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Electronic queue management systems with visual displays and voice announcements: architecture, operation, user experience, and implementation challenges-a review

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ABSTRACT

Electronic queue management systems (EQMS) are increasingly important in public services, healthcare facilities, banks, and other environments where orderly customer flow is essential. Conventional manual queues often create uncertainty, inconsistent service sequences, congestion, and additional workloads for service personnel. This review examines EQMS that combine digital number displays with audible announcements, focusing on their architecture, operating principles, service benefits, and implementation challenges. The discussion integrates studies on microcontroller-based queue controllers, electronic calling devices, voice information systems, waiting-time communication, and customer perceptions of service delays. Particular attention is given to the coordination of ticket generation, queue processing, display updates, and voice announcements, because inconsistencies among these functions can undermine system reliability. The review also considers accessibility, human factors, communication failures, and the potential contribution of networked monitoring. The literature indicates that electronic displays and voice announcements can improve information delivery and reduce uncertainty, although they do not automatically shorten actual waiting times. Effective implementation therefore requires reliable control logic, synchronized audiovisual outputs, clear interfaces, and performance evaluation under realistic service conditions.

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1. INTRODUCTION

Queues are a common feature of service environments in which customer demand and available service capacity are not perfectly balanced. In conventional systems, customers may depend on paper tickets, handwritten records, verbal instructions, or manual announcements to determine their service sequence. These approaches can create confusion when several service counters operate simultaneously or when customers cannot hear the staff calling their numbers. Electronic queue management systems (EQMS) provide an alternative by automating ticket numbering, queue progression, and information delivery through electronic displays and audible announcements [1], [2].

The main research problem is not simply the presence of long queues, but the difficulty of maintaining orderly, transparent, and understandable service processes. Customers may become dissatisfied when they cannot identify their current position, determine which counter is serving them, or recognize when their number has been called. Research on waiting experiences shows that uncertainty, perceived control, and information about delays influence how customers evaluate service encounters [3]–[5]. Consequently, an electronic queue system should be considered both an operational control mechanism and a communication facility.

This review examines the engineering principles and service implications of electronic queue systems that combine visual displays and voice announcements. It addresses four related issues, namely system architecture, synchronization of audiovisual information, customer experience, and technical reliability. The review draws on direct implementations of electronic queue controllers as well as established research on

waiting-time information and service environments. The final objective is to identify practical design considerations and research directions for developing more reliable and accessible queue management systems.

2. REVIEW SCOPE AND RESEARCH PROBLEMS

The literature was considered through an integrative narrative approach, combining technical studies of electronic queue devices with research on waiting-time communication and service operations. Direct technical evidence was prioritized when discussing microcontrollers, displays, speakers, and queue-calling functions. Related service-management studies were used to explain why information delivery and perceived waiting time matter to users. This distinction is important because research on customer waiting does not necessarily demonstrate the technical performance of a physical queue-calling device.

Three principal research problems emerge from the literature. First, manual queue procedures can make service order difficult to monitor, particularly in facilities with multiple counters and high customer traffic [1], [2]. Second, visual-only announcements may not adequately serve customers who are looking elsewhere, have difficulty reading the display, or are positioned far from the screen. Third, systems that generate display information and audio announcements through separate processes may produce inconsistent messages or delayed notifications. These problems establish the need for an integrated system in which queue data are controlled centrally and communicated through coordinated audiovisual outputs.

3. ARCHITECTURE AND OPERATING PRINCIPLES

An EQMS generally consists of a ticket-generation unit, a processing controller, a service-counter interface, a visual display, and an audio announcement module. The ticket-generation unit assigns a sequential number to each customer, while the controller stores and updates the current queue status. When a service officer requests the next customer, the controller updates the active number and identifies the corresponding service counter. The display and speaker then communicate this information to waiting customers.

Early microcontroller-based implementations demonstrate that relatively simple electronic components can perform the essential queue-calling functions. Roseno *et al.* [1] developed a queue management system using an AT89S51 microcontroller, seven-segment displays, and a recorded-voice circuit, demonstrating operation across three service counters. Sukarma *et al.* [2] subsequently described an ATmega328-based queue caller equipped with an LED display and speaker, with an MP3 decoder for audible number announcements. These implementations illustrate how embedded controllers can replace repeated manual announcements with a more structured and repeatable process. The control unit is the central element because it maintains consistency between queue status and the information presented to customers. A practical design should distinguish between the issued ticket number, the number currently being served, and the counter assigned to that service. The controller must also manage repeated calls, skipped numbers, customer absence, and operator corrections without corrupting the queue sequence. A clear state-management procedure is therefore essential for preventing conflicting display and audio outputs.

Visual information can be presented through seven-segment indicators, character LCDs, LED matrix panels, or larger digital signage screens. Seven-segment displays are suitable for basic numerical information, whereas matrix and larger displays can communicate counter identifiers, instructions, and supplementary service information. The audio subsystem may use prerecorded speech, an MP3 playback module, or a programmable voice circuit to announce the active number and counter. Wu *et al.* [6] demonstrated a microcontroller-based voice information system with an LCD interface in an intelligent transportation context, providing a related technical example of coordinated voice and visual information delivery.

4. AUDIOVISUAL COMMUNICATION AND USER EXPERIENCE

The combination of visual and auditory announcements improves the availability of queue information because customers can receive notifications through more than one sensory channel. A customer who is not looking at the screen may still hear an announcement, while someone who cannot clearly hear the speaker may rely on the display. This complementary arrangement is particularly relevant in busy service halls where background noise, crowd movement, and viewing distance can affect information reception. However, audiovisual redundancy is useful only when both channels communicate the same queue number and service counter. The timing and accuracy of announcements are as important as the availability of the display and speaker. If the display changes before the audio message is played, customers may receive conflicting information about which number is being served. A system should therefore use a single queue-state update as the source for both outputs, rather than allowing independent devices to determine the active number. Research on delay announcements indicates that communicating waiting information can reduce uncertainty and influence customer decisions within service systems [4], [7].

The psychological experience of waiting also provides a reason to communicate queue progress clearly. Researchers [3], [8] found that delay duration, perceived control, and the way waiting time is occupied can influence customer reactions to service delays. Hui and Tse [4] showed that waiting information can affect service evaluations through customers' acceptance of the wait and their emotional responses. Similarly, Antonides *et al*. [5] and Pruyn and Smidts [9] reported that information about expected waiting time can influence perceived duration and evaluations of waiting. These findings suggest that electronic queue systems should communicate meaningful progress rather than merely display changing numbers.

The physical environment and presentation of information can further influence the waiting experience. Baker and Cameron [10] explained that environmental conditions may affect customer emotions and perceptions of waiting time, while Bitner [11] established the broader importance of physical surroundings in service environments. Chebat *et al*. [12] investigated the interaction of musical and visual cues in bank waiting situations, showing that environmental cues can influence time perception. More recently, Garaus and Wagner [13] found that digital signage in retail waiting areas could improve the perceived waiting experience. These studies support the consideration of display readability, placement, message simplicity, and acoustic clarity as part of queue-system design.

5. TECHNICAL CHALLENGES AND DESIGN CONSIDERATIONS

Reliable operation requires more than connecting a microcontroller to a display and speaker. The system must maintain accurate queue records, respond consistently to operator commands, and prevent duplicate or missing announcements. Electrical noise, unstable power supplies, damaged cables, and component failure can interrupt communication between modules. These risks become more significant when a queue system is used continuously in a public facility.

Audio quality is another important engineering consideration. Announcements should be sufficiently loud and intelligible without becoming disruptive to customers or staff. Background noise, speaker placement, reverberation, and differences in room size can affect the clarity of spoken numbers. Prerecorded messages should also use consistent pronunciation and a predictable announcement format to minimize misunderstanding.

The display should provide information that can be recognized quickly from the expected customer viewing distance. High contrast, suitable character size, stable brightness, and clear separation between queue numbers and counter identifiers are important design considerations. The system should avoid unnecessary animations or excessive information that could distract users from the current service announcement. These requirements are consistent with the broader understanding that service environments and information presentation influence customer responses [10], [11].

Network connectivity can extend the system beyond a standalone electronic device. A local network may allow several counters to share queue information, while a database can record ticket issuance, service completion, and operational statistics. Such capabilities may support service monitoring and help managers identify periods of congestion. Nevertheless, network dependence introduces additional risks, including communication interruptions, unauthorized access, and data inconsistencies. For smaller facilities, a locally controlled system with offline operation may provide a more dependable starting point.

Table 1 summarizes the main components, their functions, and the engineering issues that should be considered during implementation. The comparison highlights that the effectiveness of an EQMS depends on the coordination of its subsystems rather than the performance of an individual component. It also shows why reliability and accessibility should be considered alongside basic queue-number generation.

Table 1. Main components and engineering considerations of an EQMS

Component	Primary function	Main engineering consideration
Ticket generator	Assigns a unique queue number	Sequential numbering and prevention of duplicate tickets
Microcontroller or processor	Controls queue states and operator commands	Reliable logic, memory handling, and error recovery
Operator interface	Allows staff to call, repeat, or skip numbers	Simple controls and protection against accidental input
Visual display	Shows the active number and service counter	Readability, contrast, viewing distance, and update speed
Audio module and speaker	Announces queue numbers and counter information	Speech intelligibility, volume, and announcement timing
Communication network	Shares queue status across devices	Stable transmission, synchronization, and offline fallback
Power supply	Provides electrical energy to system modules	Voltage stability, protection, and backup power

6. EVALUATION, APPLICATIONS, AND FUTURE DEVELOPMENT

Electronic queue systems can be applied in hospitals, banks, government offices, educational institutions, transportation facilities, and other public service environments. Their value is particularly apparent where several service counters operate simultaneously and customers need clear information about their service sequence. Research on waiting has consistently identified the importance of delay information, perceived fairness, and service evaluation [5]-[7], [14]–[17]. However, the introduction of an electronic queue system should not be interpreted as proof that actual waiting times will automatically decrease.

System evaluation should therefore include both technical and service-related measurements. Technical indicators may include ticket-generation accuracy, response time, display update delay, audio announcement success, and recovery from power or communication failures. Operational indicators may include average waiting time, customer throughput, queue abandonment, and the frequency of operator corrections. Customer-related indicators should examine information clarity, perceived fairness, accessibility, and satisfaction. A combined evaluation is more informative than relying only on whether the display and speaker function correctly.

Future development should focus on improved accessibility, intelligent queue monitoring, and more flexible communication. Multilingual voice announcements could support facilities serving users with different language backgrounds, while adjustable volume and repeat-announcement functions could improve usability in varied environments. Integration with online registration and mobile notifications may allow customers to monitor queue progress before reaching the service counter. Such developments should preserve a simple local operating mode so that essential queue functions remain available during network outages.

Another important direction is the use of queue data for operational analysis. Historical service records can help identify peak demand periods, estimate service durations, and support better allocation of staff across counters. Delay information should be presented carefully because inaccurate estimates may increase dissatisfaction rather than reduce uncertainty [4], [5], [7]. Future studies should therefore investigate the relationship between announcement accuracy, system reliability, customer behavior, and measurable service performance. Comparative field evaluations across different service environments would also help establish which system configurations are most effective.

7. CONCLUSION

EQMSs that combine visual displays and voice announcements provide a practical approach to improving the organization and communication of public services. Microcontroller-based implementations demonstrate that ticket processing, display control, and audible calling can be integrated using relatively simple electronic hardware. The broader literature on waiting-time communication indicates that clear information can reduce uncertainty and improve the perceived quality of the waiting experience. Nevertheless, these systems do not independently eliminate service delays or resolve insufficient service capacity. The effectiveness of an EQMS depends on accurate queue-state management, synchronized audiovisual announcements, readable displays, intelligible audio, and reliable electrical operation. Designers should also consider accessibility, operator usability, network resilience, and the physical characteristics of the service environment. Evaluation should combine technical performance with waiting-time, throughput, and customer-experience measurements. Further research should prioritize field testing and comparative evaluation to determine how integrated audiovisual queue systems perform under different operational conditions.

REFERENCES

[1] D. Roseno, M. Muchlas, and T. Sutikno, "Application of AT89S51 microcontroller in a queuing system with display and voice," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 5, no. 3, p. 153, 2007, doi: 10.12928/telkomnika.v5i3.1359.

[2] I. N. Sukarma, I. N. Mudiana, and S. Udayana, "Performance of a queue caller using ATmega328 microcontroller," *Matrix : Jurnal Manajemen Teknologi dan Informatika*, vol. 7, no. 1, p. 18, Mar. 2017, doi: 10.31940/matrix.v7i1.163.

[3] S. Taylor, "Waiting for service: the relationship between delays and evaluations of service," *Journal of Marketing*, vol. 58, no. 2, pp. 56–69, 1994, doi: 10.1177/002224299405800205.

[4] M. K. Hui and D. K. Tse, "What to tell consumers in waits of different lengths: an integrative model of service evaluation," *Journal of Marketing*, vol. 60, no. 2, pp. 81–90, 1996, doi: 10.1177/002224299606000206.

[5] G. Antonides, P. C. Verhoef, and M. Van Aalst, "Consumer perception and evaluation of waiting time: a field experiment," *Journal of Consumer Psychology*, vol. 12, no. 3, pp. 193–202, 2002, doi: 10.1207/s15327663jcp1203_02.

[6] Y. Wu, W. Liu, J. Guo, and R. Liang, "Design of voice system for intelligent public transportation system," 2019, doi: 10.2991/msbda-19.2019.60.

[7] R. Ibrahim, "Sharing delay information in service systems: a literature survey," *Queueing Systems*, vol. 89, no. 1–2, pp. 49–79, 2018, doi: 10.1007/s11134-018-9577-y.

[8] S. Taylor, "The effects of filled waiting time and service provider control over the delay on evaluations of service," *Journal of the Academy of Marketing Science*, vol. 23, no. 1, pp. 38–48, 1994, doi: 10.1177/0092070395231005.
[9] A. Pruyn and A. Smidts, "Effects of waiting on the satisfaction with the service: Beyond objective time measures," *International Journal of Research in Marketing*, vol. 15, no. 4, pp. 321–334, 1998, doi: 10.1016/s0167-8116(98)00008-1.
[10] J. Baker and M. Cameron, "The effects of the service environment on affect and consumer perception of waiting time: An integrative review and research propositions," *Journal of the Academy of Marketing Science*, vol. 24, no. 4, pp. 338–349, 1996, doi: 10.1177/0092070396244005.
[11] M. J. Bitner, "Servicescapes: the impact of physical surroundings on customers and employees," *Journal of Marketing*, vol. 56, no. 2, pp. 57–71, 1992, doi: 10.1177/002224299205600205.
[12] J. C. Chebat, C. Gelinas-Chebat, and P. Filiatrault, "Interactive effects of musical and visual cues on time perception: an application to waiting lines in banks.," *Perceptual and Motor Skills*, vol. 77, no. 3 Pt 1, pp. 995–1020, 1993, doi: 10.2466/pms.1993.77.3.995.
[13] M. Garaus and U. Wagner, "Let me entertain you – increasing overall store satisfaction through digital signage in retail waiting areas," *Journal of Retailing and Consumer Services*, vol. 47, pp. 331–338, 2019, doi: 10.1016/j.jretconser.2018.12.008.
[14] R. C. Larson, "Perspectives on queues: social justice and the psychology of queueing," *Operations Research*, vol. 35, no. 6, pp. 895–905, 1987, doi: 10.1287/opre.35.6.895.
[15] F. Bielen and N. Demoulin, "Waiting time influence on the satisfaction-loyalty relationship in services," *Managing Service Quality*, vol. 17, no. 2, pp. 174–193, 2007, doi: 10.1108/09604520710735182.
[16] A. Durrande-Moreau, "Waiting for service: ten years of empirical research," *International Journal of Service Industry Management*, vol. 10, no. 2, pp. 171–185, 1999, doi: 10.1108/09564239910264334.
[17] Y. Zhang and B. J. Shao, "Influence of service-entry waiting on customer's first impression and satisfaction: the moderating role of opening remark and perceived in-service waiting," *Journal of Service Theory and Practice*, vol. 29, no. 5–6, pp. 565–591, 2019, doi: 10.1108/JSTP-12-2018-0271.