OPM 760 – Project Seminar Operations Analytics

Fall Term 2025

The goal of this seminar is conducting of scientific research in the field of operations management. Thereby, it prepares the students for writing an analytics-oriented 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, designated as either individual or in teams of two students, as specified in the catalog. Team topics can be assigned as individual topics with reduced workload.

Based on scientific literature, participants will apply and implement predictive or descriptive business analytics approaches to solve an operations management problem. They will 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 **May 2nd, 2025** until **May 16th, 2025**. Admission to the seminar will be confirmed by e-mail at latest on May 23rd, 2025 and must be reconfirmed by the participant at the kick-off meeting.

The **Kick-off meeting** will be held on **June 4th, 2025** between 08:30 and 10:00 (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 6th, 2025** 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 between **20th and 24th October 2025**. 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 2025, 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 760:** Project Seminar Operations Analytics,
  Chair of Production Management, Prof. Dr. Raik Stolletz
  (Topics labeled with "P"),
- **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 760 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 opm760@uni-mannheim.de. For any further question concerning the seminar please also contact the chair via opm760@uni-mannheim.de.

Topics Catalog

P1 – Correlation Between Yield And Waiting Time: A Quantitative Study

Type: Individual topic

Objectives: In semiconductor manufacturing, achieving high yield while maintaining low cycle times is critical for both economic performance and production efficiency. However, several studies have demonstrated that these two objectives are often in tension. Increased waiting time due to inspection queues or production bottlenecks may improve process control and defect detection but can also lead to increased contamination risks and delayed corrective actions—both of which degrade yield. The papers by Tirkel et al. (2009) and Srinivasan et al. (1995) explore these trade-offs through analytical modelling and simulation. Tirkel et al. investigate the impact of dynamic in-line inspection policies on the yield–cycle time relationship, while Srinivasan et al. provide a quantitative methodology to model how airborne particulate contamination linked to waiting time reduces die yield. Understanding and modelling this complex relationship is essential for developing robust operational strategies in advanced manufacturing systems.

The thesis requires the student to first conduct a literature review on the correlation between waiting time and yield in manufacturing systems. The student should compare different assumptions with respect to modelling of the yield. Next, the student will study the models proposed in the papers by Tirkel et al. and Srinivasan et al., with a focus on the inspection policy trade-offs and the yield loss modelling. Finally, the student is expected to develop a continuous-time Markov chain (CTMC) and implement the performance analysis in python for a simplified queuing system of a production unit. A sensitivity analysis should demonstrate how different inspection policies impact yield and cycle time under varying assumptions of process control.

Prerequisites: Knowledge of stochastic systems (e.g. OPM 661), programming in Python

Basic Papers: Tirkel et al. (2009), Srinivasan et al. (1995)

Abstract: Using SEMATECH yield modelling techniques, the effect of reductions in cycle time and of improvements in environmental cleanliness is projected to die-per-wafer yield gains in semiconductor wafer fabrication. This study provides a methodology to determine the impact upon the total process yield of the factory as a result of shortening queue times. Modelling a fabrication facility that uses a 0.25 micron high-performance logic (1poly, 4metal) process flow, the methodology is used to determine variations in yield at different concentrations of airborne particles. In turn, the methodology provides guidelines for implementing operational strategies intended to achieve increases in total process yield.

P2 – Optimization of fleet capacity in urban mobility operations with variable demand

Type: Individual or team topic

Objectives: In many urban mobility services, such as taxi companies, carsharing platforms, and other on-demand transportation services, customers may abandon their ride request (e.g. cancel the ride or switch to another service) due to a lack of patience. For urban mobility services, the number of available vehicles represents a significant investment and cannot be easily adjusted in real-time. Thus, efficient fleet capacity planning (i.e. determining the optimal number of vehicles to invest in and make available) is crucial for success. The fleet capacity planning should consider service level constraints (e.g. 90% of customers experience a wait time of less than 5 minutes), while accounting for time-dependent demand for the rides. Thus, the goal of fleet capacity planning for urban mobility services is to strategically determine the number of vehicles to deploy under time-dependent demand and service level constraints.

However, reliable methods for performance evaluation are needed to optimize the fleet capacity. For example, modified offered load (MOL) and stationary independent period by period (SIPP) approaches can be utilized. MOL approach approximates the time-dependent offered load in a queueing system by the number of busy servers in a corresponding infinite-server system. On the other hand, SIPP approach analyzes the system independently in each period utilizing stationary queueing models.

The goal of this thesis is to analyze the impact of MOL and SIPP approaches on capacity decisions for a time-dependent queueing system with abandonments. Applications and methodology behind MOL and SIPP approaches should be summarized; an overview of capacity planning approaches for time-dependent systems with abandonments should be presented. Capacity planning based on MOL and SIPP approaches should be implemented with Python. The accuracy of these approaches should be analyzed through a systematic comparison against a simulation tool (will be provided by the chair). The differences in obtained capacity decisions based on MOL and SIPP approaches and how these decisions are influenced in face of different system parameters (e.g. service and abandonment rates) should be analyzed in an extensive numerical study.

Prerequisites: Knowledge of stochastic systems (e.g. OPM 661), programming in Python

Basic Paper: Liu and Whitt (2012); Green et al. (2001)

> **Abstract**: An algorithm is developed to determine time-dependent staffing levels to stabilize the time-dependent abandonment probabilities and expected delays at positive target values in the $M_t/GI/s_t + GI$ many-server queueing model, which has a nonhomogeneous Poisson arrival process (the M_t), has general service times (the first GI), and allows customer abandonment according to a general patience distribution (the $+GI$). New offered-load and modified-offered-load approximations involving infinite-server models are developed for that purpose. Simulations show that the approximations are effective. A many-server heavy-traffic limit in the efficiency-driven regime shows that (i) the proposed approximations achieve the goal asymptotically as the scale increases, and (ii) it is not possible to simultaneously stabilize the mean queue length in the same asymptotic regime.

P3 – Computational modeling and analysis of dynamic systems

Type: Individual

Objectives: Stochastic systems play a fundamental role in modeling real-world processes across various industries, including manufacturing, transportation, and healthcare. They are significantly impacted by time-dependent behaviors, such as fluctuating arrival rates and varying resource availability. The accurate analysis of such systems is challenging because of the inherent stochastic variability, time-dependency, and complex system dynamics. Although simulation remains a flexible and widely used tool for performance evaluation, it can be computationally expensive and time consuming. Therefore, approximation methods are necessary to obtain reliable performance estimates with a reduced computational cost. QPLEX is a computational modeling and analysis methodology/tool designed to analyze such systems. By solving a system of equations that approximate the dynamics of the system, QPLEX aims to provide accurate performance metrics efficiently.

The core methodology behind QPLEX should be summarized; its positioning among other performance evaluation approaches should be outlined. The accuracy of QPLEX have to be analyzed through a systematic numerical study against a simulation tool (will be provided by the chair). The conditions (e.g. arrival patterns, load conditions, ...) under which QPLEX provides accurate estimates, as well as the conditions in which it fails have to be identified.

Prerequisites: Knowledge of stochastic systems (e.g. OPM 661), programming in Python

Basic Paper: Dieker and Hackman (2025); Schwarz et al. (2016)

> **Abstract**: This book introduces QPLEX, a powerful computational framework designed for modeling and analyzing nonstationary stochastic systems with large state spaces. The methodology excels at rapidly and accurately generating approximate distributions of system performance over time, offering a robust tool for understanding the dynamics of such systems. QPLEX circumvents the curse of dimensionality by imposing conditional independence, which may be represented via a probabilistic graphical model, and exploiting model dynamics. It is specifically crafted for transient analysis of nonstationary systems, often encountered in practical applications but rarely addressed by traditional techniques. It can work directly with empirical distributions and requires no stability assumptions. Since its output is not noisy, QPLEX is tailor-made for sensitivity analysis and optimization. The methodology's few model primitives are flexible enough to specify a rich array of models. For example, models representing queueing networks can exhibit challenging characteristics such as short operational horizons; time-varying arrival rates, service durations, and numbers of servers; and complex routing of entities. The text is accessible to those with engineering, computer science, or mathematics backgrounds and knowledge of probability and stochastic models at the advanced undergraduate level. Many fully worked-out examples aid the comprehension of the concepts and calculations, ensuring readers can effectively apply the methods to real-world systems and making this book a valuable resource for researchers and practitioners alike.

P4 – Facility location planning of closed-loop supply chains under stochastic demand

Type: Individual topic

Objectives: In closed-loop supply chains, products used by customers are collected, remanufactured, and subsequently sold to customers again. Optimal planning of closed-loop supply chains necessitate the optimization of locations for production facilities and collection centers, transportation routes, production, recycling, and disposal volumes. Due to the increasing emphasis on sustainability in the manufacturing industry, various environmental goals (e.g., minimizing CO_2 emissions) have to be considered. Additionally, the stochastic nature of customer demand plays a crucial role in planning and must be accounted for.

Optimization of a closed-loop supply chain with stochastic demand can be done with two-stage stochastic programming. The optimization procedure selects the facility location before the uncertain demand is realized (first stage), and adjusts transportation decisions afterwards (second stage). This helps to manage the variability in demand and provides a robust solution. Two key indicators that assess the impact of stochastic demand are the expected value of perfect information (EVPI), and the value of stochastic solution (VSS). While EVPI measures the potential cost savings that could be achieved with a perfect demand forecast, the VSS evaluates benefit of incorporating stochastic variability into the planning process compared to using a deterministic model.

The goal of this thesis is to analyze the impact of stochastic demand distributions on the optimal planning of a facility location problem for a closed-loop supply chain. A literature review should give an overview of objective functions and constraints related to environmental targets used in closed-loop supply chain planning problems. A two-stage stochastic problem for the facility location problem of a closed-loop supply chain should be modelled and implemented in Python. Managerial insights on the impact of demand distributions on the optimal solution, as well as on the EVPI and the VSS should be generated with a numerical study.

Prerequisites: Knowledge of optimization models (e.g. OPM 662), programming in Python and docplex

Basic Paper: Amin and Zhang (2013)

> **Abstract**: Integration of forward and reverse channels results in closed-loop supply chain networks. In this research, a mixed-integer linear programming model is proposed to configure a closed-loop supply chain network. The network includes multiple products, plants, recovery technologies, demand markets, and collection centres. The objective function is minimisation of the total cost. The model can determine number and locations of open facilities, and flows of products in the network. In addition, we develop the model to multi-objectives by considering minimisation of defect rates and time of operations in collection centres. To solve the model, weighted-sums and distance methods are applied in copier remanufacturing example and the results are analysed. Moreover, value path approach is applied to compare the results of different methods.

P5 – Waiting for a Better Service: The Quality-Speed Trade-Off

Type: Individual topic

Objectives: In service systems, lower service rates often correspond to services of higher (perceived) quality. E.g., a call center agent might use small talk to calm customers, or spend more time on resolving problems. Another example could be a physician who spends more time diagnosing a patient and thus increasing the quality of treatment. Nevertheless, decreasing the service rate results in higher waiting times. Thereby customer satisfaction suffers. The quality-speed trade-off optimizes service rates to balance waiting and quality. Demand can be determined endogeneously, i.e., the provided service quality and chosen price can influence the demand of future periods.

The objective of this seminar thesis is to describe and analyze the quality-speed trade-off optimization problem with pricing addressed in the base paper in detail. In addition, the paper should be positioned in the related stream of literature. The model presented in the paper should be described, analyzed, and implemented (e.g., in Python, GAMS, etc.). Numerical studies should generate managerial insights. A critical assessment of the model concludes this thesis.

Prerequisites: Knowledge in optimization models and stochastic optimization (e.g., OPM 661 or 662), programming in Python and docplex

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.

P6 – Shift Scheduling: Prescriptive Analytics for Fair Schedules

Type: Individual or team topic

Objectives: Besides creating feasible schedules, fairness considerations are relevant in workforce planning. Employees want to be treated in a fair manner - but as fairness can be a subjective topic, the question is which objective to pursue. In Karsu and Morton (2015), different measures of fairness are presented. Thereby, they differentiate between equitability and balance. The first concept comes into play if customers are indistinguishable, then the goal is to, e.g., allocate some resources over the population or to ensure, that workloads are distributed fairly among employees (Ernst et al., 2004). Balance is important under heterogeneity, e.g., if customers or employees have different preferences regarding products or shift schedules.

This thesis analyzes an optimization model incorporating fairness aspects into the shift scheduling of physicians. Different measures of fairness in the context of workforce planning should be presented, characterized and quantified. The mixed-integer linear programming model (MIP) proposed by Stolletz and Brunner (2012) should be described and briefly positioned within the existing body of literature. Both the reduced set covering and the implicit modeling approach of the model will be implemented using an optimization tool such as Python's DoCPLEX, GAMS, or AMPL. A sensitivity analysis will be conducted, focusing on parameters like minimum and maximum shift length to assess their impact on optimal shift scheduling and provide managerial insights into shift scheduling under fairness considerations.

Prerequisites: Knowledge in optimization models (e.g., OPM 662), programming in Python and docplex

Basic Paper: Stolletz and Brunner (2012)

> **Abstract**: This research addresses a shift scheduling problem in which physicians are assigned to demand periods. We develop a reduced set covering approach that requires shift templates to be generated for a single day and compare it to an implicit modeling technique where shift-building rules are implemented as constraints. Both techniques allow full flexibility in terms of different shift starting times and lengths as well as break placements. The objective is to minimize the paid out hours under the restrictions given by the labor agreement. Furthermore, we integrate physician preferences and fairness aspects into the scheduling model. Computational results show the efficiency of the reduced set covering formulation in comparison to the implicit modeling approach.

P7 – Design of Rail Car Fleets

Type: Individual topic

Objectives: In 2023 (source: Statistisches Bundesamt) almost 20 % of total freight transportation, i.e., 134 billion tonne-kilometres, were transported via rail. For this thousands of rail cars (wagons) are used to transport freight. Thereby, different cars are required for different goods. E.g., Open wagons transport logs, iron, barrels, etc. Bulk materials like coal, sand, are transported by bulk freight wagons (even there one can distinguish between different categories, e.g., covered ones or open ones). Other car types are car carrier wagons, flat wagons for containers, or tank wagons for chemicals, etc. Thereby, for a given order, different rail car types could be feasible means of transport, i.e., there is substitution between rail wagon types. Rail companies have to decide which types and how many units of which type of wagons to use, in order to fulfill customer demand. The total number of wagons drives investment costs, but also provides flexibility. A reduced number of wagon types reduces the maintenance and handling workload of rail companies, as economies of scale can be used, and storing of wagons, which is a time-consuming activity, becomes easier. When deciding on the number of wagons to operate, it is important to consider that exact customer demand is not known for each period of the planning horizon. E.g., situations could appear where customer demand is larger than the number of wagons currently not serving other customer orders. This shortfall of wagons negatively impacts revenues and customer satisfaction, which decision makers have to trade-off against investment and handling costs.

In this thesis, the mixed-integer linear programming model (MILP) proposed by Klosterhalfen et al. (2014) should be described and briefly positioned within the existing body of literature. Furthermore, the model should be implemented using an optimization tool such as DoCplex, GAMS, or AMPL. Exemplary data, based on the information given by the base paper, should be generated. The student should provide insights into how the shortfall distribution affects the structure of the optimal rail car fleet design decisions. A critical assessment of the model and suggestions for future research concludes the thesis.

Prerequisites: Knowledge in optimization models (e.g., OPM 662), programming in Python and docplex

Basic Papers: Klosterhalfen et al. (2014)

> **Abstract**: We develop a model to determine the optimal structure and size of a railcar fleet at a chemical company under uncertainty in demand and travel times as well as substitution between railcar types. First, we formulate an MILP model that accounts for the substitution relations between the types and minimizes the total direct railcar cost under given railcar availability constraints and a predefined maximum number of types. Second, based on the fleet structure obtained by the MILP model, the fleet size is computed by using an approximation from inventory theory that considers the existing uncertainties. Compared to the current approach of the railcar fleet management team, the model produces a reduction in safety stock of 120 railcars and thus direct cost savings of 8 % as well as further indirect cost savings due to a smaller number of railcar types, which reduces the switching effort of the railcars on the storage tracks.

References

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