OPM 761 – Research Seminar Production Management

Spring Term 2023

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 11th, 2022** until **November 25th, 2022**. Admission to the seminar will be confirmed by e-mail at latest on December 2nd, 2022 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on **December 5th, 2022** 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 Thursday, **March 31st, 2023** 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 the week **24th to 28th of April 2023**. 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 2023, 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 Management
  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@bwl.uni-mannheim.de. For any further question concerning the seminar please also contact the chair via opm761@bwl.uni-mannheim.de.

Topics Catalog

P1 – Workforce scheduling with break assignments

Workforce scheduling is an important task in various industries such as service, health care and logistics. The aim is often to construct a cost-minimal schedule that does not violate a set of constraints (e.g. work regulations). Allowing break times to be assigned individually within a given time window instead of having a fixed lunch break time can improve the objective value of an optimal schedule as it allows for more flexibility. While the problem of workforce scheduling is difficult to solve on its own, the assignment of flexible breaks adds another challenge to this problem.

The problem can be formulated as a MIP. The model is presented in the base paper and should be implemented and tested in Python. However, the solution time with a stadard solver is expected to be large. To solve the problem sufficiently, the base paper describes a decomposition approach that should be explained in detail and implemented in python. Furthermore, managerial insights should be generated by analyzing the effects of break time flexibility.

Prerequisites: Knowledge of optimization problems and how to implement them in a programming language (e.g. OPM 662)

Basic Paper: Kiermaier et al. (2020)

Abstract: The paper examines the complexity of assigning multiple breaks to shifts in the context of large-scale tour scheduling. A mixed-integer programming (MIP) model is presented that includes shift and days-off scheduling along with break assignments for a multi-skilled workforce. To achieve tractability, a two-stage decomposition procedure is proposed that separates the tour scheduling problem (TShP) from the break assignment problem (BAP). The former MIP is first solved to determine the shifts and days off for the workforce that minimize labor and shortages costs over the planning horizon. The results are used as input to a second MIP that optimally places the breaks to minimize the costs of working hours and uncovered periods. Three implicit BAP formulations are investigated. To better understand the literature and the models previously developed, a 3-field break classification scheme is introduced. The first field characterizes the number of breaks permitted per shift, the second specifies whether the length of the breaks is fixed or variable, and the third limits their position in a shift. A complexity analysis of the resulting 12 BAPs along with a few special cases is also included. Most problems are shown to be strongly NP-hard. Computations are presented for a wide variety of scenarios for both the TShP and the BAP using data provided by a European airport ground handler company. In all, over 500 instances were investigated using high and low demand fluctuation curves and the various break and shift flexibility options. The results indicate that increasing flexibility in break regulations can make a significant difference in coverage, but the degree depends on the underlying structure of the demand curve as well as on the types of shifts permitted. Formulations with the most flexible shift and break regulations reduced undercoverage by up to 16.68 % compared to the most common scenarios in which shifts are limited to a single lunch break.

P2 – Heuristics for Shift Design

Objectives: The design of shifts is an important stage in the general workforce scheduling process. For the employer it is desirable to deploy a small set of shifts that on the one side respect all the legal regulations concerning working times and on the other hand allow to cover the demand in each period of the working day.

The aim of this thesis is to provide an overview on shift design methods categorizing papers e.g. by aims, constraints, applications. In a second step the heuristic to find a good initial solution as well as the MIP approach, both described in the base paper, should be implemented . Finally a workforce scheduling optimization problem with a longer planning horizon should be implemented that uses the previously constructed shifts as input. On different instances, the student should then evaluate the schedules evolving from the different sets of shifts.

Prerequisites: Knowledge of optimization problems and basic knowledge in a programming language (e.g. OPM 662).

Basic Paper: Musliu et al. (2004)

> **Abstract**: Designing shifts is one of the important stages in the general workforce scheduling process. In this paper we consider solving the shift design problem by using local search methods. First we propose a set of move types that give rise to a composite neighbourhood relation. In the move selection process, we make use of the basic prohibition mechanisms of tabu search. In addition, in order to avoid having to explore the whole neighbourhood which could be prohibitively large, we evaluate the moves in decreasing order of their promise to yield some improvement. Furthermore, we propose an algorithm for generating a good initial solution, which also exploits knowledge about requirements and shift structure. Experimental results on both real-life and randomly-generated instances show the advantages of these in- gredients. The solver is part of a commercial product and has shown to work well in practical cases.

P3 – Defining and assessing resilience levels

Objectives: It is estimated that almost three quarters of organizations experience a supply chain disruption each year, i.e. an event that impacts the flow of goods, materials and/ or services, thereby limiting the ability of an organization to serve the end consumer. Last year, 75% of companies have had negative or strongly negative impacts on their businesses due to the COVID-19 pandemic. Besides the ongoing pandemic, further possible external disruptions can originate from natural or man-made disasters, financial and political turbulences, others are internal, e.g. production line break downs, IT problems, demand fluctuations, sustainability issues or quality problems. Meanwhile, the performance impact of such events is also dependent on the severity and duration of the disruption as well as on the organizations' ability to manage disruptions and threats. Resilience can give the organization a competitive advantage, as it is able to continue operating even in the face of disruptions.

The purpose of this seminar topic is to understand how resilience is conceptualized and assessed. Analyzing and comparing quantitative approaches for improving resilience and their critical appraisal are also an essential part of the seminar thesis.

Prerequisites: Knowledge of stochastic variability and optimization problems (e.g. OPM 661 or OPM 662)

Basic Papers: Behzadi et al. (2020)

> **Abstract**: Resilience, defined as the ability to recover quickly and effectively from a disruption, is critically important for supply chains. Yet, it has not been quantified as frequently as supply chain robustness. In this paper we review the existing metrics for supply chain resilience and introduce a new metric, titled the net present value of the loss of profit (NPV-LP). We test these metrics on a small supply chain problem consisting of one supply and one demand node for a perishable good over a multi-period horizon with a possible port shut-down. We show how the different metrics cause different investment decisions for the supply chain, and hence why it is important to carefully pick the correct metric when modeling supply chain resilience.

P4 – Assessing Emergency Capacity in Healthcare

Objectives: Hospital emergency departments are obligated to stabilize and treat incoming patients who have immediate or life-threatening illness or injury, regardless of the impact on hospital operations. However, bed shortages often occur, which can compromise the ability of hospitals to adequately accommodate emergency patients. Healthcare planners have to plan for bed availability to manage demand changes and surges. This is a particular challenge in times of increasing urbanization, rising numbers of natural disasters and pandemics. Decision makers rely on various bed shortage metrics to plan bed utilization and ensure quality patient care.

This seminar topic is intended to provide a comprehensive and detailed overview of the latest bed shortages metrics based on the basic paper. The different metrics should be compared, analyzed and the respective advantages and disadvantages identified.

Prerequisites: Knowledge of stochastic variability and optimization problems (e.g. OPM 661 or OPM 662)

Basic Paper: Xie et al. (2022)

Abstract: Bed shortages in hospitals usually have a negative impact on patient satisfaction and medical outcomes. In practice, healthcare managers often use bed occupancy rates (BORs) as a metric to understand bed utilization, which is insufficient in capturing the risk of bed shortages. We propose the bed shortage index (BSI) to capture more facets of bed shortage risk than traditional metrics such as the occupancy rate, the probability of shortages, and expected shortages. The BSI is based on the riskiness index by Aumann and Serrano, and it is calibrated to coincide with BORs when the daily arrivals in the hospital unit are Poisson distributed. Our metric can be tractably computed and does not require additional assumptions or approximations. As such, it can be consistently used across the descriptive, predictive, and prescriptive analytical approaches. We also propose optimization models to plan for bed capacity via this metric. These models can be efficiently solved on a large scale via a sequence of linear optimization problems. The first maximizes total elective throughput while managing the metric under a specified threshold. The second determines the optimal scheduling policy by lexicographically minimizing the steady-state daily BSI for a given number of scheduled admissions. We validate these models using real data from a hospital and test them against data-driven simulations. We apply these models to study the real-world problem of long stayers to predict the impact of transferring them to community hospitals as a result of an aging population.

P5 – Impact of buffers and retrials on performance of call centers

Objectives: Queueing systems are used in various service systems, such as call centres, health care, emergency services, and repair facilities. In many of these service systems, customers leave the queue before being served (e.g. abandonment or balking) due to a lack of patience. However, these impatient users may re-enter the system at a later time point. In many service systems, the number of buffers (waiting space) is limited. In call center for example, if all waiting lines are full, a new caller receives a busy signal and is blocked. While this may influence the customer experience in a negative way, important performance measures (e.g. expected waiting time) can be influenced.

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.

P6 – Robust staffing in service systems with retrials using stochastic programming

Objectives: Queueing systems are used in various service systems, such as call centres, health care, emergency services, and repair facilities. In many of these service systems, customers leave the queue before being served (e.g. abandonment or balking) due to a lack of patience. However, these impatient users may re-enter the system at a later time point. To safeguard the performance of such systems, adequate personnel capacity planning (i.e., determining appropriate staffing levels) is often crucial in order to meet a specific performance target at minimal cost. There are different approaches to optimize the number of utilized personnel. Stochastic programming is one of these approaches which can be used, which replaces probability distributions by samples or scenarios.

The goal of the research seminar is to analyze the effects of stochastic interarrival and patience times on staffing decisions. The resulting optimization model should be implemented with Python and solved using a standard solver (e.g. CPLEX). Furthermore, insights on the impact of patience distribution and rates on the performance measures should be analyzed through a sensitivity analysis.

Prerequisites: Knowledge of stochastic optimization problems (e.g. OPM 661 or 662), prior knowledge in a programming language (e.g. Python), knowledge in queueing theory recommended but not necessary (e.g. OPM 661)

Basic Paper: Helber and Henken (2010)

> **Abstract**: This paper presents a profit-oriented shift scheduling approach for inbound contact centers. The focus is on systems in which multiple agent classes with different qualifications serve multiple customer classes with different needs. We assume that customers are impatient, abandon if they have to wait, and that they may retry. A discrete-time modeling approach is used to capture the dynamics of the system due to time-dependent arrival rates. Staffing levels and shift schedules are simultaneously optimized over a set of different approximate realizations of the underlying stochastic processes to consider the randomness of the system. The numerical results indicate that the presented approach works best for medium-sized and large contact centers with skills-based routing of customers for which stochastic queueing models are rarely applicable.

P7 – 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 queueing theory (e.g. OPM 661)

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.
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> 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.

P8 – Reinforcement learning for order release planning

Objectives: For the make-to-order manufacturing firms to remain competitive, it is of crucial importance to be able to achieve short flow times. This goal becomes even more difficult to achieve with the rapid increase in customer expectation, which makes the classic methods fail because of their limiting assumptions. Machine learning methods in general, and reinforcement learning in particular, have shown to be helpful in this situation because of their potential to learn from the system's behavior without making restricting assumptions.

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 (e.g., OPM 562) and knowledge in modeling production management problems (e.g., OPM 661 or OPM 662)

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.

P9 – Workforce Planning Under Demand Uncertainty

Objectives: Determining the size and composition of the workforce is one of the most important tasks, especially for service systems. The problem becomes difficult if there are fluctuations in the demand which are known beforehand. One of the approaches to hedge against the demand uncertainty is to use stochastic optimization.

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 modlling 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.

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.

P10 – Approximation methods for stochastic systems controlled with the shortest processing time discipline

Objectives: The first-come-first-serve discipline is the default setting of many operating systems with heterogeneous demand. While in many applications, e.g. service operations, this assumption often holds, in production systems, the sequence of the items being processed is less restricted and managers can chose sequencing methods that fit their operation best. For example, the shortest-processing-time-first (SPT) rule is capable to drastically reduce waiting times.

The objective of this seminar thesis is to review approximation methods for the SPT discipline. The available studies have to be compared in terms of the performance measures they study, their assumptions, and their managerial insights. In addition, selected methods have to be implemented and numerically assessed.

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

Basic Paper: Mönch et al. (2012) Schrage and Miller (1966)

> **Abstract**: A priority queuing model in which the processing times of jobs are known upon arrival and preemption without loss of time or processing already accomplished is studied. Priority is assigned to jobs according to the length of processing remaining with highest priority going to the job with least processing left. A preemption will occur whenever the processing time of a newly arriving job is less than the remaining processing time of the job then in service. The Laplace-Stieltjes transforms of the waiting time and time-in-system distributions are obtained and comparisons with other queuing disciplines are made.

P11 – Application of time-dependent queueing networks in health care

Objectives: Many healthcare operations can be modeled using queueing models. The available data for these applications shows a considerable dependence of the processes on the time of the day. Additionally, these operations can involve multiple steps. For this reason, there is a need for fast and accurate methods for approximating the performance measures of time-dependent networks of queues. Blood donation operations are an example of such an application. This operation can be modeled by three consecutive steps: registration, interview, and donation. Since this network model is relatively small, it can be analyzed by the uniformization method, whose state space size increases exponentially with the number of nodes in the network. However, the computational performance and, therefore, the method's usefulness depends on the system's parameters, i.e., the number of servers and utilization.

This seminar thesis aims to perform a comprehensive sensitivity analysis of the computational performance of the uniformization method for the three-node network as described by Van Brummelen et al. (2018). The method has to be explained and implemented in Matlab or Python. A sensitivity analysis has to evaluate the speed and memory requirements for various parameter sets. Managerial insights can be drawn applying the method using realistic parameter values.

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

Basic Paper: Van Brummelen et al. (2018)

> **Abstract**: Service systems often experience time-dependent aspects, typically due to time-dependent arrivals and capacities. Easy and quick to use queueing expressions generally do not apply to these situations, but are still used. At the same time a large

number of computational papers exist that deal with queue length distributions for time-dependent queues. Most of these are fairly theoretical and based on single queues. Real-life service systems, however, might resemble a queueing network structure. With this paper we aim to bring both worlds together. It presents a computational method for time-dependent queueing networks based on uniformization.

Although uniformization is generally perceived to be too computationally prohibitive, we show that our method is very effective for practical instances, as shown with a Dutch blood collection site. The results shown in this paper take a matter of seconds to compute. The objective of the results is twofold: (1) to show that the time-dependent queueing network approach is imperative for some queueing networks, including this application and (2) to evaluate possible improvement scenarios for Dutch blood collection sites that can only be properly assessed with a time-dependent queueing method.

References

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