

Teaching Introduction to Queueing Using Excel

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Abstract. The paper provides practical guidelines, teaching suggestions, and many examples for teaching an introduction to queueing theory in business and operations courses. Queueing theory is an important topic with many practical applications, but students often find it difficult because the standard textbook formulas, especially for the M/M/k model, are mathematically complicated and cumbersome to use. To make the topic more accessible, we developed an easy-to-use Excel spreadsheet for teaching the M/M/k model and two useful extensions: finite-capacity queues and queues with a general service-time distribution. The spreadsheet allows students to focus on interpretation, what-if analysis, and managerial decision making rather than on lengthy formula manipulation. The paper also provides a structured list of topics and exercises that can help instructors design and deliver a queueing module. Student feedback has been very positive, with many students reporting that the Excel file was useful and helpful in understanding practical applications.

Keywords: queueing theory; Excel; spreadsheet modeling; operations management education; teaching tool.

1. Introduction

Queueing theory remains highly relevant in business education. However, in today's business environment, managers increasingly confront queues as data-rich, cross-functional design problems rather than as isolated waiting-line phenomena. In customer care, for example, firms are balancing rising contact volumes, labor constraints, outsourcing, waiting-time tradeoffs, and many other factors (Brynjolfsson et al., 2025; Long et al., 2024). For restaurants and various other service providers, drive-thru and checkout performance ultimately depend on the same operational decisions that queueing models formalize: lane design, task allocation, order batching, staffing, and the tradeoff between speed, accuracy, and customer experience (Hou et al., 2025). In healthcare, emergency department boarding illustrates how congestion in one part of a system can propagate across an organization, creating delays, safety risks, and costly mistakes (Kolikof et al., 2025; Norton et al., 2025). Airport security and passenger-processing systems similarly require

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forecasting arrivals and allocating limited staff to maintain acceptable waiting times under peak demand and uncertainty (Brun et al., 2025). Digital businesses also face queueing problems when cloud and AI-inference systems manage resources based on request queues, cost constraints, workload forecasting, and other factors (Alharthi et al., 2024; Mitzenmacher and Shahout, 2025). The above examples demonstrate that queueing theory gives business students practical knowledge and equips them to analyze many key issues, such as congestion or service capacity and to evaluate managerial tradeoffs in physical and digital operations.

The contribution of the paper is to help professors design and deliver a queueing section in a course. A list of practice questions is included. The goal is to provide a user-friendly Excel file that significantly helps both professors and students. Most existing publications offering educational tools for queueing propose simulations (Dobson and Shumsky, 2006; Grossman Jr, 1999; Ingolfsson and Grossman Jr, 2002; Leong, 2007; Leong and Ma, 2024), aimed at illustrating queue behavior in the long run. Our paper, on the other hand, provides an analytical tool that incorporates what-if analysis and Goal Seek to facilitate managerial-level experimentation. We demonstrate that queueing concepts can be effectively taught without specialized simulation software or programming, using only basic Excel, which is readily available to students. Hora (2003), who does not propose a simulation, focuses on the task of constructing a general queueing model, going beyond the introductory queueing instruction. De Treville and Van Ackere (2006) show the superiority of queueing-theory-based models in teaching over simulation-based models.

The distinction is therefore not simply that the proposed tool performs queueing calculations in Excel. Its pedagogical value lies in using Excel as a transparent analytical environment in which students can experiment with assumptions, examine sensitivities, and interpret managerial tradeoffs. This framing is consistent with prior work on spreadsheet-based business modeling, which emphasizes the value of spreadsheets for making analytical modeling accessible to students without requiring advanced programming or specialized software (Leong and Cheong, 2008). It is also consistent with spreadsheet-modeling pedagogy that stresses interactive learning, modeling concepts, and active experimentation rather than the mechanical use of spreadsheet commands alone (Leon et al., 2007). In the proposed queueing tool, students can change arrival rates, service times, number of servers, or service-level targets and immediately observe how utilization, waiting time, queue length, and capacity requirements respond. This allows the spreadsheet to function not merely as a calculator, but as a decision-support setting for exploring the operational consequences of staffing and service-design choices.

This distinction has become more important with the growing availability of generative AI tools. If the instructional goal were only to obtain numerical answers to standard queueing problems, students could increasingly rely on AI

systems or other computational tools to generate those answers quickly. Recent work on quantitative business education notes the relevance of comparing tools such as Excel and ChatGPT in helping students perform and interpret analytical work (Williams and Rudchenko, 2026). The contribution of the present paper should therefore be understood less as computational automation and more as a pedagogical structure for guided experimentation, sensitivity analysis, and managerial interpretation. By making the formulas visible and allowing students to manipulate key inputs, the spreadsheet helps them see why queueing performance often changes nonlinearly as utilization increases, why small changes in capacity can have large service-level effects, and how analytical queueing models can inform practical decisions about staffing, waiting-time targets, and service quality. Finally, the proposed tool aims to help students identify managerial situations in which queueing analysis is useful.

The following are the learning objectives:

- selecting the appropriate queueing model,
- identifying and interpreting key performance measures,
- understanding the impact of assumptions,
- performing what-if analysis,
- identifying managerial situations in which queueing theory is useful.

We teach an introduction to queueing theory using Excel in an elective course taken by fourth-year undergraduate students and MBA students. We spend about three to four weeks on the topic in addition to other topics such as advanced linear programming, VBA, nonlinear programming, and Markov chains, all of which are solved using Excel.

An Excel spreadsheet (queform.xlsx), which is easy to use, was designed for this part of the class. We received many positive comments from students indicating that the spreadsheet was very helpful, both in understanding the concepts and in applying them in practice. Over the years, several students have shared that this teaching exercise gave them inspiration and confidence to apply the concept in their own workplace, resulting in measurable, real-world improvements. For example, one student who worked at a bank in the summer noticed that the flow of customers was relatively slow in the morning, before lunchtime it increased significantly for a few hours and then slowed down to about average flow. He estimated the arrival rates in these three time periods and the average service time. He thought of introducing two shifts: one starting in the morning through the end of the busy period and another running from the start of the busy period through the end of the day. This way, the busy period would have the total number of servers from the two shifts. He then applied the Excel file and found the best combination to be two servers in the morning shift and three in the afternoon, so that five servers would be available during the busy period. The bank manager was very excited about the idea, implemented it and was impressed by the resulting performance.

Other examples that can be presented in the introduction but should be solved as a review before the exam, or given as final assignments, include:

You operate a car wash with one machine. When you charge \$10 per car wash, you expect to have 20,000 customers per year. For every 10-cent reduction in price you expect to add 250 customers per year. Your fixed cost is \$100,000 per year and your variable cost is negligible. Your car wash is open 300 days a year, 10 hours per day. It takes about 5 minutes to wash a car. You consider pricing your car wash between \$8 and \$10 in 10-cent increments. Suppose you lose 2 cents per minute of waiting in line per customer in goodwill (future business). How much should you charge to maximize profit?

At a drive-through window, customers arrive at a rate of 15 per hour. You measured the mean service time to be about 3.4 minutes, but the standard deviation of the service time depends on the person serving the customers and you found it in a range between 2 and 4 minutes. You lose 3 cents per minute in goodwill of a customer waiting in line. You pay \$8 per hour for the server with a 4-minute standard deviation and are willing to pay \$2 per hour more for every minute reduction in the standard deviation. What is your preferred standard deviation?

Berman and Drezner (2007) considered the problem of having several bank branches and a given number of ATM machines. Once k ATM machines are assigned to a bank, the time spent at the ATM can be estimated by a queueing system formula. Each customer spends a total amount of time driving plus the time at the ATM. Customers may prefer a branch with more ATMs. How many ATM machines should be assigned to each branch so that the sum of the total times for all customers is minimized? Aboolian et al. (2009) considered minimizing the maximum total time for all customers.

2. General Discussion

The purpose of this section is not to provide a complete review of queueing theory, nor to repeat material that is already available in standard textbooks. Rather, it is intended to give the instructor a practical roadmap of what to emphasize when introducing queueing with the spreadsheet. The discussion therefore focuses on the modeling choices that students must understand in order to use the Excel file appropriately: the arrival process, the service-time assumption, the number of servers, and whether the waiting space is unlimited or finite.

At the first class meeting, the background and the parameters of the queueing models are described and discussed.

1. Customers arrive at a service facility. There are $k \geq 1$ servers available. Customers may have to wait in line. When a server becomes available, the first in line starts its service activity.