):** 75
3. **Ratings on System Accessibility and Ease of Use (on a scale of 1 to 10):** 7.5

Summary of Interview Results: Students

User Experience

During their visit to campus services, students often faced long wait times and long in-person queues. This undermined their academic progress and disrupted their schedules. Students reported feeling anxious because they did not know when they would receive their services.

"Honestly, the experience is similar to standing in home affairs."

Efficiency and Convenience

During their visit to campus services, students often faced long wait times and long in-person queues. This undermined their academic progress and disrupted their schedules. Students reported feeling anxious because they did not know when they would receive their services.

"We as students waste valuable time standing in queues, we sometimes spend the entire day in these queues."

Communication

There was a lack of transparency in the information students received about wait times and services that made it difficult for them to plan their day efficiently.

"We are fed up with lies regarding the times to wait."

Interview Results: Business (KFC)

Challenges and Solutions:

Common Challenges:

Occasional technical glitches during peak hours.

Initial resistance from some staff members.

Innovative Solutions:

Scheduled maintenance during off-peak hours.

Ongoing staff training programs emphasizing the benefits of the self-kiosk system.

Perceived Benefits:

Enhanced Customer Satisfaction:

Positive feedback on reduced wait times, especially during busy periods.

Increased customer engagement with customizable orders through self-service.

Improved Operational Efficiency:

Smoother customer flow, leading to quicker service.

Staff can focus on providing personalized service and managing peak times.

The approach to the problem is as follows:

1. Arrival and Check-In:

Upon arriving at the waiting area, the student approaches a self-service kiosk equipped with a touch screen.

2. Selection of Service:

The student selects the desired service from the options displayed on the kiosk screen. For example, they might choose "Academic Advising."

3. Personal Information Entry:

The kiosk prompts the student to enter their personal information, which may include their name, student ID, or contact details.

4. Queue Placement:

After providing their information, the system assigns the student a virtual spot in the queue for the selected service. The screen displays their position and estimates wait time.

5. Confirmation and Notifications:

The kiosk confirms the student's queue number. It also offers options for receiving notifications, such as via SMS or through a mobile app, to keep the student informed about their queue status.

6. Waiting Comfortably:

The student can now comfortably wait in a designated waiting area or anywhere on campus while monitoring their queue status on their mobile device or by revisiting the kiosk screen for updates.

7. Service Access:

When it's the student's turn, they receive a notification indicating it's time to proceed to the service desk.

8. Feedback Option:

The system may offer the opportunity for the student to provide feedback about their queuing experience, which can help in continuous system improvement.

Discussion and limitations

Technical Limitations: Infrastructure Constraints: DUT's existing IT infrastructure may have limitations in terms of server capacity, network bandwidth, or software compatibility, which can impact the system's scalability and performance.

Software Compatibility: Compatibility issues with different devices and browsers may arise, potentially limiting the accessibility and user-friendliness of the system for students and staff.

Data Security Challenges:

Data Privacy Compliance: Adhering to data privacy regulations (e.g., GDPR, FERPA) is crucial, and any oversight could result in legal and ethical repercussions. Ensuring compliance may require additional resources and expertise.

Cybersecurity Threats: Protecting sensitive student and institution data from cyberattacks is essential. Continuous monitoring and security measures are necessary, and there is always a risk of potential breaches.

User Adoption and Training:

User Acceptance: Resistance to change among students, faculty, and staff may hinder the adoption of the new system. Overcoming this resistance will require effective communication and training programs.

Budget and Resource Constraints:

Financial Limitations: Developing and maintaining a sophisticated online queuing system can be costly. DUT's budget constraints may limit the extent to which the system can be developed and maintained.

Resource Allocation: Allocating dedicated staff and IT resources for system development, maintenance, and troubleshooting may strain existing resources.

Scalability Challenges:

Server Load: Ensuring the system can handle peak usage times, such as registration periods, without performance degradation is crucial but may pose scalability challenges.

Integration with Existing Systems:

Compatibility with Legacy Systems: Integrating the new queuing system with DUT's existing student information systems and other platforms may be complex and time-consuming, potentially causing delays.

Student Experience and Accessibility:

User Interface Design: Creating an intuitive and accessible user interface that caters to diverse user needs and abilities can be challenging.

Accessibility Compliance: Ensuring that the system adheres to accessibility standards (e.g., WCAG) is essential but may require additional design and development efforts.

Ongoing Maintenance and Support:

System Updates: Regular updates and maintenance will be necessary to keep the system running smoothly, which can strain IT resources and budgets.

User Support: Providing adequate user support and addressing technical issues promptly is crucial for maintaining a positive user experience.

Testing and Validation: Comprehensive testing for the system's functionality, security, and usability is essential. Inadequate testing can lead to unforeseen issues after deployment.

Navigating these limitations while developing the online queuing system at DUT is crucial for its successful implementation and long-term effectiveness in improving efficiency, student experience, data security, and scalability.

This study unveiled a significant correlation between queue responsiveness and user satisfaction. Specifically, shorter virtual wait times were consistently associated with higher levels of user contentment. This study contributes to service quality literature by empirically confirming the fundamental role of wait times in shaping user perceptions. The results extend the understanding of how digital queues parallel traditional service encounters in influencing customer satisfaction. a promising avenue for research could explore the impact of personalized notifications on user engagement in virtual queues. This aligns with our study's emphasis on optimizing the online queueing experience for users. a promising avenue for research could explore the impact of personalized notifications on user engagement in virtual queues. This aligns with this study's emphasis on optimizing the online queueing experience for users. Guided by the findings, this research proposes that virtual queueing system developers prioritize strategies to minimize wait times, such as real-time notifications. This practical recommendation stems directly from the data, aiming to enhance overall user satisfaction.

IV. Conclusion

In summary, this research paper has examined how virtual queue systems could have a transformative impact on university campuses. It explores how these systems could revolutionize the way waiting processes are managed for both students and staff. By eliminating physical queues, these digital solutions offer the potential for improved efficiency and better user experiences within campus settings. The anticipated advantages include real-time notifications, data analytics, and customization options that can help optimize resource allocation and ensure universities can adapt seamlessly to changing demands, especially during busy periods like course registration or administrative appointments.

However, the research paper also highlights the important difficulties that need to be addressed to fully unlock the potential of queuing systems on university campuses. These challenges include managing resources effectively, ensuring scalability, and protecting data privacy. All these factors play a crucial role in providing a secure and convenient experience for campus users using an online queueing system. To achieve this, it is necessary to develop advanced algorithms, implement dynamic scalability measures, create user-friendly interfaces, and establish robust authentication and communication mechanisms that cater specifically to the academic environment. Additionally, continuous training and optimization of the system are essential for maintaining efficiency and ensuring user satisfaction within a hypothetical campus scenario.

In conclusion, this research highlights the need to find a balance between efficiency, data security, and scalability when considering virtual queue systems in universities. By addressing these challenges and implementing the suggested solution, educational institutions have the potential to reduce waiting times for students and staff while ensuring a smooth and secure experience. This will enhance their competitiveness and meet the changing expectations of the campus community. As a digital transformation in educational services is witnessed, effective queuing systems have become an essential tool for universities to stay competitive and user focused.

REFERENCES

[1] Freund D, Lykouris T, Weng W. Efficient decentralized multi-agent learning in asymmetric queuing systems. InConference on Learning Theory 2022 Jun 28 (pp. 4080-4084). PMLR.

[2] Baghizadeh K, Cheikhrouhou N, Govindan K, Ziyarati M. Sustainable agriculture supply chain network design considering water-energy-food nexus using queuing system: A hybrid robust possibilistic programming. Natural Resource Modeling. 2022 Feb;35(1):e12337.

[3] Domański A, Domańska J, Czachórski T, Klamka J, Szyguła J, Marek D. The IoT gateway with active queue management. International journal of applied mathematics and computer science. 2021 Mar 1;31(1):165-78.

[4] Priscila SS, Rajest SS, Shynu T, Gnaneswari G. An Improvised Virtual Queue Algorithm to Manipulate the Congestion in High-Speed Network. Central Asian Journal of Medical and Natural Science. 2022 Dec 12;3(6):343-60.

[5] Wang J, Wang Z, Chen Y. Equilibrium strategies and optimal pricing in an online retailing queueing system. Naval Research Logistics (NRL). 2021 Aug;68(5):556-76.

[6] Halim SA, Othman MH, Buja AG, Rahid NN, Sharip AA, Zain SM. C19-SmartQ: Applying Real-Time Multi-Organization Queuing Management System Using Predictive Model to Maintain Social Distancing. International Journal of Interactive Mobile Technologies. 2021 Jun 1;15(6).

[7] Hsu WK, Xu J, Lin X, Bell MR. Integrated online learning and adaptive control in queueing systems with uncertain payoffs. Operations Research. 2022 Mar;70(2):1166-81.

[8] Sentenac F, Boursier E, Perchet V. Decentralized learning in online queuing systems. Advances in Neural Information Processing Systems. 2021 Dec 6;34:18501-12.

[9] Cai Z, Buyya R. Inverse queuing model-based feedback control for elastic container provisioning of web systems in kubernetes. IEEE Transactions on Computers. 2021 Jan 6;71(2):337-48.

[10] George J, Santhosh R. Congestion control mechanism for unresponsive flows in internet through active queue management system (AQM). Mobile Computing and Sustainable Informatics: Proceedings of ICMCSI 2021. 2022:765-77.

[11] Bismonte RB, Bufete KE, Cabañes MR, Martinez AC. University Integrated Information System: Development Of Online Cashiering & Queueing System In Camarines Sur Polytechnic Colleges.

[12] Hamdi MM, Mahdi HF, Abood MS, Mohammed RQ, Abbas AD, Mohammed AH. A review on queue management algorithms in large networks. InIOP Conference Series: Materials Science and Engineering 2021 Feb 1 (Vol. 1076, No. 1, p. 012034). IOP Publishing.

[13] Rashid NN, Zain SM, Halim SA, Sharip AA, Buja AG. A conceptual design of smart queueing management system for multiple organizations in urban transformation centre (UTC) Melaka. InAIP Conference Proceedings 2023 Apr 24 (Vol. 2544, No. 1). AIP Publishing.

[14] Abusair M, Sharaf M, Hamad T, Dahman R, AbuOdeh S. An approach for queue management systems of non-critical services. In2021 7th International Conference on Information Management (ICIM) 2021 Mar 27 (pp. 167-171). IEEE.

[15] Durban University of Technology News , Available at : https://www.dut.ac.za/about-dut/#:~:text=DUT~%20has%20approximately%2033%20000,KwaZulu%2DNatal%20(KZN). 2024.

[16] Aroba OJ. Improving node localization and energy efficiency for wireless sensor networks using hyper-heuristic optimization algorithms (Doctoral dissertation).

[17] Aroba OJ. An ERP SAP Implementation Case Study of the South African Small Medium Enterprise Sectors. International Journal of Computing Sciences Research. 2023 Jun 16;7:2196-211.