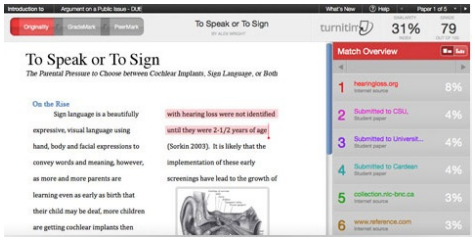
OPM 761 - Research Seminar Production Management

Key topics:

- Application of business analytics approaches
- Literature review
- Paper discussion

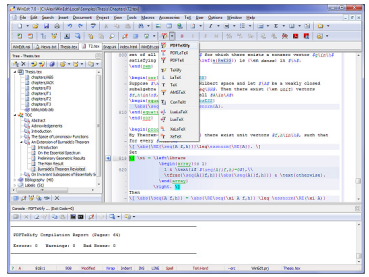


Grading: (6 ECTS)

- Seminar thesis (15-20 pages) (60%),
- presentation (30%) and discussion (10%)

Dates/course structure:

- Application together with other OPM chairs (at the end of previous semester)
- Kick-Off, individual meetings with supervisor
- Introduction to literature research, scientific writing & presentations
- Master's thesis in the same semester is possible



CHAIR OF PRODUCTION MANAGEMENT
Prof. Dr. Raik Stolletz
http://stolletz.bwl.uni-mannheim.de

UNIVERSITY OF MANNHEIM

OPM 761 – Research Seminar Production Management

Spring Term 2020

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 (15 to 20 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 Friday, **November 1st, 2019** until Friday, **November 15th, 2019**. Admission to the seminar will be confirmed by e-mail on Friday, November 22nd, 2019 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on Monday, **December 2nd, 2019** between 15:30 and 18:00 o'clock in room SO 322. During this meeting, an introduction to scientific writing and presentations for term papers will be given.

The **written reports** have to be submitted by Monday, **March 2nd, 2020** 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 between March 23rd and April 3rd, 2020 (exact times and the room will be announced). Attendance at the 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%). The report and the presentations can be delivered either in English or in German, unless stated otherwise.

There is a joint application process for all seminars offered by the chairs of the Area Operations Management. In the Fall term 2019, 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 Amir Foroughi (A.foroughi@bwl.uni-mannheim.de), who can also be contacted for general questions concerning the seminar.

Topics Catalog

P1 – Additive Manufacturing: New Production Management Challenges

Objectives: The technical development of generative manufacturing techniques, also known as 3D printing, enables manufacturers to flexibly address customer-specific orders. The availability of the technologies affects the way how manufacturing systems are designed and operated.

The student is expected to present an overview of the fundamental differences of the existing generative manufacturing techniques. Moreover, the applicability of these technologies in classical manufacturing systems such as job shops and flow lines has to be discussed. A comprehensive literature review on optimization problems in the context of 3D printing is the starting point for a discussion of future challenges and newly arising planning problems.

Prerequisites: Knowledge of Production Management Challenges (e.g.,OPM661 or OPM662).

Basic Paper: Mellor et al. (2014)

> **Abstract**: As mass production has migrated to developing countries, European and US companies are forced to rapidly switch towards low volume production of more innovative, customised and sustainable products with high added value. To compete in this turbulent environment, manufacturers have sought new fabrication techniques to provide the necessary tools to support the need for increased flexibility and enable economic low volume production. One such emerging technique is Additive Manufacturing (AM). AM is a method of manufacture which involves the joining of materials, usually layer-upon-layer, to create objects from 3D model data. The benefits of this methodology include new design freedom, removal of tooling requirements, and economic low volumes. AM consists of various technologies to process versatile materials, and for many years its dominant application has been the manufacture of prototypes, or Rapid

Prototyping. However, the recent growth in applications for direct part manufacture, or Rapid Manufacturing, has resulted in much research effort focusing on development of new processes and materials. This study focuses on the implementation process of AM and is motivated by the lack of socio-technical studies in this area. It addresses the need for existing and potential future AM project managers to have an implementation framework to guide their efforts in adopting this new and potentially disruptive technology class to produce high value products and generate new business opportunities. Based on a review of prior works and through qualitative case study analysis, we construct and test a normative structural model of implementation factors related to AM technology, supply chain, organisation, operations and strategy.

P2 – Aggregate Analysis of Multi-server Service and Production Systems

Objectives: Queueing systems with multiple servers are found in many real life operations systems. In service systems like call centers, service counters, and security checkpoints at airports, several service workers usually work in parallel. In addition, production systems often feature several parallel machines or manual workstations. In the literature, multi-server systems are sometimes modelled as single-server queues with a modified service rate.

The objective of the work is to investigate this technique of aggregating multi-server systems into single-server queues. Therefore, the student is expected to conduct a literature review of different application areas in service and production systems in which this technique is applied. Aggregation techniques have to be described. Numerical studies shall be conducted with a given Business analytics tool to examine the approximation quality for several performance measures to investigate in which situation which technique works well.

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

Basic Paper: Vidyarthi and Jayaswal (2014)

Abstract: We consider a class of location-allocation problems with immobile servers, stochastic demand and congestion that arises in several planning contexts: location of emergency medical clinics; preventive healthcare centers; refuse collection and disposal centers; stores and service centers; bank branches and automated banking machines; internet mirror sites; web service providers (servers); and distribution centers in supply chains. The problem seeks to simultaneously locate service facilities, equip them with appropriate capacities, and allocate user demand to these facilities such that the total cost, which consists of the fixed cost of opening facilities with sufficient capacities, the access cost of users' travel to facilities, and the queuing delay cost, is minimized. Under Poisson user demand arrivals and general service time distributions, the problem is set up as a network of independent M/G/1 queues, whose locations, capacities and service zones need to be determined. The resulting mathematical model is a non-linear integer program. Using simple transformation and piecewise linear approximation, the model is linearized and solved to ϵ-optimality using a constraint generation method. Computational results are presented for instances up to 400 users, 25 potential service facilities, and 5 capacity levels with different coefficients of variation of service times and average queueing delay costs per customer. The

results indicate that the proposed solution method is efficient in solving a wide range of problem instances.

P3 – Trading-off Quality and Waiting in Time-dependent Operations Systems

Objectives: In various service systems in health care, call centers, or consulting, tasks are completed according to the worker's subjective standards. A physician for example can decrease the time spent with a patient by skipping additional tests or by reducing the time devoted to questioning the patient. This decreases the quality of the service for the patient, however, the expected waiting time for the other customers is improved. Thus, in such systems there exists a trade-off between service quality and waiting time.

The goal of this seminar thesis is to carefully motivate and discuss the decision problem and applications considered in the base paper. The literature should be reviewed based on considered/ potential applications and managerial insights. In addition, the student is expected to validate and/or critically assess the results found in the paper.

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

Basic Paper: 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.

P4 – Newsvendor Models with Stochastic Yield

Objectives: Yield problems occur when a share of the produced products does not meet the quality specifications and can therefore not be used to fulfill demand. Yield problems play a critical role in many high-tech industries, such as the semiconductor industry. Typically, yield is stochastic and can be modeled by a probability distribution. Different Newsvendor models have been proposed to obtain the optimal production quantity for different yield and demand models.

The student is expected to present the literature on Newsvendor models with yield, specifically highlighting the different assumptions of the yield and demand models. Furthermore, the student is expected to implement a sampling-based Newsvendor model and conduct a numerical study on the impact of the different yield and demand models found in the literature.

Prerequisites: Knowledge of a modeling language for Linear Programming (e.g., OPM662).

Basic Paper: Choi et al. (2019)

> **Abstract**: We study a binomial yield production process using a newsvendor approach by considering the mismatch costs between a given demand and a non-defective yield amount. Using a normal approximation, we re- formulate the original discrete and exact model as a continuous and approximate model. We conduct a comparative static analysis of the parameters in the approximate model and derive the monotone prop- erties of the (approximate) optimal solution in the case that the given demand is sufficiently large. The analytical results are all consistent with our insights and are also supported by economic explanations. Our numerical study with sample-based optimization indicates that the approximate model is sufficiently close to the exact model in most real-world examples, with some limiting cases included. Then, a simple and naive solution is found to have significant suboptimality. Finally, the results of a sensitivity analysis of the model parameters are confirmed numerically.

P5 – Improving Healthcare Systems with Queueing Models

Objectives: In healthcare, appointment systems are applied to regulate the demand for various services. They help reduce the variability in the patients' arrival process so that patients wait less and the system is kept highly utilized. Two scheduling approaches can be considered in appointment systems: On-line (i.e., sequential) and offline (i.e., simultaneous). In the offline approach, appointments are scheduled after all requests have arrived, while in the online approach, patients are scheduled immediately upon the arrival of their request. Online systems are more common in practice. Kemper et al. (2014) apply the online approach and optimize the arrival times.

The objective of this seminar thesis is to identify the main issues addressed by the paper by Kemper et al. (2014) and explain the developed quantitative model as well as the applied solution methodology. The assumptions of the studied problem have to be discussed. In addition, students are expected to position the paper in the corresponding stream of scientific literature and critically assess its contribution.

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

Basic Paper: Kemper et al. (2014)

Abstract: In service systems, in order to balance the server's idle times and the customers' waiting times, one may fix the arrival times of the customers beforehand in an appointment schedule. We propose a procedure for determining appointment schedules in such a D/G/1-type of system by sequentially minimizing the per-customer expected loss. Our approach provides schedules for any convex loss function; for the practically relevant cases of the quadratic and absolute value loss functions appealing closed-form results are derived. Importantly, our approach does not impose any conditions on the service time distribution; it is even allowed that the customers' service times have different distributions. A next question that we address concerns the order of the customers. We develop a criterion that yields the optimal order in case the service time distributions belong to a scale family, such as the exponential family. The customers should be scheduled then in non-decreasing order of their scale parameter. While the optimal schedule can be computed numerically under quite general circumstances, in steady-state it can be computed in closed form for exponentially distributed service times under the quadratic and absolute value loss function. Our findings are illustrated by a number of numerical examples; these also address how fast the transient schedule converges to the corresponding steady-state schedule.

P6 – Scheduling Doctor's Appointments with Uncertainty in Demand

Objectives: Appointment systems are used in many service systems (e.g. healthcare systems) to manage access to service providers. They improve productivity and match capacity and demand by reducing uncertainty in demand. Appointment scheduling problems arise in such systems, which are to set appointed arrival times of clients/ patients. However, due to the presence of variability, obtaining a suitable appointment schedule is challenging. Sources of variability include random service times, unscheduled arrivals (walk-ins), no-shows, and unpunctuality of arrivals. The unpunctuality of arrivals has not been comprehensively considered in the literature so far.

The main goal of this seminar is to conduct a structured literature review for the papers dealing with appointment systems and unpunctuality of arrivals. We expect students to classify all the papers related to the topic and briefly describe them.

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

Basic Paper: Deceuninck et al. (2018)

We assess appointment scheduling strategies for outpatient services. To this end, we consider a fixed-length consultation session in which K patients have to be scheduled at predefined appointment times, but who may not be punctual. Their effective arrival time deviates from their appointment time by a stochastic unpunctuality time. We assume general, possibly distinct distributions for the patients' consultation times as well as for their unpunctuality. The heterogeneity of the consultation times is motivated by patient classification: the schedule can be adapted to the patients' characteristics. Our evaluation approach is based on a modified Lindley recursion in a discrete-time framework and obtains accurate

predictions for the moments of the patient waiting times as well as the doctor's idle times and overtime. This evaluation method is then included in a local search algorithm to provide general insights into appointment scheduling under unpunctual patients. Our results suggest that the proposed method obtains substantial cost reductions when patient classification is correctly exploited. Finally, it is shown that our analysis can also be used to determine optimal sequencing rules for patients who arrive out of turn.

P7 – Multi-department Multi-day Shift Scheduling

Objectives: Personnel scheduling problems exist in many work environments such as banks, hospitals, restaurants and retail stores. One of the variants of the problem arise in organizations which are divided into departments and transfer of workers among the departments is possible, i.e. each department has its own staff and on top of that, it can borrow staff from other departments if need be. This flexibility helps reduce the costs, especially when there are short-term changes in the demand of departments.

The objective 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 Mixed-Integer Programming (MIP) model has to be described and implemented in a modeling system (e.g. GAMS). A numerical analysis with standard solver must be conducted to generate some managerial insights. Critical assessment of the contribution of the proposed model will conclude this thesis.

Prerequisites: Knowledge of a modeling language for MIPs (e.g. OPM 662)

Basic Paper: Dahmen et al. (2020)

Abstract: In this paper, we address a personalized multi-department multi-day shift scheduling problem with a multi-skill heterogeneous workforce where employees can be transferred between departments under some restrictions. The objective is to construct a schedule that minimizes under-coverage, over-coverage, transfer and labor costs. We propose a novel two-stage approach to solve it: the first stage considers an approximate and smaller problem based on data aggregation and produces approximate transfers. The second stage constructs personalized schedules based on the information deduced from the first stage. An exhaustive experimental study is conducted and proves the efficiency of the proposed approach in terms of solution quality and computing times.

P8 – Literature Overview on Personnel Scheduling with Employee Transfers

Objectives: Personnel-related cost is the major cost component in many service and production systems. Therefore, cutting labor costs by only a small percentage will result in a significant savings in total costs. One of the options managers use to reduce the costs is the transfer of workers between different parts of the system.

The goal of this seminar thesis is to review the papers in the field of personnel scheduling

that consider the transfer of workers between different parts of the system. The student is supposed to explain the underlying assumptions of optimization problems. The overview is expected to classify the literature based on the features of the problems especially with regard to the transfers.

Prerequisites: Knowledge of mathematical modeling and optimization (e.g. OPM 662)
Basic Paper: Dahmen et al. (2020)

> **Abstract:** In this paper, we address a personalized multi-department multi-day shift scheduling problem with a multi-skill heterogeneous workforce where employees can be transferred between departments under some restrictions. The objective is to construct a schedule that minimizes under-coverage, over-coverage, transfer and labor costs. We propose a novel two-stage approach to solve it: the first stage considers an approximate and smaller problem based on data aggregation and produces approximate transfers. The second stage constructs personalized schedules based on the information deduced from the first stage. An exhaustive experimental study is conducted and proves the efficiency of the proposed approach in terms of solution quality and computing times.

P9 – Patient Flow and Waiting Time Management in Inpatient and Emergency Departments

Objectives: The demand for health care services has been rapidly increasing over the last decades. Statistics show that in 2017 19.4 million patients required emergency or inpatient treatment with associated costs of about 91.3 billion in Germany. As patients may face serious consequences as well as mental distress if not treated in a timely manner, waiting time management is an important problem for hospitals and health care systems. A staffing and resource allocation is required that allows the health care system to run cost efficiently, while maintaining target waiting times. In order to determine an appropriate staffing and resource allocation, a performance evaluation is required to assess the expected waiting time for a given setting. Health care systems are not only facing a multitude of sources of stochasticity e.g. arrival rates and treatment times but they also consist of multiple processes with interdependencies. In order to capture both, queuing networks have been proposed in the literature to model the patient flows.

The student is expected to characterize and structure the different existing optimization models in inpatient and emergency departments. The different models as well as the underlying stochastic assumptions have to be structured. Particular attention should be paid to the way the process complexity is captured within the models.

Prerequisites: Basic knowledge in queuing theory (e.g. OPM 661) as well as optimization problem modeling (e.g. OPM 561).

Basic Paper: Kim and Kim (2015)

> **Abstract**: Unlike ordinary outpatient clinics, an emergency care center sees a variety of patients with diverse diseases and injuries of different levels of severity. Since patients who are in a critical condition face serious consequences, target waiting times must be determined based on patient acuity levels. To reflect the special situation in emergency care centers included in this study, patient flows are formulated using an open Jackson network with multiple patient

classes. This paper is unique because of the integration of pooling and prioritizing patient classes with the open Jackson network. In particular, a hybrid priority model is presented in which a first-come-first-served discipline is applied in some processes and a priority discipline is applied in other processes in the open Jackson network, in order to minimize waiting times for patients with more urgent concerns. A case study based on actual data from an emergency care center demonstrates that the proposed model of pooling and prioritizing patient classes is effective in decreasing waiting times for higher-priority classes without substantially sacrificing those for lower-priority classes.

P10 – Capacity Planning with Uncertain Parameters in Call Centers

Objectives: More than 70% of customer-business interactions are handled by call centers, requiring more than 3.5 million people or approximately 2.6% of the U.S. workforce. Since staffing cost is a major component in the operating costs of call centers, considerable literature has focused on determining appropriate staffing levels ensuring a certain service level. Traditionally, most models in the literature assume known and constant mean arrival rates. However, real data show uncertainty in the problem parameters itself. Bassamboo et al. (2010) propose a model incorporating both variability and parameter uncertainty and elucidate their effect on the capacity decision. They formulate a model with customer arrivals modeled using a doubly stochastic Poisson process, where the arrival rate itself is a random variable and therewith uncertain.

The student is expected to structure the literature on capacity planning with parameter uncertainty, specifically highlighting the different assumptions on the uncertainty and the characteristics of the underlying model.

Prerequisites: Basic knowledge in queuing theory (e.g. OPM 661)

Basic Paper: Bassamboo et al. (2010)

Abstract: We study a capacity sizing problem in a service system that is modeled as a single-class queue with multiple servers and where customers may renege while waiting for service. A salient feature of the model is that the mean arrival rate of work is random (in practice this is a typical consequence of forecasting errors). The paper elucidates the impact of uncertainty on the nature of capacity prescriptions, and relates these to well established rules-of-thumb such as the square-root safety staffing principle. We establish a simple and intuitive relationship between the incoming load (measured in Erlangs) and the extent of uncertainty in arrival rates (measured via the coefficient of variation) that characterizes the extent to which uncertainty dominates stochastic variability or vice versa. In the former case it is shown that traditional square-root safety staffing logic is no longer valid, yet simple capacity prescriptions derived via a suitable newsvendor problem are surprisingly accurate.

References

Bassamboo, A., R. S. Randhawa, and A. Zeevi (2010). Capacity sizing under parameter uncertainty: Safety staffing principles revisited. *Management Science 56*(10), 1668–1686.

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