Spring Semester, 2021-2022

Course Code	**CIVL4100K**
Course Title	**Multi-agent Decision-Making in Smart Cities**
Class Time & Venue	Two 1.5-hour lectures per week TBD
Instructor	Sen Li (cesli@ust.hk)
Course Credits	3
Class Quota	50
Prerequisites	None
Course Description	This course will focus on multi-agent decision making problems in Civil Engineering. We will formulate and analyze the interactions among multiple strategic decision makers using mathematical tools from optimization and game theory. In the context of Smart Cities, we will primarily focus on decision makers in modern power and transport systems, such as energy consumers (buildings, electric vehicles), energy producers, mobility-on-demand customers, etc. Through lectures, assignments and reading, students will learn state-of-the-art models and tools to identify, formulate, and address emerging challenges in the smart city development.
Course Objectives	At the end of this course, students will be able to: 1. Analyze the interactions among strategic decision makers based on mathematical models; 2. Formulate multi-agent decision making problems in power systems; 3. Formulate multi-agent decision making problems in intelligent transportation systems; 4. Recognize the importance and challenge in developing sustainable smart city and familiarize with tools relevant to smart city development.
Topics	➢ Introduction to distributed optimization and game theory ➢ Multi-agent decision making for modern power systems ➢ Game-theoretic model in electricity markets ➢ Multi-agent decision making for intelligent transport systems ➢ Game-theoretic model for emerging mobility services
Intended Learning Outcomes (ILOs) of this course	On successful completion of this course, students are expected to be able to: 1. Formulate and solve electricity market problems based on game-theoretic models and equilibrium analysis. 2. Formulate and solve multi-agent decision making problems in mobility-on-demand service based on game-theoretic models and optimization tools 3. Identify the potential for improvement in transport and energy systems and design strategies to realize the potential.

	4. Appreciate a broad impact of civil engineering on smart city development and environmental sustainability.
Relationship to the program objectives	**PEO1:** Provide students with professional skills in the design, construction and management of the civil infrastructure, as well as an awareness of environmental sustainability. This course provides students with professional skills to address decision making problems related to the management of civil infrastructure, including the power systems, transport systems, and the nexus between these two. (ILO#1, 2, 3) **PEO2:** Train students with good communication skills so they can work effectively in large projects involving different parties and professions. The course requires students to actively discuss research problems with their classmates in groups to effectively communicate with others from distinct background. (ILO#1, 2) **PEO3:** Challenge students with research-type and open-ended design problems to stimulate self-learning and innovative problem solving skills. The course requires students to work on open-ended problem in order to formulate game-theoretic models and conduct equilibrium analysis for smart grid optimization or intelligent transportation system optimization. (ILO#1, 2) **PEO4:** Expose students to real world engineering projects as well as cutting edge research to improve their understanding of the profession and technological advancements that can improve current practice. The course will introduce challenging issues related to smart city development and cover technological advances that address these issues. (ILO#3, 4)
Relationship to program outcomes	**PO1:** Acquire fundamental knowledge in mathematics and science on which civil and environmental engineering research and practice are based. Students will apply tools and knowledge from mathematics and science to solving engineering problems related to smart city development in this course. (ILO #1, 2) **PO2:** Understand fundamental principles of engineering science relevant to civil engineering disciplines. Students will learn fundamental engineering principles in the area of power systems and transportation systems in the civil disciplines. (ILO #1, 2, 3) **PO5:** Develop an ability to identify and formulate civil and environmental engineering problems, and propose feasible solutions with an appreciation of

	their underlying assumptions, uncertainties, constraints, and technical limitations. Students have to identify and formulate multi-agent decision making problems in smart city development and propose feasible solutions based on game-theoretic model and equilibrium analysis. (ILO #1, 2, 3) **PO6:** Develop technical competency to design civil engineering components and systems, with an understanding of the principles behind the design methodologies. Students will be required to design strategies to improve the system performance of transport and energy systems based on optimization principles. (ILO #3) **PO7:** Develop an appreciation of the breadth of civil and environmental engineering, and acquire basic knowledge in several disciplines to enable effective performance within a multidisciplinary work environment. This course covers a wide range of subjects in the smart city development including applications in both power systems and transportation systems. The course also requires the students to integrate distinct systems to harvest the synergistic value through multidisciplinary study. (ILO #3, 4) PO11: Obtain in-depth knowledge in at least one major area of specialization within civil engineering. The course discusses cutting-edge technology in emerging intelligent transportation systems, and requires students to acquire in-depth knowledge in this area of specialization. (ILO #2)
Textbook / Reference material	Joao P. Hespanha. *Noncooperative Game Theory*. Princeton University Press, 2018, 2017.
Assessment of outcomes	This course contributes to the assessment of program outcomes as follows: 1. Homework assignments (40%) with real world examples on multi-agent decision making problems of modern transport and energy systems to assess students' capability to design and analyze smart urban infrastructures. [PO 1,2,5,6,7] 2. Final exam (50%) allows for assessment of students' ability to apply learned knowledge to address real-world smart city design problems. [PO 5,6,11, 12] 3. Participation (10%) allows for assessment of students' motivation to study, the ability to effectively express opinions, and the sense of professional responsibilities. [PO 11, 12]
Date	20 Dec 2021

Tentative Class Schedule

(Note: The actual topics covered in each lecture may vary depending on the class pace.)

Week	Lecture Topic
1	Introduction to multi-agent decision making in Smart Cities
2	Fundamentals of game theory
3	zero-sum games
4	non-zero sum games
5	Existence and computation of equilibrium
6	Auctions and Mechanism design
7	Overview of smart grid
8	Renewable integration and electricity storage
9	Storage investment game
10	Overview of intelligent transportation systems
11	Routing under information constraints
12	Information design for navigation apps
13	Course overview and homework discussion