OPM 761 – Research Seminar Production Management

Fall 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 **April 28th, 2023** until **May 12th, 2023**. Admission to the seminar will be confirmed by e-mail at latest on May 19th, 2022 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on **May 22nd, 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, **October 11th, 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 **23th to 27th of October 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 fall term 2023, this includes the following seminars:

- **OPM 701:** Research 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 791:** Research 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 – 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 – Personnel Scheduling with Full-Time and Part-Time Employees

Personnel Scheduling is an important task in various industries such as service, health care and logistics. On an operational level the workforce needs to be scheduled efficiently, while on a strategic level, decisions about how many workers should be employed to cope with the expected demand are made. This becomes particularly interesting, when a heterogenous workforce, i.e., full- and part-time employees, perhaps with different wage rates and proficiencies, is considered.

The aim of this thesis is to give an overview on the assumptions and constraints concerning full- and part-time employees in optimization models of personnel scheduling problems. In a second step, the model described in the base paper should be implemented and tested in Python. Furthermore, a sensitivity analysis varying the percentage of part-time employees should be conducted.

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

Literature: Eitzen et al. (2004)

> **Abstract**: This paper describes a problem faced by CS Energy's Swanbank Power Station in the Australian state of Queensland. It involved the personnel scheduling (rostering) of staff with multiple skill levels at the power station. Such a problem can be classified using the six stage construction process proposed by Ernst et al. We assume that the three processes of 'demand modelling,' 'shift starting times' and 'task scheduling' are specified. We are concerned with the essential processes of 'day off scheduling,' 'line of work construction' and 'shift assignment to staff' with requirements to maintain multiple skills. Several other authors have reported results for staff with hierarchical skills while the methods proposed in this paper are for non-hierarchical skill sets. The paper describes a set covering approach to the multi-skilled rostering problem. We propose a number of solution strategies for the set covering approach and give a comparison of the results.

P4 – 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.

P5 – Overview of staffing goals in call centers

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 that process quality does not suffer with the aim to provide a certain service level. One example could be to consider the negative impacts of waiting time or customer abandonments.

The goal of the research seminar is to provide a comprehensive overview on different performance goals that are considered during recent staffing approaches for call centers. The reviewed articles must be classified based on system assumptions (e.g. time-dependent vs. stationary), assumptions on the optimization problem, and performance metrics (e.g. period-wise vs. global goals). The necessity, goals, and drawbacks of using various period-wise or global performance metrics should be discussed extensively. Moreover, the thesis must provide an overview of the managerial insights mentioned in the reviewed research papers.

Prerequisites: Knowledge in optimization models and stochastic systems (e.g. OPM 560, 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.

P6 – Effects and identification of ramp-up phase

Objectives: In production management, the so called ramp-up phase occur during the transition of a product-process-system from development into a stable series production. This phase an important step in the life cycle of a new product, and efficiently managing ramp-ups can lead to business success. From an operations perspective, system performance such as utilization and work-in-process are of high interest. While the performance of a system may be stable in the long run, ramp-up phase causes an unstable production phase. Being able to identify when ramp-up phase is over (i.e. when steady-state is reached) can be of high importance in planning of other processes, e.g. maintenance. Planning these processes based on a unstable system can lead to sub-optimal operations. One way to identify the end of ramp-up phase based on system output is the usage of truncation heuristics. These heuristics try to find the timepoint where ramp-up is over based on system output, e.g. by trying measuring standard deviation of system output or analyzing patterns.

The goal of the research seminar is to compare different approaches to identify ramp-up phase (e.g. truncation heuristics, graphical approaches, ...). Causes and resulting effects of ramp-up phase for system performance and other processes should be discussed extensively, focusing on the managerial insights. Moreover, possible approaches to identify the ramp-up phase and their performance should be compared.

Prerequisites: Knowledge in stochastic systems (e.g. OPM 560, 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.

P7 – 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)

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.

P8 – 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 and 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.

P9 – 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, 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.

P10 – 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.

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.

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