Graph Theory and Operational Research

1. **Course number and name:** 020TROES2 Graph Theory and Operational Research

2. **Credits and contact hours:** 4 credits, 2x1:15 course hours

3. **Name(s) of instructor(s) or course coordinator(s):** Marc Ibrahim

4. **Instructional materials:** Course handout; Powerpoint slides; exercise sheets

5. **Specific course information**
   a. **Catalog description**:
      This course introduces graph theory and operational research as engineering tools for modeling, optimization, and decision making. It covers the basics of graph theory; mathematical and numerical graph representation; connectivity; paths and cycles; graph search algorithms; algorithmic complexity; well-known problems in graph theory: minimum cost spanning tree, shortest path, and max-flow min-cut problems, matching, coloring, etc.; solving engineering and real-world problems using graphs; manipulating graphs using Networkx Python library; Markov chains and applications; complex networks analysis; optimization and linear programming; numerical tools for solving optimization problems.

   b. **Prerequisites**: None

   c. **Required** for CCE students; **Selected Elective** for EE students

6. **Educational objectives for the course**
   a. **Specific Outcomes of Instruction:**
      - Understand the basics of graph theory and the well-known operational research problems that can be modeled and solved using graphs (e.g. shortest path, max-flow, minimum cost spanning tree, coloring).
      - Model and solve engineering and real-world problems using graph tools.
      - Apply Markov chains to solve stochastic problems.
      - Use linear programming to model and solve decision and optimization problem.
      - Use numerical tools to solve graph and operational research problems.

   b. **PIs addressed by the course:**

PI	1.1	1.2	1.3	6.4
Covered	x	x	x	x
Assessed	x	x	x	x

7. Brief list of topics to be covered

- Global introduction to graph theory and operational research (1 lecture)
- Basics of graphs: definitions, classifications, and representation (1 lecture)
- Connectivity in graphs: paths, cycles, diameter, connected components, cuts, etc (1 lecture)
- Adjacency matrix algebra and transitive closure (1 lecture)
- Pseudocode for algorithms and algorithmic complexity and introduction to pseudocode (2 lectures)
- Search algorithms: breadth first and depth first using queues and recursive function Application of search algorithms to solve graph problems (2 lectures)
- Trees: basic theorems, minimum cost spanning tree problem, Kruskal and Prim algorithms Applications (2 lectures)
- Shortest path problem: Bellman-Ford and Dijkstra algorithms Generalized Dijkstra algorithm Applications (2 lectures)
- Max-flow min-cut problem and applications (1 lecture)
- Other graph problems such as matching, coloring, and clustering (1 lecture)
- Networkx library: manipulate graphs in Python Implement pseudocodes Analyze large networks (2 lectures)
- Introduction to Markov chains: transition matrix, states classification, marginal distribution, stationary probabilities (2 lectures)
- Solve and simulate Markov chains using Matlab (1 lecture)
- Application of Markov chains to real-world problems (2 lecture)
- Linear programming: definition, graphical solution in the case of two decision variables, overview of the simplex method (1 lecture)
- Modeling real-world problems using linear programming and solving them using a numerical tool (2 lectures)