University of Patras, Department of Mathematics
Postgraduate Program
«Computational Data Science and Statistical Analytics (MCDA)»

Academic year: 2018 -2019
Course: **Data-driven Probabilistic Models in Decision Making Process**
Term: B
Instructors: Ioannis Dimitriou (Lecturer), B/M 232, e-mail: idimit@math.upatras.gr
Frosso S. Makri (Assoc. Professor), B/M 233, e-mail: makri@math.upatras.gr

Brief description and goals
The goal of this course is to present and apply a set of mathematical techniques to be used for the design, performance and reliability of systems operating under probabilistic rules. For the optimal design of these systems, it is first necessary to identify their structural elements, such as arrival and service processes, by using data-based methods. On the other hand, their optimal performance is closely relying by their reliability, i.e., the probability that the system will perform its intended function during a specified time period under stated conditions. In such a scenario, we aim to study and estimate the reliability of components and systems using lifetime and other data. The course consists of two parts. In the first part, we present data-based techniques to optimize the performance of service systems, while in Part B, we focus on probabilistic models and methods for the study of failure data in the reliability of engineering systems. In the following, we present the detailed course schedule.

PARTA: Service Engineering
Service sector is central in the life of post-industrial societies - more than 70% of the Gross National Product in most developed countries is due to this sector. Important examples are healthcare systems (hospitals), financial services (banks) and telephone and internet services. In concert with this state of affairs, there exists a growing demand for high-quality multi-disciplinary research in the field of services, as well as for a significant number of *Service Engineers*, namely scientifically-educated specialists that are capable of designing service systems, as well as solving multi-faceted problems that arise in their practice. The course will provide a framework for modeling service systems and techniques that are used to design, analyze, and operate service systems. Our teaching approach is data oriented: examples from various service sectors are presented at lectures and homework assignments, with the call center industry being the central application area. In this course, a service system is viewed as a stochastic network. Thus, the main theoretical framework is queuing theory, which primarily involves a large class of stochastic models. However, the subject matter is highly multi-disciplinary; hence alternative frameworks are useful as well, including ones from Statistics, Psychology, and Marketing.

PART B: Engineering Reliability
The mathematical theory of reliability has grown out of the continually increasing demands of technology. Reliability is the probability of a system performing its purpose adequately for a period of time intended under operating conditions encountered. The teaching of this part of the course concentrates on coherent system reliability, failure data analysis and maintenance policies. It will be developed the use of probability theory for the study of reliability and life time of the systems, via appropriate probabilistic models and statistical methods for studying reliability data.

Prerequisites: Probability theory and a course on stochastic modeling/processes.

Course Schedule of PART A		
Week	***Lecture Subject***	***Details***
1	Introduction to Service Engineering, Flow Basics and Little's Law	Service Engineering of a Call Center, Service Engineering of an Emergency Department, Data-Based Service Engineering (Science, Management) in Call Centers, Hospitals…. Inflow,

		Outflow (rates), Capacity, Utilization (Occupancy), Offered Load, Resources: Servers, Highway, Examples and Applications The customer/server/manager paradigm, Scenarios: finite horizon, periodic, steady state, Queueing/Inventory buildup diagrams
2	Measurements - The First Prerequisite	The importance of measurements: Analysis and control, connection to firm's goal. Methods of obtaining data: Face-to-face, automated systems (call centers).Transaction-based (Event-based) measurement: Bank Tellers, Telephone, Internet, Transportation, Administrative. Summary statistics and simple tools: changes over time, resolution, Pareto charts, Histograms, Fishbone diagrams, Scatterplots, Some subtleties in Measurements: Patience; What is Service-Time (Duration)? Queues in Hospitals: Empirical Study, Call Center Measurements, Data Models and Data Analysis
3	Models-The 2nd prerequisite; Project (Processing) Networks; Empirical (data-based) models, Dynamic-Stochastic PERT/CPM	Processing Networks and DS PERT/CPM, The Processing Network Paradigm (BPR), Building Blocks: customers (jobs), activities, resources, processes (routes); Conceptual Descriptions: Activity Diagram, Resource Diagram, Combined (Activity + Resource) Diagram, Project Management: dynamic stochastic (process) view. Why (operational) queues? A systematic answer via Dynamic Stochastic PERT/CPM, Defining Capacity of a service station.
4	Fluid model of a service station	The Fluid View, Flow Models of Service Networks, A Deterministic Model of a Service Station
5	Scaling and Dynamic Randomness; Poisson Processes, Service times, modelling (im)patience	Empirical Introduction, The Poisson Process: Definitions, Properties, PASTA = Poisson Arrivals See Time Averages, Biased Sampling, Intuitive construction: from Bernoulli to Poisson, or The Law of Rare Events, Non-homogeneous Poisson process, Testing: Poisson or not Poisson, Beyond Poisson: Internet applications. Forecasting of the arrival rate, Calculating the Offered Load, Phase Type Distributions, abandonments.
6	Markovian queues	Markov Jump Processes, Markovian networks
7	The Palm/Erlang-A Queue, Non-parametric queues G/G/m with/without abandonments	The Palm/Erlang-A Queue, with Applications to Call Centers, The M/M/n+G Queue: Summary of Performance Measures, Designing a Call Center with Impatient Customers, Non-Parametric Models of a Service System; GI/GI/1, GI/GI/n.
8	Operational Regimes and Staffing,Quality and Efficiency Driven (QED) Queues; application to staffing, Time varying – Erlang-R	Erlang-B/C: Some Proofs, Facts and Analysis, Markovian Many-Server Queues: Excursions, Asymptotics, Time-Varying Loads, Workforce Management, Erlang B/C/A in the QED Regime, Time-Varying Queues.
9	Skills-Based Routing and its Operational Complexities. • Design, Staffing, Control; • A Multidisciplinary Challenge; • Operational Complexities.	Time-Varying Queues and Skills-Based Routing (SBR). Agent Scheduling, Customer Routing and Workforce Staffing. E-Driven SBR: Index strategies. QED SBR: Special Cases. Dimensioning a call center

Evaluation of Part A:

1. Homeworks **(30%):** Home assignments will be theoretical, empirical and practical. Empirical analysis will involve real data from a call center that serves one of the Israeli banks (http://ie.technion.ac.il/serveng2013S/callcenterdata/index.html). Further data resources are from the Technion SEE Center (SEE = Service Enterprise Engineering). Practical analysis will be based on two tools: SEEStat and 4CallCenters. The first tool, developed at the SEECenter, provides an online graphic-

based interface with transactional data (call centers, hospitals); the second tool supports workforce management (staffing).
2. Research paper presentations **(20%)**
3. Final examination test **(50%)**

	Course Schedule of PART B
Week	***Lecture Subject***
10	Failure data analysis. Finite population models. Lifetime data analysis. The economics of inspection and maintenance.
11	System reliability. General methods for system reliability evaluation. Fundamental system and network reliability models. Reliability of coherent systems. Bounds on System reliability.
12	Importance measures of system components. System availability and maintainability. System signature. Signature-based analysis of reliability characteristics.
13	Data-driven reliability estimation.

Evaluation of Part B:
1. Research paper presentations **(20%)**
2. Final examination test **(80%)**
3. During teaching, solution of exercises will be required

Final Course Evaluation: Ax65%+Bx35%

Textbooks-related material to Part A:

1. J. Fitzsimmons, M. Fitzsimmons, Service Management: Operations, Strategy, Information Technology, 4thEdition, McGraw Hill, 2004.
2. R. W. Hall, Queueing Methods: For Services and Manufacturing, Prentice Hall, Englewood Cliffs, NJ, 1991.
3. N. Gans, G. Koole and A. Mandelbaum, Telephone Call Centers: Tutorial, Review and Research Prospects. Manufacturing and Service Operations Management (M&SOM), 5 (2), 79-141, 2003.
4. L. Brown, N. Gans, A. Mandelbaum, A. Sakov, S. Zeltyn, L. Zhao, and S. Haipeng, Statistical Analysis of a Telephone Call Center: A Queueing-Science Perspective. JASA, 2005.
5. G. F. Newell, Applications of Queueing Theory, 2ndedition, Chapman and Hall, 1982.
6. W. Whitt. Stochastic-Process Limits. Springer, New York, 2002.
7. W. Whitt, Time-varying queues. Queueing Models and Service Management, forthcoming, 2017.
8. W. Whitt, X. Zhang, A data-driven model of an emergency department, Operations Research for Health Care 12, 1–15, 2017

Textbooks-related material to Part B:

1. R. Barlow, Engineering Reliability. SIAM, 1998.
2. R. Barlow, F. Proschan, Statistical Theory of Reliability and Life Testing. To Begin With; Reprint edition, 1981.
3. R. Barlow, F. Proschan, Mathematical Theory of Reliability. SIAM, 1996.
4. W. Kuo, M.Zuo, Optimal Reliability Modeling. John Wiley & Sons 2003.
5. W.Q. Meeker, L.A. Escobar, Statistical Methods for Reliability Data. John Wiley & Sons, 2014.
6. F.J. Samaniego, System Signatures and Their Applications in Engineering Reliability. Springer, 2007.