Graph Theory and Operational Research

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

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

3. **Instructor's or course coordinator's name:** Marc Ibrahim

4. **Text book:**
   a. **Other supplemental materials:**
   Professor textbook and 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:

   c. **Required:** Required for CCE students

6. **Specific goals for the course**
   a. Specific outcomes of instruction
   - Understand the basics of the 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. KPI addressed by the course:

KPI	a1	a2	e2	e3	k1	k3	
Covered	x	x	x	x	x	x	
Assessed	x	x		x	x	x	
Give Feedback	x	x					

7. **Topics and approximate lecture hours:**

- 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 (2 lectures)
- Other graph problems such as matching, coloring, and clustering (2 lectures)
- Networkx library: manipulate graphs in Python. Implement pseudocodes. Analyze large networks. (3 lectures including an evaluation session)
- 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 lectures)
- Linear programming: definition, graphical solution in the case of two decision variables, overview of the simplex method (2 lectures)
- Modeling real-world problems using linear programming and solving them using a numerical tool such as Excel or Matlab (2 lectures)