OPM 761 – Research Seminar Production Management

Fall Term 2022

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 29th, 2022** until **May 13th, 2022**. Admission to the seminar will be confirmed by e-mail at latest on May 20th, 2022 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on **May 23rd, 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, **October 1st, 2022** 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 **10th to 14th of October 2022**. 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 2022, 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 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 problems 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 goal of the research seminar topic is to provide a detailed explanation of the decomposition approach in the base paper and to compare it with the integrated approach (modeling and solving as one MIP). As a second step these two solution methods should be 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 – Comparison of workforce regulations in different countries and analysis of their practical implications

Objectives: Different countries have different regulations on employee protection that must be taken into account when creating a duty roster. In Germany, for example, this is regulated in the "Arbeitszeitgesetz (ArbZG)". These regulations provide managers with a framework in terms of freedoms and restrictions when creating duty rosters. The literature on tour scheduling often only takes these regulations into account to a limited extent or even assumes restrictions that do not exist. However, especially in the healthcare sector managers often face the problem of creating feasable schedules which

fulfill legal regulations while meeting the demand for employees due to the shortage of workers.

The goal of this thesis is to provide an overview and comparison of the most important regulations on employee protection in two different countries, for example Germany and the US. In a second step, the reduced set-covering model formulation in the base paper which already considers some flexibilities should be adapted to meet the regulations in the corresponding countries. Finally, the models must be implemented in Python and a numerical analysis with standard solver must be conducted using the same input data (e.g. workforce requirement) for each of the country specific models. By comparing the resulting rosters for the two countries managerial insights should be created.

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

Basic Paper: Stolletz (2010)

> **Abstract**: This paper addresses operation models for workforce planning for check-in systems at airports. We characterize different tasks of the hierarchical workforce planning problem with time-dependent demand. A binary linear programming formulation is developed for the fortnightly tour scheduling problem with flexible employee contracts. This binary programming model is solved for optimality by CPLEX for real-world demand scenarios with different workforce sizes. The numerical study analyzes the impact of the degree of flexibility and economies of scale. The model formulation is extended to generate convenient tours with regard to employee preferences.

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 – Advances in modelling uncertainty

Objectives: Manufacturer and supplier regularly have to make decisions based on uncertain and incomplete information. Future demand, delivery times and/or availability of raw materials and resources can be uncertain and thus make reliable planning difficult. Stochastic programming and robust optimization are among the most common and proven techniques for integrating uncertainties into optimization models. However, there are still many challenges that need to be addressed. How to generate an efficient set of scenarios, especially in scarce-data environments? How to formulate multi-stage models in multi-period settings? And how to integrate risks into robust planning?

This seminar topic is intended to provide a comprehensive and detailed overview of the latest advances in stochastic programming and robust optimization based on the basic paper. The different approaches should be compared, analyzed and the respective advantages and disadvantages identified.

Prerequisites: Knowledge of optimization problems, in particular stochastic and robust approaches (e.g. OPM 661 or OPM 662)

Basic Paper: Govindan and Cheng (2018)

> **Abstract**: This special issue addresses the advances in stochastic programming and robust optimization for supply chain planning by examining novel methods, practices, and opportunities. The articles present and analyze opportunities to improve supply chain planning through exploring various uncertainty situations and problems, sustainability assessment, vendor selection, risk mitigation, retail supply chain planning, and supply chain coordination. This editorial note summarizes the discussions on the stochastic models, algorithms, and methodologies developed for the evaluation and effective implementation of supply chain planning under various concerns. A dominant finding is that supply chain planning through the advancement of stochastic programming and robust optimization should be explored in a variety of ways and within different fields of applications.

P5 – Performance analysis of retrial queues with fluid approximation

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. There are different methods to analyze the performance of such complex queueing systems, one being the fluid approximation. This approach is based on deterministic assumptions, e.g. no waiting clients are predicted until the system is in overload. Performance measures of the system are approximated numerically by solving differential equations.

The goal of the research seminar is to implement a fluid approach for such a retrial queueing system. The resulting ordinary differential equations should be implemented with Python and solved with a numeric library. Furthermore, managerial insights should be generated by analyzing the effects of various patience times and retrial rates through a numerical study.

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

Basic Paper: Mandelbaum et al. (2002)

> **Abstract**: We consider a Markovian multiserver queueing model with time dependent parameters where waiting customers may abandon and subsequently retry. We provide simple fluid and diffusion approximations to estimate the mean, variance, and density

for both the queue length and virtual waiting time processes arising in this model. These approximations, which are generated by numerically integrating only 7 ordinary differential equations, are justified by limit theorems where the arrival rate and number of servers grow large. We compare our approximations to simulations, and they perform extremely well.

P6 – Solution methods for the performance analysis of retrial queues

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. Such queueing systems are very complex and difficult to analyze, so that closed form solutions are only available under strict assumptions. Therefore, the performance measures of these systems are approximated using simulation or heuristic approaches, e.g. fluid and diffusion approximations.

The goal of the research seminar is to conduct a literature review by classifying and analyzing solution methods for the performance analysis of such queueing systems with retrials. Existing literature should be critically assessed by comparing exact and approximate solution methods with respect to their assumptions, different characteristics, and performance.

Prerequisites: Knowledge in queueing theory (e.g. OPM 661)

Basic Paper: Aguir et al. (2004)

> **Abstract**: This paper models a call center as a Markovian queue with multiple servers, where customer balking, impatience, and retrials are modeled explicitly. The resulting queue is analyzed both in a stationary and non-stationary setting. For the stationary setting a fluid approximation is proposed, which overcomes the computational burden of the continuous time markov chain analysis, and which is shown to provide an accurate representation of the system for large call centers with high system load. An insensitivity property of the retrial rate to key system parameters is established. The fluid approximation is shown to work equally well for the non-stationary setting with time varying arrival rates. Using the fluid approximation, the paper explores the retrial phenomenon for a real call center. The model is used to estimate the real arrival rates based on demand data where retrials cannot be distinguished from first time calls. This is a common problem encountered in call centers. Through numerical examples, it is shown that disregarding the retrial phenomenon in call centers can lead to huge distortions in subsequent forecasting and staffing analysis

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 as-

sumptions 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.
>
> 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 problem

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 – 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**: This work aims to assess the performance of approximation methods developed for the shortest processing time discipline and classify the studies that investigate the performance of queues controlled with various service disciplines in terms of the performance measures they approximate. The criteria of classification for the studies include the service discipline they study and the performance measures they consider specifically the queue length, total waiting time and the output process parameters.

P10 – Diffusion approximation method for time-dependent queueing networks

Objectives:

Often in production systems, a part has to go through various machines for its production to complete. Also, depending on the specifics of each part, it might need to visit different machines. Networks of queues are used for modelling such systems. Since the parameters of these networks can be time-dependent, there is a need for analysis of time-dependent queueing networks. Serial production lines (flow lines) are a special case of such manufacturing networks.

The aim of this seminar is the implementation of a diffusion based queueing network analysis method for a serial production line. Its accuracy has to be assessed numerically for a large set of parameters, especially for different patterns of time-dependent parameters. An additional objective of this seminar is reviewing the literature about the analysis of time-dependent queueing networks, specially with a focus on identifying the specifics and assumptions of the models related to each application.

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

Basic Paper: Kopats and Matalytski (2020)

> **Abstract**: Queueing networks provide a rich modelling framework for flow of material in production systems. However, queueing network analysis methods developed for time-dependent systems are often tested on restricted settings. In this work, we implement and assess the performance of a diffusion based time-dependent queueing analysis method on a flow line over a large range of parameter values to evaluate the method's accuracy.

References

Aguir, S., Karaesmen, F., Akşin, O. Z., and Chauvet, F. (2004). The impact of retrials on call center performance. *OR Spectrum*, 26(3):353–376.

Behzadi, G., O'Sullivan, M. J., and Olsen, T. L. (2020). On metrics for supply chain resilience. *European Journal of Operational Research*, 287(1):145–158.

Govindan, K. and Cheng, T. (2018). Advances in stochastic programming and robust optimization for supply chain planning. *Computers & Operations Research*, 100:262–269.

Kiermaier, F., Frey, M., and Bard, J. F. (2020). The flexible break assignment problem for large tour scheduling problems with an application to airport ground handlers. *Journal of Scheduling*, 23(2):177–209.

Kopats, D. and Matalytski, M. (2020). Diffusion approximation for an open queueing network with limited number of customers and time-dependent service. *SN Computer Science*, 1(1):1–4.

Mandelbaum, A., Massey, W. A., Reiman, M. I., Stolyar, A., and Rider, B. (2002). Queue lengths and waiting times for multiserver queues with abandonment and retrials. *Telecommunication Systems*, 21(2):149–171.

Mönch, L., Fowler, J. W., and Mason, S. J. (2012). *Production planning and control for semiconductor wafer fabrication facilities: modeling, analysis, and systems*, volume 52. Springer Science & Business Media.

Schneckenreither, M. and Haeussler, S. (2019). Reinforcement learning methods for operations research applications: The order release problem. In Nicosia, G., Pardalos, P., Giuffrida, G., Umeton, R., and Sciacca, V., editors, *Machine Learning, Optimization, and Data Science*, pages 545–559, Cham. Springer International Publishing.

Schrage, L. E. and Miller, L. W. (1966). The queue m/g/1 with the shortest remaining processing time discipline. *Operations Research*, 14(4):670–684.

Schwarz, J. A., Selinka, G., and Stolletz, R. (2016). Performance analysis of time-dependent queueing systems: Survey and classification. *Omega*, 63:170–189.

Stolletz, R. (2010). Operational workforce planning for check-in counters at airports. *Transportation Research Part E: Logistics and Transportation Review*, 46(3):414–425.