

Preface

Game Theoretic Analysis of Congestion, Safety and Security is an interdisciplinary undertaking. Many researchers working on congestion have not extensively considered safety/security, and vice versa. However, significant interactions exist between the two research areas, which motivated this book. This book is intended to establish a new and enhanced current state of affairs within this topic, illustrate linkages between research approaches, and lay the foundation for subsequent research. Congestion (excessive crowding) is defined broadly to include all kinds of flows; e.g., road/sea/air traffic, people, data, information, water, electricity, and organisms. The book considers systems where congestion occurs, systems which may be in parallel, series, interlinked, or interdependent, with flows one way or both ways. Congestion models exist in abundance. The book makes ground by introducing game theory and safety/security. For the analysis to be game theoretic, at least two players must be present. For example, in [1] one approver and a population of normal and adversary travelers are considered. Similarly, in [2], one defender and one attacker are considered, in addition to drivers who choose the more time-efficient of two arcs of different lengths. Multiple players can be adversaries with different concerns regarding system reliability; e.g., one or several terrorists, a government, various local or regional government agencies, companies, or others with stakes for or against system reliability. Governments, companies, and authorities may have tools to handle congestion, as well as ensure safety/security against various threats. The players may have a variety of individual concerns which may or may not be consistent with system safety or security. Much of the congestion literature is not game-theoretic, and does not extensively consider safety or security. Also, most game-theoretic analyses do not account for congestion. The book consists of eight chapters.

In “[Congestion Management in Motorways and Urban Networks Through a Bargaining-Game-Based Coordination Mechanism](#),” Felipe Valencia, José D. López, Alfredo Núñez, Christian Portilla, Luis G. Cortes, Jairo Espinosa and Bart De Schutter acknowledge that road traffic networks are large-scale systems that demand distributed control strategies. Local traffic controllers for each subnetwork play a cooperative game where they communicate with each other. Their strategies

are the control sequences, their payoffs are the local performance indices such as avoiding congestion, thus balancing local against global performance.

In “[Advanced Information Feedback Coupled with an Evolutionary Game in Intelligent Transportation Systems](#),” Chuanfei Dong, Yuxi Chen, Xu Ma and Bokui Chen study a mean velocity difference feedback strategy and a congestion coefficient difference feedback strategy for intelligent transportation systems. The two strategies are based on the time-varying trend in feedback information, which could lead to higher route flux with better stability. The authors also investigate information feedback coupled with an evolutionary game in a 1-2-1-lane intelligent transportation system with dynamic periodic boundary conditions.

In “[Solving a Dynamic User-Optimal Route Guidance Problem Based on Joint Strategy Fictitious Play](#),” Tai-Yu Ma develops a multi-player repeated game to model users’ compliances to route recommendations by a system administrator. Users use their experience to estimate travel time through different routes. Users can be informed or non-informed, engage in joint strategy fictitious play, and adapt their route choices progressively to reach their destinations.

In “[A Psycho-Social Agent-Based Model of Driver Behavior Dynamics](#),” Theodore Tsekeris and Ioannis Katerelos present a psycho-social agent-based model of interaction between drivers, accounting for heterogeneity and dynamic adjustment responses. Cognitive processes, risk assessment, time responsiveness of driving behavior, control dimensions of neighboring drivers, and the topology of interaction cause states such as fixed point, periodicity, and transient chaos.

In “[Game-Theoretic Context and Interpretation of Kerner’s Three-Phase Traffic Theory](#),” Kjell Hausken and Hubert Rehborn interpret Kerner’s three-phase traffic theory game theoretically applying the chicken game. The three phases, claimed to be incommensurable with classical two-phase theory, are free flow and two congested phases, which are synchronized flow and wide moving jam. They show how the number of chickens changes through the hysteresis loop in a density versus flow rate diagram.

In “[A Heuristic Method for Identifying Near-Optimal Defending Strategies for a Road Network Subject to Traffic Congestion](#),” Mengyao Gao, Bo Zhang, Vicki M. Bier and Tao Yao analyze how road networks are vulnerable to interdictions. An attacker interdicts links to maximize congestion. A heuristic method is developed to determine how the defender protects the road network to minimize congestion assuming that selfish drivers choose routes to minimize individual travel cost.

In “[Multiple Stakeholders in Road Pricing: A Game Theoretic Approach](#),” Anthony E. Ohazulike, Georg Still, Walter Kern and Eric C. van Berkum consider a game-theoretic approach as an alternative to the standard multi-objective optimization models for road pricing. A non-cooperative game is modeled to study road pricing strategies considering various and potentially conflicting externalities in traffic such as congestion, air pollution, and noise. The game is sequential where the leaders determine link tolls in the first stage and the road users choose routes in the second stage. A “first-best taxation” schedule is proposed to deal with the scenario that a Nash equilibrium may not exist.

In “[Stackelberg and Inverse Stackelberg Road Pricing Games: State of the Art and Future Research](#),” Kateřina Staňková and Alexander Boudewijn consider a game-theoretical toll design problem for improving the performance of road traffic systems. The road authority is modeled as the first mover to decide the toll; and the drivers are modeled as the second mover to respond to the toll by adapting driving behavior and thus impacting traffic flows. Depending on the toll structure, the authors discuss two problem formulations: a Stackelberg game where toll is uniform or time-varying; and an inverse Stackelberg game where toll is traffic-flow dependent.

References

1. Bier V, Hausken K (2013) Defending and attacking networks subject to traffic congestion. *Reliab Eng Syst Safe* 112:214–224
2. Wang X, Zhuang J (2011) Balancing congestion and security in the presence of strategic applicants with private information. *Eur J Oper Res* 212(1):100–111

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