INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 8, Issue 5 - V8I5-1158)
Available online at: https://www.ijariit.com

Application of Queuing Theory in Passenger Queuing Optimization at Airports – A Systematic Review

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ABSTRACT

Waiting lines and queues are a frequent occurrence in both the workings of businesses and the daily lives of clients. A queue is the first contact point of a business and its client. Clients may not be satisfied with lengthy queues. Therefore, in order to leave a lasting first impression on the client's mind, it is crucial for a company to ensure minimal queuing. The aviation industry experiences significant queuing issues as a result of passengers queuing up for boarding, departure, luggage pickup, and so on. A systematic queue network is also required to guarantee that planes experience minimum air and runway congestion. Queuing theory is a mathematical approach to the analysis of queue waiting times. This paper presents a run through of queuing theory and its application in the aviation industry, covering a detailed explanation about queuing theory, terminologies associated with it, recent advancements in airport queuing, various queuing models, as well as some suggestions for further research.

Keywords— *Queuing Theory, Queuing Models, Simulation, Airport Queuing, Passenger Queuing*

1. ORIGINATION OF QUEUING THEORY

Early in the twentieth century, a Danish mathematician and engineer named Agner Krarup Erlang was the first to develop queueing theory (Mehri et al., 2008). The Copenhagen Telephone Exchange hired Erlang, who had the goal of reviewing and streamlining the business' procedures. He was curious about the number of circuits needed to provide a quality of phone service that would prevent excessive hold times or phone queues. Additionally, he was interested in how many phone operators were needed to handle a specific number of calls. His mathematical work culminated in the 1920 publication of the paper Telephone Waiting Times, which laid the groundwork for applied queuing theory. The international telephone traffic unit is called the Erlang in his honour.

2. INRODUCTION

Queuing theory, a branch of operations research, refers to "a mathematical study of waiting lines and queues". It is one of the most traditional and popular methods of quantitative analysis, and aids in connecting the demand for anything to a service. It aims to analyse and determine the length of queues, average waiting time, service and time (Naji et al., 2020). Waiting lines find their application in most everyday activities such as grocery shopping, petrol purchases, bank deposits, and phone waits for the first available airline reservationists. Queues, which are another term for waiting lines, often find their application in machine repairing, traffic lines, loading and unloading of material, and airplanes on the runway, awaiting permission to fly ('Cooper RB', 1981). The goal of the queueing theory is to cut down on waiting time. "Queuing theory aims to minimise clients' wait time in queues and optimise utilisation of limited resources." Using queuing theory, analysis of a business's expected queue length, frequency of the queue system being in certain states as well as the client expected wait time can be derived (Mehri et al., 2008). It also seeks to assist in the effective and timely allocation of resources to meet demand. Queuing theory finds wide application in the airlines industry. The airlines industry nurtures employment creation, economic expansion, and eases travel and commerce abroad. It is expected to show exceptional growth in the future. However, with increased growth comes increased operating difficulties. Until the early 1990s, major air traffic delays were largely focused on a small number of airports, but a strong growth in the number of airport operations took place during that decade, leading to system wide congestion problems between 2003 and 2007 (Pyrgiotis et al., 2013). In their everyday operations, airports contend with a variety of issues, with revenue, increased wait times and rising security expenditures ranking among the most significant. When it comes to human lines, queue psychology is critical for understanding the experience. According to queue psychology research, it is not how long people wait that determines whether they have a good or bad line experience, but how they feel while waiting. (Abdulaziz Alnowibet et al., 2022a). A major challenge is how to balance the trade-off between maximizing security and decreasing predicted waiting times and costs (Chen et al., 2017). To address these issues, cutting the security budget, for example, by reducing employees, is troublesome since it might result in longer queues at security checks. In order to maintain a smooth queuing process at airports, this study proposes the use of queuing theory in process optimization. This will have a substantial impact on waiting times, passenger flows, and space allocations, all of which will have an impact on terminal performance and the overall passenger experience. This will help predict and measure how the new systems, guidelines, level of service (LOS), and overall traveller experience will affect things. The purpose is to supply enough information to analysts who wish to use queuing theory to model an airport process and find specifics of relevant models.

3. LITERATURE REVIEW

This Section begins by discussing the history and meaning of queuing theory in general, along with a concise explanation of queuing theory terminologies. It then moves on to a theoretical literature study on the topic "Queuing Theory V/S Simulation." This is followed by a short review and discussion of various queuing theory articles.

3.1 History and Meaning of Queuing Theory-

The queuing system refers to "the process by which a client enters the queue, waits for the service, and then exits the system after receiving it." (Abdulaziz Alnowibet et al., 2022b) The active research in this area started in the early 1960s, when queuing models were developed for enplanement passenger check-in resulting in the determination of average service and wait times. (Fayez et al., 2008a). This research was beneficial in the designing and redesigning of efficient ticketing functional areas, such as optimal capacity and space distribution. With changing times, other queuing models were developed and utilised to analyse not only ticketing sections, but the full departure lounge at an airport terminal, taking economic consequences into account (Mckelvey, n.d.). A revised version of queueing the-ory was described in 1953 by Kendall, which is known as Kendall notation. The behaviour of this notation is denoted as A/B/C/D/E, where A is the inter-arrival time distribution, B is the service time distribution, C is the number of servers, D is the buffer size and E is the discipline, such as LIFO (last-in–first-out) or FIFO (Naji et al., 2020) similar studies considered stochastic analysis and included other functional areas such as corridors, seating, immigration, well-wishers, greeters, etc ('de Neufville & 'Grillot, 1982)

It should be noted that queuing system elements have been categorised differently by different sources (Abdulaziz Alnowibet et al., 2022c). However, the basic queuing system elements are covered in the categorisation of Bhat, namely the Arrival Process, Service Mechanism, System Capacity, and Queuing Disciplines (Mehri et al., 2008). The arrival or Input Process is the first element of the queuing system. When designing an airport's queue structure, it is critical to consider all data pertaining to the number of passengers coming at specific intervals, generally known as the arrival rate. This may be further classified as- Source determines whether consumers came from finite or infinite populations. The known or random intervals between incoming traffic are defined by time. The final category, quantity of clients, decides whether clients arrive individually or as a group. (Abdulaziz Alnowibet et al., 2022c). Another component of the queuing system is the service mechanism or service process. It consists of two components: the way the service system is structured and the speed of the service. System capacity refers to" The maximum consumers that may wait in the line at the same time." Queue Disciplines refers to the order in which clients are chosen from the service queue. (Abdulaziz Alnowibet et al., 2022b) used queue discipline is known as" First Come First Served (FCFS)", in which consumers are served in the order of their arrival. FCFS is regarded as the system performed with the highest level of fairness (Rogiest et al., 2015). Another commonly used queue discipline is" Last Come First Served (LCFS)". Both these queue disciplines have been explained in detail further in the paper. Speed Of Service is a widely used term in queuing theory, which means" The speed at which the consumer receives service after entering the queue system" Service Rate refers to" The number of clients served in a certain time period", and service time refers to" How long it takes to service a client."

3.2 "Queuing Theory v/s Simulation" A theoretical review-

Queuing theory and simulation modeling are the two approaches most commonly used to translate client arrivals during different time intervals into the staffing levels needed to maintain the required service standards (Ernst et al., 2004)

Queuing theory, a traditional scientific research topic, is too limited to anticipate and quantify wait times at check-in counters. Although the check-in process is described by using a basic M/G/s-model, these calculations describe a constant-state condition. For the procedure of checking in, this would indicate that passenger arrival rates remain stable over lengthy time periods. However, this is generally not quite the case with check in patterns of clients. Nonetheless, "queuing theory" does provide valuable contributions. One of them is just figuring out the workload is insufficient, which, even if far below 100%, will lead to queue formation (Joustra & van Dijk, n.d.)

As an example, queuing theory predicts an average queuing time of nearly three times the average check-in processing time for a single check-in counter with a workload of 75%, despite a 25% idleness rate.

Working along with queuing algorithms and workloads under constant-state assumptions, another realistic model is required for predicting the queuing times. This method is known as simulation. Simulation allows for the use of arbitrary distributions for check-in processing time and arrival patterns (Fayez et al., 2008b). As an added bonus, simulation provides animation to enhance communication at executive and operational levels, both. Nonetheless," queuing theory" may be used to verify and validate a simulation model. Theory is useful in defining experiments and assessing outcomes during the experimental phase.

3.3 A Review of Peer Papers for an in depth understanding of various queuing models and their outcomes-

Several studies and works on queuing theory and airports have been published by renowned academics worldwide. Following is a summary of some of those studies:

In the paper by (Abdulaziz Alnowibet et al., 2022b), authors benchmarked an existing departure queue system against the Level of service concept wait time. According to the International Air Transport Association's LOS concept, the optimal check in wait time is between one to five minutes (Abdulaziz Alnowibet et al., 2022b). After the analysis, it also identified areas for improvement and advised the CAI to concentrate on enhancing service times for its check-in, security, and boarding processes. Talking about LOS, the paper states that LOS model provides logistical help in the administration of passenger service. This model aids in determining the structure of each flight, and the passenger receives a system rating. It was concluded that combining FCFS (first come, first served) with PQ (priority) is an excellent approach for managing queues. Increasing airport terminal capacities, effective employee training, adopting a passenger flow forecast system, and increased investment in automation systems were some of the solutions states in the paper.

In the paper by (Mehri et al., n.d.), the authors have described queuing situations, and demonstrated how linear programming, and in certain circumstances mathematical analysis, may be utilised to estimate system performance metrics. Further, a developed model was applied to a real-world case of the "Tunisian Airport". This paper concluded that simulation may be the only option, if there arises a case featuring the most realistic queuing systems. Operations researchers have created handling models. The computations that occur from resulting mathematical formulations, are on an even more complex side than the ones covered in this case, and many real-world queuing applications are far too complicated to be analytically modelled (Mehri et al., 2008). When this happens, quantitative analysts usually turn to computer simulation. ((Mehri et al., 2008)

In the paper by (de Lange et al., 2013), the possibility of implementation and the potential of a distinct 'virtual queuing' model is discussed, through a simulative study involving a large airport in 'Western Europe'. The main objective is to identify whether the application of VQ could reduce the number of agents at airport security lanes, while not increasing the average passenger waiting time. ((de Lange et al., 2013) A simulation model, consisting of a base case and an experiment case was developed. The authors concluded that the forecast model's accuracy, the pattern of passenger arrivals, the proportion of qualified participants, the size of the time slots, and other factors are all necessary for VQ to be successful. Their analysis concluded that in general, the major advantage of VQ for travellers is lower wait times in security lanes during peak hours. The decrease in the security lane queue can be explained by the smoother arrival of passengers. This also leads to fewer peak moments when all passengers face long waiting times (de Lange et al., 2013).

In the paper by (Lee & Jacobson, 2011), the queueing process for a multi-level airport checkpoint security system, in which different security classes are established by subsets of specialised screening equipment, has been modelled. A static assignment policy that reduces the steady-state predicted amount of time a passenger spends in the security system is obtained. Then, using a transient analysis, an ideal dynamic assignment strategy is developed by balancing the predicted number of true alarms with the estimated length of time a passenger spends in the security system. The optimal assignment procedures that result maximise security and efficiency by employing existing screening resources efficiently and effectively.

In the thesis by (Jacquillat & Dipl, 2010), a stochastic and dynamic queuing model was applied to study operations at JFK and Newark (EWR), two of the busiest airports in the United States. To approximate the dynamics of the queuing system, two models are used: a numerical model called DELAYS and a novel Monte Carlo simulation model that integrates time-varying stochastic models of demand and capacity. The models are then demonstrated to properly forecast both the amount and development of the delays throughout the course of a day of operations. These two models are then used to analyse recent scheduling and on-time performance patterns at JFK and EWR.

4. RESEARCH METHODOLOGY

The methodology outlines the motivation for conducting the research and objectives of the research. It then states the various sources, keywords and parameters used to obtain an initial group of articles, which acted as a base for beginning the research. It also states the various inclusion and exclusion criteria used to produce a filtered group of articles.

The motivation for conducting this research arises from the need to try to alleviate the ever-growing problem of long airport lines, as a result of which many people miss important flights, and trying to present a tangible answer for passenger queue optimisation at airports. This research is also motivated by a desire to help society by serving as a foundation for future research in this field.

The objectives and aims of this research are to review and examine previous studies in the topic over the years. This study will serve as a beginning point for aspiring researchers. It will serve as a one-stop solution for obtaining the gist of most significant discoveries and studies in this field. It would also assist future researchers in understanding how much work has already been done in the subject and where there is still room for more. Future researchers can therefore study the unexplored areas. This research will make it easier to comprehend how deeply this subject has been explored throughout the years.

To provide the groundwork for further study, we began by searching the terms 'queuing theory' and 'airports' on the website 'Google Scholar.' This search revealed around 60 publications with generic information that we could utilise. This provided the report a head start. Going further, sites such as 'Google Scholar,' 'ScienceDirect,' 'EbscoHost,' and 'SciHub.se' were used to collect more research publications. The search tray was widened by adding more terms such as 'passenger queuing,' 'process optimization, 'simulation,' and 'queuing models.' All of this resulted in additional 150 publications, the substance of which was scrutinised and selected for this review study.

The selected reference articles were converted into RIS format using applications such as 'Mapmyaccess' and 'Mendeley Desktop.' The RIS files were then exported to the 'Vos viewer' tool, which was used to transform the required data into maps. The maps assist us in determining the most commonly used keywords as well as the writers who have done the most research in this topic. The maps are discussed in depth in the analysis section. To produce a graph showing the number of papers authored over the years, the application 'Microsoft Excel' is used. This graph allows us to assess the extent to which studies have previously been conducted, as well as their future potential. It has been discussed in depth in the analysis section. For citations and referencing, "Mendeley Desktop" has been used.

The application 'Microsoft Excel' was used to create a systematic table that included writers, their contributions, and the methods and approaches they used to solve queuing difficulties. This table contains information on numerous queuing models, their popularity based on usage in articles, and provides a learning edge for understanding and analysing the limitations of less popular models. Out of these models, M/M/1, M/M/C, Bayesian model, Simulation model, LOS model, are some of the most talked about models, in other research articles. These models are discussed in depth in the analysis section.

5. ANALYSIS

This section, through use of charts, graphs, figures, and data from peer papers, presents an analysis on the authors in relation to the level of work done in the subject. In addition, the section provides a review of popularly used queuing models. It further provides an analysis about two popularly used queuing disciplines. These assessments are based on characteristics such as success rates, results, model assumptions, mathematical words used in the model, applicability in current times, and more.

An analysis of the authors, their work, and keywords:

Figure 5.1

Figure 5.1 shows the 'Number of Research and Review articles published on the topic over the years.' This graph was generated by taking into account both individual and cumulative papers over the years. Work in this domain began in 1998, with 9 articles published in the first year. Over time, the number of individual papers on the topic has increased to 65-70 every year. The cumulative count has reached up to 673 papers by August 2022. This indicates that the airport queueing problem remains a major concern. This topic has received increased attention over the years and remains a persistent concern. Despite several models and articles produced on the subject, there are still gaps in the area that need to be addressed, and there is still room for additional research. Ongoing research in the topic implies an effort to fill in the gaps.

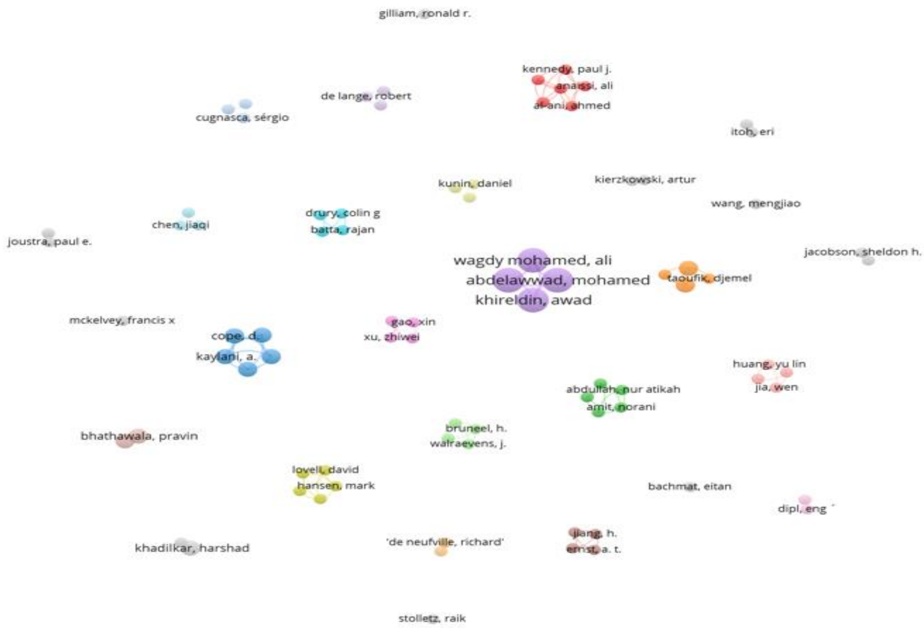


Figure 5.2 Most prominent authors in the field

Figure 5.2 is a map that shows the writers who have done the most research in the domain. These are some of the writers that are responsible for revisions in the area of airport queuing. Their studies have filled significant gaps in the discipline and have resulted in favourable advancements. Their models and research contributions offered a sense of direction and served as a starting point for the researchers in charge of making structural improvements to the airport and queuing structures. Some of the most prominent authors in the area are Ali Wagdy Mohamed, Awad khireldin, Mohamed Abdelawwad, D.cope and A.Kaylani.

6. A REVIEW OF POPULARLY USED QUEUING MODELS

(a) M/M/s model – In queuing theory, "An M/M/s queue describes the queue length in a system with a single server, where arrivals are governed by a Poisson process and task service times have an exponential distribution." The effective usage of M/M/s model can be observed in the research article "Application of the Queuing Theory in Characterizing and Optimizing the Passenger Flow at the Airport Security"

In this paper, firstly, a Poisson model is utilised to estimate the flow of travellers awaiting security. The Poisson distribution is then coupled with a multiple M/M/s model.

(b) Certain Assumptions for the M/M/s model in this paper are-

- Based on statistics from major airports throughout the world, we assume that an airport's operating hours are 16 hours per day (Wang, 2017)
- All lanes are run asynchronously, and no emergencies have occurred (Wang, 2017)
- All screeners, guides, and policemen give homogenous service quality that is more than adequate, and they are completely prepared to get to work as soon as a new lane is opened. Staff is fully trained and competent, therefore there will be no human errors that may slow down the processing time (Wang, 2017)
- This study will only look at passengers flying in economy class. Queues for first and business class are out of the question (Wang, 2017).

(c) A single asynchronous M/M/s queuing model is constructed by a sequence of asynchronous servers represented by Si where iN is a number (i.e., 1, 2, 3, 4, 5...) and a lane of passengers waiting to be verified. Asynchronous servers deal with passengers at various times (each server in this queue architecture is independent of the others). When a passenger has completed his server screening, another passenger from the lane will take up that spot to keep the server running without a pause. (Wang, 2017)

- Figure 1 depicts a typical single M/M/s queuing system with a full load of clients. Ti specifies the time interval between two passengers passing through the gate for each server. When this passenger completes this stage, he passes on to the next inspection phase, and the next costumer will come to the server and continue this procedure, while it differs for different clients. (Wang, 2017)
- Figure 2 depicts a typical traveller dividing his personal goods into three baskets. Each basket takes around tbj seconds to prepare. To generalise the situation for each passenger with n baskets, we have:

$$t_i = \sum_{j=1}^{n} tb_j$$

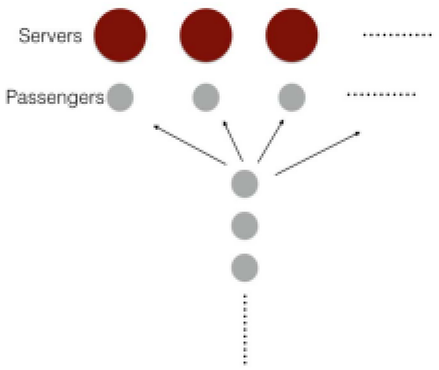


Figure 6.1: a single M/M/s queue (Wang, 2017)

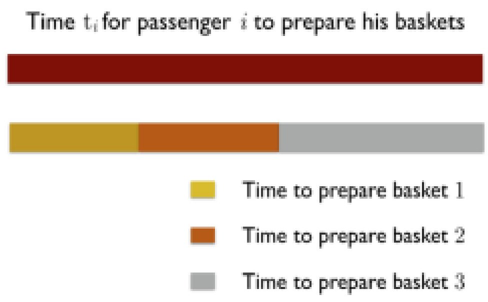


Figure 6.2: Waiting time model (Wang, 2017)

- Most airline laws limit the amount of baggage allowed for economy-class clients. As a result, we assume that all economy-class passengers can only split their belongings into baskets smaller than six.
- A Poisson process is used to represent the number of baskets per passenger by a. Furthermore, the Poisson distribution we used has been significantly changed to meet the scenario. (Wang, 2017)

(d) Some Suggestions after usage of this model, as expressed in the paper were-

- Set an express - Set express bypass swift pass for individuals with only one piece of light baggage. These persons, who just have a few items to inspect, can rapidly pass through the Swift pass.
- Promoting a Pre-check - Such travellers pay an extra $85 for a background check and five years of a separate screening procedure with little improvements to save time. We may market this service by offering lower-cost choices, such as $20 per year vs $85 per five-year period, which would attract more potential passengers, such as overseas students who will not stay in the United States for five years. (Wang, 2017)

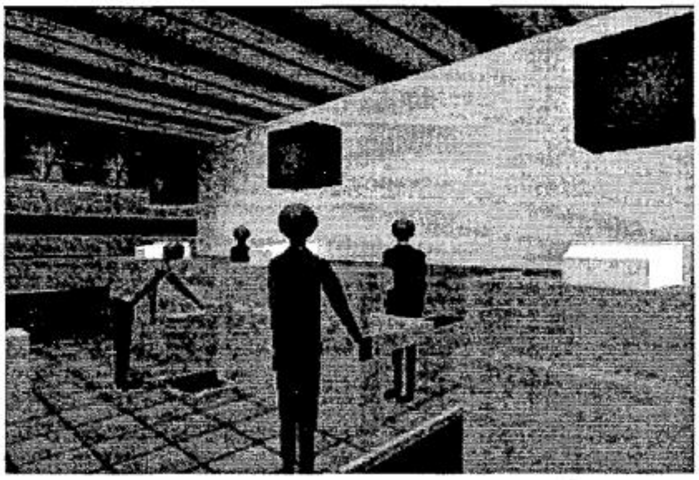
(e) Even though the M/M/s model is one of the simplest queuing models, it has certain limitations -

- One apparent drawback is that the available waiting space may be restricted.
- The arrival rate varies by state. In other words, potential consumers are deterred from entering the queue if there is a big wait when they arrive.
- The arrival process is not steady. It is highly likely that the service station may encounter peak and slack periods when the arrival rate is greater and lower than the general average.

Simulation Model- Simulation Model is another approach to realistically predict queuing times at check in counters. Simulation refers to "A realistic approach for predicting the queuing times, working with workloads and/or queuing algorithms under steady-state assumptions". Simulation analysis is widely used in studying operations problems at airports, since simulation in general is an effective tool that allows for the control of extraneous variables while allowing the researcher to generalize the results. (Li et al., 2018)

(f) Certain Advantages of Simulation model are -

- Simulation can cope with peaks in arrival patterns and provide insight into the short-term impacts of, say, half-hour peaks.
- For check-in processing time and arrival patterns, Simulation permits the use of arbitrary distributions.
- It is feasible to examine various check-in processes and reach a quantifiable result using simulation (Peters et al., n.d.)
- Animation is also available in simulation to help with communication at both the management and operational levels (Peters et al., n.d.)
- The study "Simulation of check in at airports" illustrates the effective application of a simulation model. In this paper, a simulation building block toolkit has been developed. This toolkit allows you to create simulation models to examine the airport check-in procedure. Through a case study, it is explained about "A single bay simulation model with 24 check-in counters ". The simulation model's animation is shown below-



(g) The following operational check-in rules were studied:

- **Common versus dedicated check-in -** The simulation model shown that employing common check-in results in a significant reduction in average queue times. This has a good impact on both counter planning and personnel planning. When deciding which flights should be checked in via the common check-in technique, several factors such as flight arrival patterns and check-in processing time must be considered.
- **Dynamic versus static opening and closing -** Dynamic counter opening and closure indicates that, "depending on the amount of passengers queuing, either an extra counter is opened or a counter is closed". This is essential for better check-in counter personnel planning. Using dynamic opening and closing times instead of operating a constant number of counters throughout the check-in period can result in significant reductions in queuing time (Peters et al., n.d.).
- **Extension of the check-in period prior to a flight-** The average queue time may be reduced significantly by opening the check-in counters an hour sooner. If a significant number of people arrive before any of the counters for this flight open, a large peak will occur when the counters open. This peak will result in long lines. An expansion of the check-in time does not have to result in an increase in total operator hours when using dynamic opening and shutting of the counter (Peters et al., n.d.).
- **Overflow for economy class passengers to business class counters -** Business class check-in counters are often less busy than economy class check-in counters. Allowing economy class clients to check in at a business class counter will have a

significant influence on the average queue time of economy class passengers. As a result, shared resources are utilised more efficiently (Peters et al., n.d.).

- **Bank lining -** Bank line refers to the use of a single queue for numerous counters. The effect on queue time is heavily dependent on how evenly people disperse among the counters. Passengers travelling in groups can lead to this situation (Peters et al., n.d.).
- Through the case study, it was concluded that when studying the check-in process, a simple calculation based on workloads or application of queuing theory reveals various errors. As a result, queue times cannot be correctly anticipated using these analytical approaches. The peaks in arrival patterns are the most important reason. The sole remaining option is simulation, which has additional benefits such as customizable modelling and animation.

(h) However, Simulation Model has certain limitations-

- Model construction necessitates specialised skills, and developing complicated simulations is an art form. Two simulation models may be different from one another. The findings of simulations may be difficult to understand.
- The findings of simulations may be difficult to understand. Simulation modelling and analysis can be time consuming and expensive too.
- Simulation modelling and analysis can take a long time and be costly. Simulations frequently produce inferior solutions. The solution may be the best discovered after numerous simulations with varied settings, but this is no assurance that it is the best available. (*Simulation and Queueing Theory Contents*, 2004)

(i) An Analysis of popularly used queue disciplines

Queue Disciplines refers to the order in which clients are chosen from the service queue. One commonly used queue discipline is known as" First Come First Served (FCFS)", in which consumers are served in the order of their arrival. (Abdulaziz Alnowibet et al., 2022b). FCFS is regarded as the system performed with the highest level of fairness.(Rogiest et al., 2015). First in first out (FIFO) is a phrase that may occasionally be used while discussing service models. However, this concept is basically the same as FCFS. While all of the queuing models can be supplied by the FIFO process, alternative systems may exist. High priority and low priority queues are one of those systems, with the low priority queue served after the high priority queue (Zhu et al., 2021) .When capacity is reached, high-priority clients are frequently let go due to a failure to evaluate service time and significance of consumers. Therefore, the Priority Queuing (PQ) system tackles this problem by sorting clients based on their level of importance. FCFS is frequently integrated into PQ, where multiple queues are formed to serve clients of varying priority levels. (Abdulaziz Alnowibet et al., 2022b) Under FCFS, when a person usually arrives at a self-check in kiosk, if there is an idle kiosk, the client will be approved immediately. If not, the consumer will go to the front of the line and wait for the service. If, however, the wait times get too long, clients may opt to use a check-in counter instead (Zhu et al., 2021).

On the other hand, LCFS is the exact opposite to FCFS. Last Come, First Served (LCFS) refers to "when the service is provided to clients who arrive last". In the LCFS discipline of service, it removes the incentive provided to arrive early in FCFS (Zhu et al., 2021). It also eliminates the inefficiencies of observing queues to determine which client has arrived first. According to a peer paper, loading and offloading to/from aircrafts, also impatient clients or those with higher urgency (Abdulaziz Alnowibet et al., 2022c) .This is illustrated in the form of an example that an aircraft in a holding pattern upon landing; an aircraft experiencing technical difficulties; or an aircraft nearing fuel exhaustion will be attended to first when a large queue has developed in the landing pattern.

7. CONCLUSION AND FUTURE RESEARCH PROSPECTS

This paper conducts a systematic review on the applications of queuing theory, to minimise passenger queuing on airports. To conduct this review, past research conducted in this area employing various queuing models and approaches is taken into consideration. The aviation sector is one of the world's leading industries, contributing significantly to the ease of worldwide commerce, speedy passenger travel, and trade. Excessive queuing at airport terminals for baggage check-in, passenger check-in, and check-out has been a long-standing issue at airports. The aviation industry is expected to show exponential growth in the future, and hence, increased queuing problems will lead to increased client dissatisfaction, which may prove detrimental for the aviation industry. This paper assists in contributing to queue minimization on the airports. Through a review of the best works in this subject by some of the most prominent authors, this paper serves as a referring guide, to gain an idea about the major developments in this industry over the years, the progress that current and previous research has made in this subject, and further scope of progress.

Regarding the models covered in the research, certain conclusions are drawn. Both the M/M/s model and the simulation model have advantages and limitations. These must be taken into consideration while employing these models in the papers, to effectively contribute in minimising queuing. Sometimes, queue times that are difficult to predict using analytical models like M/M/s and M/M/c, can be predicted using simulation models.

Furthermore, we would like to highlight some study limitations and propose future research prospects. This study has been carried out by considering and analysing databases like "Google Scholar", "EbscoHost", "Scihub" and "Science Direct". However, other potentially valuable information sources such as books, editorials, news articles, and conference recordings have not been explored. Additionally, this research has been conducted just by considering sources in the language "English." Due to linguistic barriers, sources of knowledge in vernacular languages have not been studied. There are currently very handful published research articles in this domain that revolve around the concept of "Virtual queuing". "Virtual Queuing" has the potential to significantly reduce queuing troubles, however it is currently a niche area. Further exploration and study into "Virtual queuing" may result in a quantum leap in the field.

Another unexplored area in the domain is the "impact of the global pandemic Covid 19" on airport queuing. The pandemic majorly impacted the human resources, operations, and revenues of most sectors. There are only a handful of publications written about the pandemic's impact on airport queues. This is an essential research field, since airport operations had become tougher during the pandemic owing to a decrease in human resources, more travel, and tighter travel norms and regulations. Therefore, research should be conducted in this area in the future.

Finally, another finding was that all previously published research articles focused on and demonstrated the use of individual queuing models to solve queuing problems. All queuing models have their own set of limitations that impede obtaining a better solution after a certain level. Future research should demonstrate the integration of several queuing models. Multiple queuing models working together will ensure that the constraints of one model are transcended by other models. This might result in a better solution. This could be another topic for future study.

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