innovation of this work lies in considering the co-creation of app quality by the app developer and the distribution platform while using a revenue-sharing contract, which is popular in the mobile app industry. We investigate both tactical equilibrium (the parties' operational decisions for a given market structure) and strategic equilibrium (for the developer — whether or not to bypass; for the platform — whether or not to discourage bypassing by improving the contract terms). Our research provides answers to the following strategic questions: Is it beneficial for the app developer to bypass the distribution platform and offer the app to users directly in a competitive environment? Is it beneficial for the distribution platform to introduce a private label to compete with the app developer? Can bypassing also be beneficial for the platform and/or the rival developer? In response to these questions, several counter-intuitive results are revealed.

2 - Co-creation of mobile app quality in a bi-platform supply chain
Priel Levy, *Tatyana Chernonog*

Mobile apps development is a fast growing industry nowadays, with Google Play and App Store being the two largest distribution platforms, providing app developers a global coverage of audience. While each platform has its own captive app users, developers have the freedom to distribute their app via either one single platform or both of them. In the latter case, developers should create two versions of the app, differing in their conformance quality (dictated by the platform) but coinciding their design quality (defined by the developer). The innovation of this work lies in considering the co-creation of app quality by the platform and the developer using a revenue-sharing contract, which is popular in the mobile app industry. We analyze a supply chain of mobile apps, where a strategic developer chooses how to distribute his app—via both platforms or via one of them, so each platform might lose the contract and has a priori to strategize accordingly. Equilibrium analysis is given for two market power structures: horizontal power balance (both platforms simultaneously offer their contract) and horizontal power imbalance (the platform-leader has the right to offer the contract terms first). Several counterintuitive properties of the equilibrium are obtained, in particular regarding the first-move advantage, the mutual effect of the platforms market conditions on the app quality and the conditions under which the developer prefers to distribute his app via a single platform.

3 - New product development with technology uncertainty and the effect of upstream supplier competition
Minxin Wu

This study investigates the problem of new product development with technology uncertainty in a supply chain comprising two competing suppliers and a single manufacturer. In this supply chain, the manufacturer playing the role of stackelberg leader determines the design quality of the product. The two suppliers are in charge of developing the product the manufacturer need and determine the conformance quality to design specification. Using the principal-agent model and taking R&D uncertainty into account, we propose an analytical framework that investigates the effect of upstream competition in new product development. Rich managerial insights into supply chain innovation are provided by analyzing the equilibrium behaviors of decision variables (design quality, the suppliers conformance quality) with respect to three aspects: market and market share, customer preference and cost.

4 - Design of distribution systems in grocery retailing
Tobias Potoczki, *Andreas Holzapfel*, *Heinrich Kuhn*

We examine a retail distribution network design problem that considers the strategic decision of determining the number of distribution centers (DC) as well as their type (e.g. central, regional, local) and anticipates the tactical decision of allocating products to different types of DC. The resulting distribution structure is typical for grocery retailers that choose to operate several types of DC storing a distinct set of products each. We propose a novel model considering the decision-relevant costs along the retail supply chain and present a case study of a major European retailer.

■ HD-03

Thursday, 14:00-15:40 - Room 3

Logistics, Transportation and Traffic 2

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: *Ying Lian*

1 - Aggregate probabilistic modelling framework to evaluate business resiliency in transport sector
Aristi Karagkouni, *Dimitrios Dimitriou*

The ability to absorb and adapt in a changing environment of both incremental changes and sudden disruptions is widely mentioned as business resiliency, which is the cornerstone of dynamic risk management. Hence, the quantification of business risks is an essential counterpart of the decision process, especially, for capital intensive investments in transportation where financing long-term payback period may rise high provisions in the business plans. This paper objective deals with the development of a business resiliency evaluation framework for the transportation sector. The modelling approach is based on discrete modelling, where the aggregate value of resiliency is driven by three state variables determined as continues functions over time. The continues in time state functions adjust the outputs in terms of the demand variations probabilities; the supply chain services conditional probabilities (including contingency) to adapt changes and mitigate risks; and the impact severity dealing with the socioeconomic effects. The assessment framework provides results regarding the impact in terms of cost and business contingency for unpredict events (e.g. climate change) and times over high uncertainty (e.g. COVID-19 pandemic period). The numerical application will illustrate essential messages to planners, managers and decision makers in transportation sector business ecosystem, providing results for economies with high seasonal travel demand such as the south Europe region.

2 - Stochastic modelling for assessing business attractiveness in the shipping sector.
Dimitrios Dimitriou, *Georgios Sklias*

Shipping business environment is maybe the most deregulated in transportation sector, where business performance impacts the commodity prices and business attractiveness related to stock market prices.For the shipping companies, the volatile business environment and the capital-intensity nature of the industry can create liquidity and cash flow problems, especially, in times of unpredicted market changes.The purpose of this paper is to present a dynamic performance evaluation tool based on stochastic modelling approach that can enhance decision making capabilities.Performance assessment modelling framework based on Markov Chains formulation,where the key input states will include the variation of three categories of impact:(a)price of commodities,including crude oil,coal,and LNG;(b)economic development indicators such as GDP, purchasing power and socioeconomic indicators; and(c)shipping industry conditional performance issues, such as existing and orderbook fleets.The performance objective function will provide aggregate results for each shipping category, by extrapolating results over time in three dimensions:revenues and profit maximization, opportunity cost minimization and fleet usage optimization. The numerical example will highlight key results for shipping industry performance due pandemic Covid-19 time window.Conventional wisdom is to provide an easy-to-handle business intelligence tool to support decision making in the frame of risk management and funding allocation.

3 - The multi-port berth allocation problem with speed optimization: Exact methods and a cooperative game analysis
Bernardo Martin-Iradi, *Dario Pacino*, *Stefan Ropke*

In this study, we focus on a variant of the Berth Allocation Problem (BAP), which aims at assigning berthing times and positions to vessels in container terminals. The problem, known as the multi-port berth allocation problem (MPBAP) extends the BAP to cover multiple ports where vessel traveling speeds are optimized between ports, thus exploiting the potentials of a collaboration between carriers and terminal operators. Exploiting a graph representation of the problem, we reformulate an existing mixed-integer problem formulation into a generalized set partitioning problem where each variable refers to a sequence of feasible berths in the ports visited by the vessel. Integrating column generation and cut separation in a branch-and-cut-and-price procedure, the method is able to outperform commercial solvers in a set of benchmark instances and adapts better to larger instances. In addition, we apply methods of cooperative game theory for distributing efficiently the savings of a potential collaboration and show that both carriers and terminal operators would benefit from such collaboration.

4 - Static on-demand bus routing problem with consideration of potential requests
Ying Lian, Kenneth Sörensen

The On-Demand Bus Routing Problem (ODBRP) is defined as large-scale dial-a-ride problem with bus stop selection, where the route is completely determined by the passengers, and each passenger may have alternative stops to get on/off. The static case assumes requests are known before routing and scheduling. In this case, as the objective is to maximize the total number of served passengers, there is a possibility to lose the potential passengers that can be easily integrated into the solution. One way to make this model more realistic is, we also take into consideration potential requests along or nearby the bus routes, when routing and scheduling according to the current requests list, while the known requests have priority. The potential requests are expressed by time-variant probability. Thus the objective function also includes the expected value of incoming passengers that will be served upon arriving those stops. The problem is solved by large neighborhood search. Experimental results with artificial data show the effectiveness of this proactive method.

■ HD-04

Thursday, 14:00-15:40 - Room 4

Stochastic modeling and simulation in engineering, management and science

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: Felix Grumbach

1 - A Quantum Algorithm for optimising venture capital portfolios
Sanjeev Naguleswaran

A typical Venture Capital investment strategy relies on picking at least one company that will provide a return high enough to offset losses even if all other companies in the portfolio fail to provide returns. Therefore, the optimal portfolio requires identifying companies with a high probability of achieving large returns. We propose that by simulating the startup eco-system as a Brownian motion model with data driven drift and diffusion parameters, we can provide more rigour and insight in this challenging decision-making scenario. The company attributes corresponding to explanatory variables, such as Industry sector, Product-Market Fit, Founding Team etc. can be used to determine the drift and diffusion parameters. Time varying coefficients are used in the model to accommodate change in the magnitude of drift and diffusion through the evolution of a company. The level of diffusion would correspond to startup energy (or returns) and a successful winning investment such as an exit would be represented and predicted by the crossing of a pre-defined energy level. These levels are determined by analysing previous data and back-testing through simulation. Given that the model is based on a well understood physical system that has quantum effects, we will also show that this method is amenable to using more computationally competitive quantum algorithms that have the potential to solve larger scale and currently intractable scenarios.

2 - Digital twin optimises container terminal handling
Holger Schuett, Hoon Lee

Container terminals are under pressure forced by all stakeholders to serve bigger and bigger vessels with more cargo per arrival in shorter times. Digitisation and automation are providing some opportunities to optimise the handling processes, but still the strategies built in the terminal operating system (TOS) are the kernel for high efficiency. The paper will present a solution, which is based on a simulation model directly connected to a TOS. The current state of all processes, the equipment and the container inventory within the model is updated in real time. Using this digital twin to forecast the future operation based on the planned strategies allows the combined system (TOS + digital twin) to detect bottlenecks before they occur. In this way warnings about potential delays in vessel departures may be shown to the planner and he or (in the future) AI-based algorithms may (automatically) optimise the strategies to avoid them. The approach has been funded in several Korean-German research projects between research organisations (universities from Busan and Bremen) and industrial partners of both countries.

3 - Problem-oriented initialization of discrete simulation models for a socio-technical shopfloor scheduling
Felix Grumbach, Pascal Reusch

Job Shop Scheduling Problems (JSP) are becoming more extensive to depict real planning situations. A current research trend is, to interlink the physical shopfloor with a digital twin for more realistic analytics. It can be assumed, that simulation-based optimization will gain importance in context of predictive and reactive scheduling. It is fueled by the fact, that AI research has achieved great success in recent years. E.g., reinforcement learning agents (RLA) can explore environments in a self-learning manner. However, it is a complex matter to develop precise simulation models. A key challenge is to reduce the real-world situations to its essential components. Our research is focussed on dual resource JSP in manufacturing. Based on current literature and case studies, we mapped identified parameters and dependencies into a object model (OM). First, the OM represents a live interface to the shopfloor (enables reactive scheduling). Second, the OM is used to generate a simulation environment automatically. Third, the OM can be used for forecastings (enables predictive scheduling). We have found that it is effective to integrate even complex scenarios in this way. We have developed a generic, expandable and adaptable framework for a problem-oriented simulation, which can be initialized with live data. In detail we describe the OM, a generic simulation routine and a constraint module. Followed by an outlook on how RLA can be implemented on identified decision nodes.

■ HD-05

Thursday, 14:00-15:40 - Room 5

Individual behavior and implications to operations management

Stream: Behavioral OR
Invited session
Chair: Yang Zhang

1 - Product Variety and Quality Perception for Innovative Products
Haoyu Liu