# OPM 761 – Research Seminar Production Management

## Spring Term 2024

The goal of this seminar is to introduce the participants to conduct scientific research. Thereby, it prepares the students for the writing of their Master's thesis. The seminar is geared towards students intending to write their thesis at the Chair of Production Management.

Participants will explore one of the topics listed below. They will review and critically assess the corresponding scientific literature and present their findings in a written report (18 to 22 pages) as well as in an in-class presentation (15 - 20 min + 20 min discussion). Each participant is also expected to critically assess the presentations of the other students in the ensuing discussion.

**Applications** will be accepted from **November 10th, 2023** until **November 24th, 2023**. Admission to the seminar will be confirmed by e-mail at latest on December 1st, 2023 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on **December 4th, 2023** between 8:30 a.m. and 10 a.m. (CET). During this meeting, an introduction to scientific writing and presentations for term papers will be given.

A brief session on introduction to Overleaf and LaTeXwill also be offered. The time and date of this session will be decided in the Kick-off meeting among the interested students.

The **written reports** have to be submitted by Monday, **April 3rd, 2024** in the following formats:

- Two-fold hard copy version.
- Electronic version including a copy of the references cited in the report and auxiliary information (tables, data, programming code, etc.).

The **presentations** will be held as a blocked session during between **17th and 24th of April 2024**. Attendance at all presentations is mandatory.

The final grade for the seminar is composed of the following components: Written report (60%), presentation (30%), and contribution to the discussion (10%).

There is a joint application process for all seminars offered by the chairs of the Area Operations Management. In the spring term 2024, this includes the following seminars:

- **OPM 741:** Applied Seminar Supply Chain Management
  Chair of Logistics and Supply Chain Management, Prof. Dr. Moritz Fleischmann
  (Topics labeled with "L"),
- **OPM 761:** Research Seminar Production Management,
  Chair of Production Management, Prof. Dr. Raik Stolletz
  (Topics labeled with "P"),

- **OPM 781:** Research Seminar Service Operations
  Chair of Service Operations Management, Prof. Dr. Cornelia Schön
  (Topics labeled with "S"),
- **OPM 792:** Applied Seminar Procurement
  Endowed Chair of Procurement, Prof. Dr. Christoph Bode
  (Topics labeled with "B").

Detailed information on the seminar topics and the link to the online registration tool are available on the home pages of the respective chairs. In their applications, students can indicate up to five preferred topics from all seminars.

In addition, applicants for OPM 761 must send an email with (1) CV, (2) official B.Sc. and M.Sc. grades overviews, and (3) the list of courses in the Area Operations that you are currently enrolled in to opm761@uni-mannheim.de. For any further question concerning the seminar please also contact the chair via opm761@uni-mannheim.de.

Topics Catalog

## P1 – Impact of buffers on performance of call centers with retrials

**Objectives**: The interaction between a company and its customers have significant impact for a companies reputation. Therefore, call centers are of high importance as the first point of contact for customers. Customers may leave the queue before being served (e.g. reneging) due to a lack of patience. However, this can also occur due to limited number of trunk lines (buffers). Some of these customers re-enter the system at a later time point as retrials, others result in lost calls. These impact the customer satisfaction and companies reputation. Therefore, companies have to decide between increasing number of buffers and reducing costs.

The goal of the research seminar is to analyze the effects of buffer size on system performance. The resulting differential equations of the corresponding Markov chain should be implemented with Python and solved using a numeric library. Different performance measures (e.g. number of blocked clients, expected waiting time, ...) should be implemented and analyzed with respect to buffer size. Furthermore, a sensitivity analysis should generate insights on the impact of buffer size and retrials on the performance measures.

**Prerequisites:** Knowledge in queueing theory (e.g. OPM 661), prior knowledge in a programming language (e.g. Python)

**Basic Paper**: Aguir et al. (2008)

> **Abstract**: This paper models a call center as a Markovian queue with multiple servers, where customer impatience, and retrials are modeled explicitly. The model is analyzed as a continuous time Markov chain. The retrial phenomenon is explored numerically using a real example, to demonstrate the magnitude it can take and to understand its sensitivity to various system parameters. The model is then used to assess the impact of disregarding existing retrials in the staffing of a call center. It is shown that ignoring retrials can lead to under-staffing or over-staffing with respect to the optimal, depending on the forecasting assumptions being made.

## P2 – Overview of optimization models in call center staffing

**Objectives**: In many service systems, staffing drives both costs and service quality by ensuring that the right number of employees are available for various processes. A call center for example, might aim to minimize personnel cost while ensuring a certain service level. One example could be to consider the negative impacts on waiting time or customer abandonments.

The goal of this research seminar is to provide a comprehensive overview of utilized optimization models for time-dependent staffing in call centers. Existing literature should be critically assessed and compared by describing the utilized optimization models (objective, constraints, ...) and solution approaches. Relevant trade-offs (e.g. balancing cost savings and lost sales) and managerial findings presented in literature should be presented and discussed.

**Prerequisites:** Knowledge in optimization models and stochastic systems (e.g. OPM 561, 662)

**Basic Paper**: Defraeye and Van Nieuwenhuyse (2016); Gurvich et al. (2008)

> **Abstract**: Many service systems display nonstationary demand: the number of customers fluctuates over time according to a stochastic—though to some extent predictable—pattern. To safeguard the performance of such systems, adequate personnel capacity planning (i.e., determining appropriate staffing levels and/or shift schedules) is often crucial. This

paper provides a state-of-the-art literature review on staffing and scheduling approaches that account for nonstationary demand. Among references published during 1991–2013, it is possible to categorize relevant contributions according to system assumptions, performance evaluation characteristics, optimization approaches and real-life application contexts. Based on their findings, the authors develop recommendations for further research.

## P3 – Predictive analytics approaches for ramp-up phase

**Objectives**: Companies face different challenges during the development and manufacturing of new products. Due to different processes that are performed during manufacturing, units that do not exceed certain quality standards can be produced. This results in an unstable production process with decreased production quality and quantity. This phase is called production ramp-up. The instability of ramp-up phase makes planning tasks difficult from an operations perspective. For example, decreased system output can cause violation of contracts with clients and harm the reputation of the firm. However, the unstable production process still consumes resources (e.g. raw materials and energy). The correct estimation of ramp-up phase can enhance resource allocation, ensure quality standards, and improve production planning. Thus, being able to identify when ramp-up phase is over is of utmost importance. Predictive analytics methods can be used to identify the end of ramp-up phase. One possible method is the usage of truncation heuristics that utilize system output, e.g. by trying measuring standard deviation of system output or analyzing patterns.

The goal of the research seminar is to give an overview on predictive analytics approaches to identify the end of ramp-up phase. The importance and causes of ramp-up phase should be explained, focusing on managerial implications. The student is expected to compare different predictive analytics approaches (e.g. truncation heuristics, machine learning, graphical approaches) based on their methodology and limitations.

**Prerequisites:** Knowledge in stochastic manufacturing systems (e.g. OPM 561, 661)

**Basic Paper**: White Jr (1997); Surbier et al. (2014)

> **Abstract**: The start-up or warm-up problem arises in steady-state, discrete-event simulation, where the arbitrary selection of initial conditions introduces bias in simulated output sequences. In this paper, we develop and test a new truncation heuristic or resolving the start-up problem. Given a finite sequence, the truncation rule deletes initial observations until the width of the marginal confidence interval about the truncated sample mean is minimized. This rule is easy to implement, has strong intuitive appeal, and is remarkably effective in mitigating initialization bias. We illustrate the performance of the heuristic by comparison with enhanced implementations of alternative truncation rules proposed in the literature. All rules are applied to output sequences generated by ten runs each of four representative queuing simulations. Results confirm the significance of the start-up problem and demonstrate that simple truncation heuristics can solve this problem. All of the rules tested are shown to provide improved accuracy without undue loss of precision. We conclude that all four of the rules tested represent attractive solutions to the start-up problem.

## P4 – Literature overview on the application of time-dependent queueing systems in airport terminals

**Objectives**: Service counters in various industries (e.g., aviation or restaurant industry) face time-dependent arrivals. In addition, the total number of available servers and hence the total processing capacity can be also time-dependent. The key challenge in such systems is that most of the classic performance evaluation and optimization approaches fail in these systems due to the existing time-dependency.

The goal of this thesis is to provide a comprehensive overview of the recent publications on the application of time-dependent queueing systems in service systems in airport terminals, such as check-in counters, security checks, departure lounges, and baggage claim facilities. The reviewed articles must be classified based on their assumptions, application area, performance evaluation measures, and assumptions on the optimization problem (if applicable), i.e., input data, decisions, objective functions, etc. The thesis must also provide an overview of the managerial insights mentioned in the reviewed research papers. A critical assessment of the literature and suggestions for future research concludes this thesis.

**Prerequisites:** Basic knowledge in stochastic systems (e.g. OPM 561)

**Basic Papers**: Schwarz et al. (2016)

> **Abstract**: Many queueing systems are subject to time-dependent changes in system parameters, such as the arrival rate or number of servers. Examples include time-dependent call volumes and agents at inbound call centers, time-varying air traffic at airports, time-dependent truck arrival rates at seaports, and cyclic message volumes in computer systems.
>
> There are several approaches for the performance analysis of queueing systems with deterministic parameter changes over time. In this survey, we develop a classification scheme that groups these approaches according to their underlying key ideas into (i) numerical and analytical solutions, (ii) approaches based on models with piecewise constant parameters, and (iii) approaches based on modified system characteristics. Additionally, we identify links between the different approaches and provide a survey of applications that are categorized into service, road and air traffic, and IT systems.

## P5 – Reinforcement learning for order release planning

**Objectives**: For make-to-order manufacturing firms, the ability to achieve short flow times is crucial to remaining competitive. This objective becomes even more difficult with the rapid increase in customer expectations. Order release planning is the process of determining when and in what quantities to release orders into production. Effective order release planning is important for make-to-order firms because it directly impacts manufacturing lead times and on-time delivery performance. By controlling the timing and rate of order releases, firms can smooth production workload, avoid bottlenecks, and reduce flow times.

Machine learning methods in general, and reinforcement learning in particular, have shown potential to improve order release planning by learning from the system's behavior without restrictive assumptions. Reinforcement learning agents can learn effective release policies through repeated interactions with a simulation model of the manufacturing system.

The goal of this seminar thesis is to explain the details of the problem and method presented in the base paper. In addition, the student is expected to position the research study in the related literature with respect to the underlying problem and method. A comprehensive critical assessment of the base paper's assumptions and method will conclude this thesis.

**Prerequisites:** Knowledge in Artificial Intelligence, and knowledge in modeling production management problems (e.g., OPM 561)

**Basic Papers**: Schneckenreither and Haeussler (2019)

**Abstract**: An important goal in Manufacturing Planning and Control systems is to achieve short and predictable flow times, especially where high flexibility in meeting customer demand is required. Besides achieving short flow times, one should also maintain high output and due-date performance. One approach to address this problem is the use of an order release mechanism which collects all incoming orders in an order-pool and thereafter determines when to release the orders to the shop-floor. A major disadvantage of traditional order release mechanisms is their inability to consider the nonlinear relationship between resource utilization and flow times which is well known from practice and queuing theory. Therefore, we propose a novel adaptive order release mechanism which utilizes deep reinforcement learning to set release times of the orders and provide several techniques for challenging operations research problems with reinforcement learning. We use a simulation model of a two-stage flow-shop and show that our approach outperforms well-known order release mechanism.

## P6 – Workforce Planning Under Demand Uncertainty

**Objectives:** Personnel-related costs are a major component in many service and production systems. Hence, even small percentage reductions in labor costs can lead to significant savings in total costs. Therefor, determining the optimal workforce size and composition is crucial, especially for service systems aiming to balance labor costs against customer service levels. This problem becomes more difficult when the demand is stochastic. Stochastic optimization models incorporate uncertainty about demand into the mathematical optimization framework, allowing optimized plans that hedge against many potential demand scenarios.

The goal of this seminar thesis is to describe and analyze the optimization problem addressed in the base paper in detail. In addition, the student is supposed to position the base paper in the related stream of literature. The proposed model has to be described and implemented in a modelling system (e.g., using DoCplex in Python). A numerical analysis with standard solver must be conducted to generate managerial insights. Critical assessment of the contribution of the proposed model and its limitations will conclude this thesis.

**Prerequisites:** Basic knowledge in mathematical modeling and robust optimization (e.g. OPM 661 or 662)

**Basic Papers**: Bard et al. (2007)

**Abstract**: Service organizations that operate outside the normal 8-hour day and face wide fluctuations in demand constantly struggle to optimize the size and composition of their workforce. Recent research has shown that improved personnel scheduling methods that take demand uncertainty into account can lead to significant reductions in labor costs. This paper addresses a staff planning and scheduling problem that arises at United States Postal Service (USPS) mail processing & distribution centers (P&DCs) and develops a two-stage stochastic integer program with recourse for the analysis. In the first stage, before the demand is known, the number of full-time and part-time employees is determined for the permanent workforce. In the second stage, the demand is revealed and workers are assigned to specific shifts during the week. When necessary, overtime and casual labor are used to satisfy demand. This paper consists of two parts: (1) the analysis of the demand distribution in light of historical data, and (2) the development and analysis of the stochastic integer programming model. Using weekly demand for a three-year period, we first investigate the possibility that there exists an end-of-month effect, i.e., the week at the end of month has larger volume than the other weeks. We show that the data fail to indicate that this is the case. In the computational phase of the work, three scenarios are considered: high, medium, and low demand. The stochastic

> optimization problem that results is a large-scale integer program that embodies the full set of contractual agreements and labor rules governing the design of the workforce at a P&DC. The usefulness of the model is evaluated by solving a series of instances constructed from data provided by the Dallas facility. The results indicate that significant savings are likely when the recourse problem is used to help structure the workforce.

## P7 – Optimization Models for the Design of Energy Systems

**Objectives:** The design of energy systems plays a key role in the development towards a more environmentally friendly future. E.g., with a growing number of privately owned electric vehicles the consumption of electrical power increases, as well as requirements for efficient power grids. Large power plants relying on fossil resources are to be shut down in the next decades. Furthermore, some countries do not operate nuclear power plants and are either not able or not willing to do so in future, thus decentralized power generation (e.g., wind and solar) is of growing importance. In literature, a wide variety of works consider the design of energy systems via optimization methods as linear programming (LP), mixed integer linear programming (MIP), and non-linear programming (NLP).

The goal of this seminar thesis is to provide a comprehensive overview of the recent publications on optimization models for the design of energy systems. The reviewed articles should be classified and compared according to their assumptions, objectives, and practical insights. A critical assessment of the literature and suggestions for future research concludes this thesis.

**Prerequisites:** Knowledge in optimization models (e.g., OPM 561, 662)

**Basic Papers**: Moret et al. (2020)

> **Abstract**: Optimization models for long-term energy planning often feature many uncertain inputs, which can be handled using robust optimization. However, uncertainty is seldom accounted for in the energy planning practice, and robust optimization applications in this field normally consider only a few uncertain parameters. A reason for this gap between energy practice and stochastic modeling is that large-scale energy models often present features—such as multiplied uncertain parameters in the objective and many uncertainties in the constraints—which make it difficult to develop generalized and tractable robust formulations. In this paper, we address these limiting features to provide a complete robust optimization framework allowing the consideration of all uncertain parameters in energy models. We also introduce an original approach to make use of the obtained robust formulations for decision support and provide a case study of a national energy system for validation.

## P8 – Setting the Right Speed in Service Systems

**Objectives:** Queueing systems are analyzed in a multitude of context: Call centers, traffic, airports, healthcare, restaurants, and customer services in general. One lever for the performance of such a system is the service rate, i.e., how many customers per time unit can be served. The service rate can be increased by, e.g., speeding up services, simplifying processes, and on the other hand reduced by up- and cross-selling, or by putting more diligence into the service. A higher service rate decreases congestion, and thus waiting, but a higher service rate can come with other costs, e.g., in the so-called quality-speed trade-off literature it can also lower the value of the service provided to the customer. Depending on the business application, literature assumes different components in the objective function, such as waiting costs, revenues depending on the service rate, costs in the service rate, etc.

The goal of this seminar thesis is to provide a detailed overview, classification, and comparison of different objective functions in the field of service rate optimization in service systems. The underlying motivation of the objective functions should be explained. Relevant applications and managerial insights, as well as structural similarities and differences between the considered objective functions should be identified. A critical assessment of the literature concludes this thesis.

**Prerequisites:** Basic knowledge in queueing theory (e.g., OPM 561, 661)

**Basic Papers**: Anand et al. (2011)

> **Abstract**: In many services, the quality or value provided by the service increases with the time the service provider spends with the customer. However, longer service times also result in longer waits for customers. We term such services, in which the interaction between quality and speed is critical, as customer-intensive services. In a queueing framework, we parameterize the degree of customer intensity of the service. The service speed chosen by the service provider affects the quality of the service through its customer intensity. Customers queue for the service based on service quality, delay costs, and price. We study how a service provider facing such customers makes the optimal "quality–speed trade-off." Our results demonstrate that the customer intensity of the service is a critical driver of equilibrium price, service speed, demand, congestion in queues, and service provider revenues. Customer intensity leads to outcomes very different from those of traditional models of service rate competition. For instance, as the number of competing servers increases, the price increases, and the servers become slower.

## P9 – Waiting for a Better Service: The Quality-Speed Trade-Off

**Objectives:** In the quality-speed trade-off literature it is assumed that lower service rates correspond to services of higher (perceived) quality. E.g., a call center agent might use small talk to calm customers, or try to use up- and cross-selling to increase revenues. Another example could be a physician who spends more time diagnosing a patient and thus increasing the quality of treatment. Nevertheless, decreasing the service time comes at a cost in service systems, other customers currently waiting for service have to wait longer. Thereby customer satisfaction suffers. The quality-speed trade-off literature is concerned with setting the right service rates in such systems to optimally balance waiting and quality. In some works, price is also considered as a decision variable. Demand can be determined endogeneously, i.e., the provided service quality and chosen price can influence the demand of future periods.

The objective of this seminar thesis is to describe and analyze the quality-speed trade-off optimization problem with pricing addressed in the base paper in detail. In addition, the paper should be positioned in the related stream of literature. The models presented in the paper should be described, analyzed, and implemented (e.g., in Python). They should also be extended to study the effects different demand functions have on endogenous arrival rates. Numerical studies should generate some managerial insights. A critical assessment of the model concludes this thesis.

**Prerequisites:** Knowledge in optimization models (e.g., OPM 661 or 662), prior knowledge in a programming language (e.g. Python)

**Basic Papers**: Kostami and Rajagopalan (2014)

> **Abstract**: An important trade-off organizations face in many environments is one between quality and speed. Working faster may result in greater output and less delay, but may result in lower quality and dissatisfied customers. In this work, we consider dynamic models in a monopoly setting to explore the optimal balance among the multiple dimensions of speed, price, and wait time. The impact of quality is captured via the market demand potential, which is a function of the speed (quality) in the previous period. We obtain several results and insights. First, in scenarios where speed may be difficult to

change over time (e.g., some automated production lines) but price can be changed, we show that the optimal price charged is such that the demand rate remains constant over time, even though the price and market potential are changing. Furthermore, we identify conditions when the firm will work at a speed that is higher or lower than a benchmark speed and characterize the behavior of prices over time. Second, in scenarios where a firm may not be able to change prices but can adjust the speed each period, the firm starts at a speed that may be faster or slower than a benchmark speed but converges to it over time. In this constant price case, as the benchmark speed increases, the initial speed adopted by the firm is actually lower but increases more quickly thereafter. We also characterize the behavior of price and speed in settings where both can be changed over time. Interestingly, a firm typically starts at a slow speed and increases the speed, price, and demand over time. Although our main model assumes that the firm internalizes the congestion cost, several of our results extend to a scenario where the demand rate is impacted by the congestion level.

## References


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