CHAIR OF PRODUCTION MANAGEMENT
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UNIVERSITY OF MANNHEIM

OPM 761 – Research Seminar Production Management

Fall 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 (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 Monday, **April 27th, 2020** until Sunday, **May 10th, 2020**. Admission to the seminar will be confirmed by e-mail on May 15th, 2020 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on Monday, **May 25th, 2020** between 15:30 and 18:00 o'clock via Zoom. 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, **September 21st, 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 **October 5th** and **October 16th, 2020** (exact times and the room will be announced). Attendance at the presentations is mandatory.

The report and the presentations should be delivered in English, 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 2020, 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 (opm761@bwl.uni-mannheim.de), who can also be contacted for general questions concerning the seminar.

Topics Catalog

P1 – Managerial Insights from Stochastic Yield in a Newsvendor Model

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 implement the sampling-based Newsvendor model from Choi et al. (2019), which can be solved with a standard solver (e.g. CPLEX). The focus of the thesis is to conduct a numerical study on the impact of different distributions of yield and demand.

Prerequisites: Knowledge of a programming language (e.g. OPM562) or 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 reformulate 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 properties 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.

P2 – Variance Reducing Sampling Methods in Operations Management

Objectives: Sampling is often used in the optimization of complex stochastic systems. One common method to draw random numbers is simple random sampling. However, numerical studies have shown that the introduced variance from simple random sampling is high. Therefore, some authors replace simple random sampling by variance reducing methods such as descriptive sampling.

The student is expected to review the literature in operations management using variance reducing sampling methods. For this, the thesis first introduces the existing variance reducing methods. These methods have been compared numerically or statistically. The thesis reviews those comparisons between the different methods for different applications in operations management.

Prerequisites: Knowledge of stochastic variability (e.g. OPM661) or knowledge of sampling-based optimization (e.g. OPM662).

Basic Paper: Saliby and Pacheco (2002); Helber et al. (2013)

Abstract: This paper compares the performance, in terms of convergence rates and precision of the estimates, for six Monte Carlo simulation sampling methods: quasi-Monte Carlo using Halton, Sobol, and Faure numeric sequences; descriptive sampling, based on the use of deterministic sets and Latin hypercube sampling, based on stratified numerical sets. Those methods are compared to the classical Monte Carlo. The comparison was made for two basic risky applications: the first one evaluates the risk in a decision making process when launching a new product; the second evaluates the risk of accomplishing an expected rate of return in a correlated stock portfolio. Descriptive sampling and Latin hypercube sampling have shown the best aggregate results.

We present a stochastic version of the single-level, multi-product dynamic lot-sizing problem subject to a capacity constraint. A production schedule has to be determined for random demand so that expected costs are minimized and a constraint based on a new backlog-oriented ?-service-level measure is met. This leads to a non-linear model that is approximated by two different linear models. In the first approximation, a scenario approach based on the random samples is used. In the second approximation model, the expected values of physical inventory and backlog as functions of the cumulated production are approximated by piecewise linear functions. Both models can be solved to determine efficient, robust and stable production schedules in the presence of uncertain and dynamic demand. They lead to dynamic safety stocks that are endogenously coordinated with the production quantities. A numerical analysis based on a set of (artificial) problem instances is used to evaluate the relative performance of the two different approximation approaches. We furthermore show under which conditions precise demand forecasts are particularly useful from a production?scheduling perspective.

P3 – 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.

P4 – Reinforcement Learning Approaches to Optimize Maintenance Planning

Objectives: Maintenance activities are performed to keep machines, vehicles, or infrastructure in good condition by checking it regularly and repairing it when necessary. Key decisions are when and how often to perform such activities as maintenance activities are directly related to costs. Reinforcement learning methods belong to the class of artificial

intelligence approaches and can support this decision-making process.

The student is expected to present an overview of maintenance activities, which are optimized by Reinforcement Learning approaches. Particularities of the different applications have to be characterized. The comprehensive literature review on optimization problems is the starting point for a discussion of future challenges and fields of application.

Prerequisites: Knowledge of stochastic systems and their analysis (e.g., OPM661), Basic knowledge of Artificial Intelligence approaches (e.g., OPM562).

Basic Paper: Liu et al. (2020)

> **Abstract**:Selective maintenance, which aims to choose a subset of feasible maintenance actions to be performed for a repairable system with limited maintenance resources, has been extensively studied over the past decade. Most of the reported works on selective maintenance have been dedicated to maximizing the success of a single future mission. Cases of multiple consecutive missions, which are oftentimes encountered in engineering practices, have been rarely investigated to date. In this paper, a new selective maintenance optimization for multi-state systems that can execute multiple consecutive missions over a finite horizon is developed. The selective maintenance strategy can be dynamically optimized to maximize the expected number of future mission successes whenever the states and effective ages of the components become known at the end of the last mission. The dynamic optimization problem, which accounts for imperfect maintenance, is formulated as a discrete-time finite-horizon Markov decision process with a mixed integer-discrete-continuous state space. Based on the framework of actor-critic algorithms, a customized deep reinforcement learning method is put forth to overcome the "curse of dimensionality" and mitigate the uncountable state space. In our proposed method, a postprocess is developed for the actor to search the optimal maintenance actions in a large-scale discrete action space, whereas the techniques of the experience replay and the target network are utilized to facilitate the agent training. The performance of the proposed method is examined by an illustrative example and an engineering example of a coal transportation system.

P5 – Robust Optimization in Appointment Systems

Objectives: Appointment systems are used in many customer service industries to increase the utilization of resources, match workload to available capacity, and smooth the flow of customers. A common problem faced by decision-makers is how to determine the scheduled arrival times of each service when their durations are uncertain. Appointment scheduling is complicated by the fact that there are several sources of uncertainty such as patients' no-show, walk-in patients, and random service times. Robust optimization is a way to deal with uncertainties in appointment scheduling problems.

For this seminar thesis, the students are expected first to discuss the robust optimization problem presented in the basic paper in detail. In addition, they have to relate the paper to the corresponding stream of scientific literature by conducting a structured literature review over the robust optimizations in appointment systems. The model of the reviewed papers has to be explained and differences and similarities to the model of the base paper needs to be discussed.

Prerequisites: Knowledge of robust optimization model (e.g., OPM661 or OPM662).

Basic Paper: Mancilla and Storer (2012)

> This article develops algorithms for a single-resource stochastic appointment sequencing and scheduling problem with waiting time, idle time, and overtime costs. This is a basic stochastic scheduling problem that has been studied in various forms by several previous authors. Applications for this problem cited previously include scheduling of surgeries in an operating room, scheduling of appointments in a clinic, scheduling ships in a port, and scheduling exams in an examination facility. In this article, the problem is formulated as a stochastic integer program using a sample average approximation. A heuristic solution approach based on Benders' decomposition is developed and compared to exact methods and to previously proposed approaches. Extensive computational testing shows that the proposed methods produce good results compared with previous approaches. In addition, it is proved that the finite scenario sample average approximation problem is NP-complete.

P6 – Allocation of Capacity to Different Patient Groups in Healthcare

Objectives: In healthcare, appointment systems mainly work to regulate the patient demand for various services. They help reduce the variability to balance two conflicting objectives: The patients prefer to have a short waiting time and the physicians like to have as little idle time as possible and to finish on time. Different patient groups have different and sometimes conflicting needs. In addition, allocation of capacity to them clearly impacts what appointment slots are available for future demand and how much physicians may be idle. Thus, better managing healthcare resources helps to achieve reducing waiting times to an acceptable levels without undue additional costs. An important decision in appointment systems with heterogeneous demand is to decide about how available capacity should be divided among different patient groups.

In this research seminar, the student is expected first to discuss the optimization problem presented in the base paper in detail. In addition, the model in the basic paper must be implemented a modeling system (e.g. GAMS). Aggregation or decomposition approaches have to be developed to solve large instances. Numerical experiments on the impact of different problem parameters (e.g. appointment lead-time, consultation time) on the optimal solution and discussion of obtained managerial insights have to be included in this research seminar.

Prerequisites: Knowledge of a modeling language for mixed integer programming (e.g., OPM662).

Basic Paper: Nguyen et al. (2015)

> **Abstract**: This paper introduces a deterministic model to plan the physician requirements for outpatient clinics to achieve service targets for the appointment lead-times of patients. The Ministry of Health of Singapore has established targets for the median, 95th percentile, and 100th percentile of appointment lead-times for patients, since long appointment postponements are regarded as being unacceptable for health care services. The study is to match the capacity

of the healthcare providers to the patient demand for a re-entry system, subject to restrictions on the appointment lead-times for patients. We propose a mixed-integer programming model for planning capacity with the minimization of the maximum required capacity as its objective. In the model we assume a finite planning horizon, deterministic arrivals, multiple types of patients, identical physicians, and dependent demand between types of patients. We solve this model with a Branch and Cut algorithm. We test the model with numerical experiments using real data from the chosen specialty at the outpatient clinic of the studied hospital. The results show the value of the proposed model via a systematic push-pull mechanism in scheduling patients' requests to minimize the objective. The clinic should use one of the appointment lead-time targets to determine the patients' appointment dates. Finally, from the sensitivity analyses we demonstrate that the objective is negatively correlated with first-visit patients' appointment leadtime targets, the discharge rates, and the re-visit patients' mean appointment lead-time; we find a positive correlation between the first-visit patients' mean appointment lead-time and the appointment lead-time targets.

P7 – Voice of Optimization: Learning Optimal Strategies in Lot Sizing Problem

Objectives: Lot sizing is one of the problems managers of many manufacturing systems face. The problem seeks to determine lot sizes while considering limited production capacities in order to minimize setup costs as well as inventory holding costs. Despite all their impact in solving lot sizing problems, optimization methods are seen as black box tools into which one feeds the formulated problem and input parameters to find the optimal solution. In most of the cases, especially in high dimensional problems such as lot sizing, it is not possible for the practitioner to interpret or intuitively understand the optimal solution. Moreover, in most cases, the goal is not to solve a single problem but rather to solve multiple instances of the problem with similar structure and slightly different parameters. Bertsimas and Stellato (2018) introduce the concept of *"Voice of Optimization"* to bridge this gap and present an approach to predict the optimal strategies in an interpretable manner.

The objective of this seminar thesis is to describe and analyze the method proposed in the base paper. The method must be implemented in a programming language (e.g. Python) for a lot sizing problem in order to predict the optimal solution. Moreover, the student is expected to make a numerical analysis on the trade-off between the interpretability of the prediction methods and their accuracy. Critical assessment of the contribution of the proposed model will conclude the thesis.

Prerequisites: Knowledge of optimization models and linear programming (e.g., OPM662), knowledge of machine learning algorithms and their implementation (e.g. OPM562).

Basic Paper: Bertsimas and Stellato (2018)

> We introduce the idea that using optimal classification trees (OCTs) and optimal classification trees with-hyperplanes (OCT-Hs), interpretable machine learning algorithms developed by Bertsimas and Dunn [2017, 2018], we are able to obtain insight on the strategy behind the optimal solution in continuous and mixed-integer convex optimization problem as a function of key parameters that affect

the problem. In this way, optimization is not a black box anymore. Instead, we redefine optimization as a multiclass classification problem where the predictor gives insights on the logic behind the optimal solution. In other words, OCTs and OCT-Hs give optimization a voice. We show on several realistic examples that the accuracy behind our method is in the 90%-100% range, while even when the predictions are not correct, the degree of suboptimality or infeasibility is very low. We compare optimal strategy predictions of OCTs and OCT-Hs and feedforward neural networks (NNs) and conclude that the performance of OCT-Hs and NNs is comparable. OCTs are somewhat weaker but often competitive. Therefore, our approach provides a novel insightful understanding of optimal strategies to solve a broad class of continuous and mixed-integer optimization problems.

P8 – Multi-activity shift scheduling: Explicit vs Implicit Formulation

Objectives: Effective personnel planning is shown to be crucial for companies, especially for companies in the service sector because labor cost is one of the major cost components in such systems. In the *multi-activity shift scheduling* problem, the goal is to construct feasible shifts and simultaneously assign activities to them in a way that the demand for each activity at each time period is satisfied. Moreover, based on the application some constraints related to union agreements must be taken into account as well.

The objective of this thesis is to describe and analyze the optimization problem as well its explicit and implicit model formulations presented in the base paper in detail. In addition, the student is expected to position the base paper in the related stream of literature. Moreover, both of the formulations must be implemented in a modeling system (e.g. GAMS). Numerical experiments must be conducted to shed light on the impact of different problem dimensions on the size and solution time of the resulting models from the two formulations. Critical assessment of the contribution of the base paper both from application and solution method point of view and based on that suggestions for possible extensions and future research will conclude this thesis.

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

Basic Paper: Dahmen et al. (2018)

> We consider a multi-activity shift scheduling problem where the objective is to construct anonymous multi-activity shifts that respect union rules, satisfy the demand and minimize workforce costs. An implicit approach using adapted forward and backward constraints is proposed that integrates both the shift construction and the activity assignment problems. Our computational study shows that using the branch-and-bound procedure of CPLEX 12.6 on the proposed implicit model yields optimal solutions in relatively short times for environments including up to 2970 millions of explicit shifts. Our implicit model is compared to the grammar-based implicit model proposed by Côté et al. (Manag Sci 57(1):151–163, 2011b) on a large set of instances. The results prove that both implicit models have their strengths and weaknesses and are more or less efficient depending on the scheduling environment.

P9 – Cutoff service levels in operations management

The management of operations in warehousing, transportation and manufacturing is driven by service levels with respect to on-time delivery. In service level agreements, typically, so-called cutoff service levels (also known as Next Scheduled Deadline (NSD)) are widely used in industry and retail operations. For example, based on a cut-off time and a deadline, a certain target percentage of orders received until the cut-off time have to be processed until the deadline.

The objective of this thesis is to discuss the paper of Doerr and Gue (2013) in detail and to implement the simulation approach described in the publication. A numerical study should highlight managerial insights. The service level and the related insights should positioned in the relevant literature.

Prerequisites: Basic knowledge in stochastic systems (e.g., OPM 661 Business Analytics: Robust Planning in Stochastic Systems), knowledge of a programming language or willingness to acquire basic programming skills (e.g., Python, Java).

Basic Paper: Doerr and Gue (2013)

> **Abstract**: A performance metric and goal-setting procedure is defined for an order fulfillment operation. In this operation, order requests arrive continuously, and filled orders are shipped at a specific time each day. The metric links the continuous operation of order fulfillment to the scheduled shipment times. To prescribe goals against the metric, a performance model is developed that incorporates the motivational effect of a goal. Goal-Setting Theory is used to establish the performance goal and to show how to match arriving orders to deadlines based on their arrival times and expected processing times. Monte Carlo simulation on data from a large distribution center is used to demonstrate that setting these two parameters in the light of motivational research yields quite different results than doing so with an intuitive method. Moreover, a motivational goal leads to better operational performance; that is, correctly setting up the metric causes more customers to receive their orders sooner.

References

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