List of OCR outputs

Research papers

1. **Services Research in Hospitals, or The Multi-Disciplinary Science of Patients Care**
   Paper for JSR (Journal of Service Research)
   Abstract:
   Hospitals are among the most complex service systems, providing service that must adhere to three often conflicting dimensions: Clinical, i.e. providing the best possible medical care, Operational – e.g. matching personnel staffing levels with demand, and Financial – i.e. controlling the cost of care. To improve care processes in this complex environment, a partnership has been formed, between an academic institution, a large enterprise, and a government owned hospital. Within the scope of this partnership, a rigorous improvement approach has been defined, at the basis of which lie a scientific methodology, and utilization and fusion of established disciplines such as Operations Research, Human Factors Engineering and Information Systems Management. This article describes the project, the improvement approach and its impact. The impact is far reaching in that it can potentially revolutionize the management of patient care processes. Moreover, this project continuously produces significant research that is relevant to Service Science in general.

2. **Toward Simulation – Based Real-Time Decision Support Systems For Emergency Departments**
   Paper for WSC 2009 conference
   Authors: Marmor Y., Shtub A., Mandelbaum A., Vasserkrug S., Zeltyn S., Carmeli B., Greenshpan O., Masika Y.
   Abstract:
   Emergency Departments (EDs) require advanced support systems for monitoring and controlling their processes: clinical, operational, and financial. A prerequisite from such a system is comprehensive operational information (e.g. queueing times, busy resources,...), reliably portraying and predicting ED status as it evolves in time. To this end, simulation comes to the rescue, through a two-step procedure that is here proposed for supporting real-time ED control. The first step assists an ED manager to infer the ED’s current state, based on historical data and simulation: data is fed into the simulator (e.g. via location-tracking systems, such as RFID tags), and the simulator then completes unobservable state-components. In the second step, and based on the inferred present state, simulation supports control by predicting future ED scenarios. To this end, we estimate timevarying resource requirements via a novel simulation-based technique that utilizes the notion of offered-load.

3. **RFID-Based Business Process Transformation: Value Assessment in Hospital Emergency Department**
   Paper for BPM 2009 conference
   Abstract:
   Many enterprises, in a variety of industry domains, are evaluating RFID technology as an infrastructure for process improvement. A central domain where this
technology promises significant process improvements is healthcare, and more specifically hospital emergency departments (EDs). However, incorporating RFID technology into the ED environment is both challenging and costly – in monetary terms and organizational efforts. It is therefore necessary to evaluate the potential benefits of introducing RFID technology. In the present work, we present a multi-stage methodology for carrying out such an evaluation, supported by examples of its application (operational, clinical, financial). Our evaluation utilizes a self-developed generic ED simulator which, for the current research, was adapted to the ED of a partner-hospital. Our experience indicates that the proposed methodology is not restricted to EDs and it is applicable to a wide variety of environments and domains.

4. InEDvance: Advanced IT in Support of Emergency Department Management
Paper for NGITS 2009 conference
Authors: Marmor Y., Mandelbaum A., Vasserkrug S., Carmeli B., Greenshpan O., Vortman P., Schwartz D., Basis F.
Abstract:
Emergency Departments (ED) are highly dynamic environments comprising complex multi-dimensional patient-care processes. During recent decades, there has been an increased pressure to improve ED services. Such improvement must take into account various aspects, e.g. clinical quality, operational efficiency and cost performance, through a comprehensive reliable view of the ED state. However, current state of information systems in the ED is such that the data required to provide a holistic view of the ED is unavailable. Therefore, in this paper, we present a vision of an IT system that provides advanced management functionality to the ED. The system will be composed of three major layers: Data Collection; an Analytics component, and an Advanced User Interface to help turn the knowledge into intelligent decisions. We also describe several scenarios that demonstrate the use and impact of such a system on ED management. The multi-disciplinary vision presented here is based on extensive experience, as manifested through the list of authors and their collective track record in emergency departments, business optimization and development of IT systems.

5. Simulation-based Models of Emergency Departments: Real-Time Control, Operations Planning and Scenario Analysis
Paper for TOMACS
Abstract:
The Emergency Department (ED) of a modern hospital is a highly complex system that gives rise to numerous managerial challenges, spanning the full spectrum of operational, clinical and financial perspectives. Since realistic ED models are intractable analytically, one resorts to simulation for an appropriate framework to address these challenges, which is what we do here. Specifically, we apply a general and flexible ED simulator to address several central wide-scope problems that arose in a large Israeli hospital. First, we demonstrate that our simulation model can support realtime control by inferring missing data of the current ED state, which then enables short-term prediction and operational planning (e.g. nurse staffing). To this end, we implement a novel simulation-based technique that utilizes the concept of offered-load. Then, using the same simulation-based approach, we evaluate the impact of RFID (Radio Frequency Identification) technology on ED operational metrics and costs. Finally, we analyze design and staffing problems that arose from
physical relocation of the ED, which lead to the implementation of design and process improvements. A prerequisite for all of the above is an extensive (cleaned and validated) hospital data-based system, which is the data source for our simulations, presently offline and potentially (after implementing an RFID system) in real-time.

6. MEDAL: Measuring of Emergency Departments Adaptive Load
13th World Congress on Medical and Health Informatics Medinfo 2010
Authors: Vitkin E., Carmeli B., Marmor Y., Greenshpan O., Baras D.
Abstract:
This paper proposes an innovative approach for measuring real-time operational load within Emergency Departments. Currently, there is no agreement regarding standard matrices for measuring operational load within ED. As a result, it is difficult to develop methods and approaches for reducing operational load. We propose a flexible framework based on neural networks that calculate user-tuned load value based on a set of well-defined operational and clinical indicators. The operational load value is calculated by learning the weights of the raw operational indicators within a particular emergency department.

7. Neural Networks Application on Emergency Department Load Measurement
SMRLO 2010
Authors: Vitkin E., Carmeli B., Marmor Y., Greenshpan O., Baras D.
Abstract:
The rising cost of healthcare services imposes pressure on healthcare providers to improve the management of quality, efficiency and economics for their organisations. One of the most urgent operational problems in hospitals is emergency department (ED) overcrowding. For optimizing the ED operations one first needs to measure current crowding load level, which is very difficult task due to lack of agreement on the major parameters and their contribution to the overall load.
This paper proposes Neural Networks based Load (NNL) measurement approach – an innovative approach for measuring the real-time operational load within emergency departments targeting to overcome the lack of agreement problem. NNL suggest a flexible framework—based on neural networks—that calculates user-tuned load values, based on a set of well-defined operational and clinical indicators. The operational load value is calculated by learning the weights of the raw operational indicators within a particular emergency department without the need for implicit knowledge of true load values. We describe the neural network structure used and explain the methods we used to calculate the ED operational load.
Major contributions of our work are the possibility to flexibly define user-specific function and the innovative dynamic learning method used when no explicit calculation exist for creation of training set.

Graduate works (PhD, MSc)

1. Task Mental Models and Neonate Medical Status Maps of Doctors and Nurses in Neonatal Units
Author: Auarbach-Shpak Y. Advisor: Prof. d. Goffer
Abstract:
Patient care in ICU requires ongoing information transfer, collaboration and coordination between team members. There are frequent unexpected events due to the dynamic nature of the process and the medical status of the patient that needs
to be continuously monitored. Treatment gaps may occur if works procedures and hand over routines are not properly defined. It is claimed, that when working in a team, it is not enough that each team member develops a good representation of the situation (mental model) from his own perspective. To be efficient and work in coordination, teams should have an appropriate team shared model (TSM). TSM is a more complete understanding and representation of the task and information. When having a good TSM, the team’s performance will improve, the overall load will be better shared and effective work strategies will be adopted. The aim of the present study to examine differences and gaps between physicians and nurses TSM and its influence on creation a medical status map of the neonates. This study may enhance our understanding of ways to improve information transfer between team members and create better shared maps among medical teams.

2. Queues in Hospitals: Queueing Networks with ReEntering Customers in the QED Regime
Author: Yom-Tov G. Advisor: Prof. A. Mandelbaum
Abstract:
We study queues in healthcare. We start by developing and analyzing a queueing model, which we call Erlang-R, where the \( R \) stands for ReEntrant customers. The Erlang-R model accommodates customers who return to service several times during their sojourn within the system. It is most significant in time-varying environments. Indeed, it was motivated by healthcare systems, in which workloads are time-inhomogeneous and patients often go through a discontinuous service process. For example, in Emergency Wards, physicians are revisited by patients whose service process consists of cycles: examination by a physician, lab tests, treatment by a physician and so forth.

This thesis consists of three parts: open Erlang-R, semi-open Erlang-R, and Empirical analysis. In the first part, the main question we address is: how many servers (doctors/nurses) are required (staffing) in order to achieve predetermined service levels stably over time. Based on our theory, we propose a staffing policy that attains pre-specified service levels in the Halfin-Whitt (QED) regime. This policy applies the Modified Offered Load (MOL) approximation. We validate our policy, via simulation, both for large and small systems, and we use an EW simulator to validate its usefulness in realistic scenarios. We thus show how to stabilize, via proper staffing, both service levels and servers' utilizations, in time-varying healthcare environments.

In the second part, we concentrate on analyzing semi-open queueing networks with ReEntrant customers. These networks are used to model a Medical Unit with \( s \) nurses that cater to \( n \) beds, which are partly/fully occupied by patients. Here the questions we addressed here are: How many servers (nurses) are required (staffing), and how many fixed resources (beds) are needed (allocation) in order to minimize costs while sustaining a certain service level? We answer this by developing QED regime policies that are asymptotically optimal at the limit, as the number of patients entering the system (\( \lambda \)), the number of beds (\( n \)) and the number of servers (\( s \)) grows jointly. Our steady-state approximations turn out accurate for parameter values that are realistic in a hospital setting. We then use these approximations to develop MOL approximation to the closed-version of the Erlang-R model in a time-varying environment.

Our research was done in collaboration with one of the largest hospitals in Israel. This partnership provided us with the opportunity to analyze real data of patient-flow throughout the hospital, and validate our research in realistic situations. The last part of the research consists of this data analysis, concentrating mainly on hospitalization data in internal wards.

Author: Marmor Y. Advisor: Prof. A. Mandelbaum

Abstract:
The Emergency Department (ED) of a modern hospital is a highly complex system. Indeed, it gives rise to numerous managerial challenges from the Service Engineering area, spanning the full spectrum of operational, clinical and financial perspectives, over varying horizons: operational - few hours or days ahead, tactical - weeks or a few months ahead, or strategically - months to years ahead. Since realistic ED models are often intractable analytically, one resorts to simulation for an appropriate framework to address these challenges, which is what we do here. We start with short-term prediction and operational planning (physicians and nurse staffing) over several hours or days ahead. To this end, we implement a novel simulation-based technique that utilizes the concept of offered-load and discover that it performs better than a prevalent alternative. Next, we evaluate ED staff scheduling that adjusts for mid-term changes (tactical horizon), and then we analyze the long-term benefits of using real-time tracking in the ED (strategical horizon). We also search for "best" ED operational models, via simulation and based on real data, where DEA (Data envelopment Analysis) is the tool used to identify models that are efficient in a given operational environment. Finally, we present a methodology that enables the creation of complex simulations by reusing existing simulation submodels.

4. The Offered-Load Process: Modeling, Inference and Applications

Author: Reich M. Advisor: Prof. A. Mandelbaum

Abstract:
A standard assumption in queueing models is that the service time of customers and their patience are independent. Practice shows that this assumption is often violated, as one expects longer service times for customers who waited longer or, alternatively, higher patience for customers expecting longer services. We introduce a model for the relationship between the service time and the patience of a customer, including a statistical test for the existence of such dependency. We show that in the presence of a relationship, various performance measures are influenced, and that the classical estimation procedures of service parameters yield biased estimators.

The above mentioned dependence affects the standard way of calculating offered-load. Specifically, the offered-load of a system must account for the work that would have been required by customers who abandon prior to service. We thus carefully define the offered-load process and the offered-load function, and then derive a method for estimating and predicting them, in service systems where service-times and patience are dependent. Finally, we discuss the effect of this dependence on the square-root staffing rule.

5. Uncertainty in the Demand for Service: The Case of Call Centers and Emergency Departments

Author: Maman S. Advisor: Prof. A. Mandelbaum

Abstract:
A standard assumption in the modeling of open service systems postulates that the customers’ arrival process is Poisson with a known parameter. More specifically, the prevalent approach is to assume known arrival rates for each basic time interval.
(say, half-hour). In practice, however, arrival data violates this assumption by exhibiting more variability than the one expected from the Poisson hypothesis. We explain this “over-dispersion” by “natural” uncertainty of the arrival rate, which gives rise to a Poisson mixture model for the arrival process. Then we incorporate this mixture model into the $M|M|n + G$ queue and analyze it asymptotically, in steady state. Our approach is motivated by the seminal paper of Halfin and Whitt, assuming that both the mean arrival rate $\lambda$ and the number of servers converge jointly to infinity. It turns out that system performance strongly depends on the order of over-dispersion. Specifically, we analyze three regimes of arrival-rate uncertainty: order $\lambda$, $\sqrt{\lambda}$, and $\lambda^c$, $0.5 < c < 1$. The latter case is especially practical, since it seems to fit the call center reality. For the first two regimes, we derive asymptotically optimal staffing levels, in the sense of being the least that adhere to a pre-specified waiting probability. Key operational performance measures are asymptotically calculated as well. In the practical regime, $0.5 < c < 1$, we consider staffing levels that are characterized by $c$ safety-staffing: $n = R + \beta R + o(R)$, where $R = \lambda \cdot E[S]$ is the offered load and $\beta$ is a quality-of-service parameter. When $\beta > 0$, this staffing level reflects the need for protection against variability that exceeds that in the square-root staffing of the conventional QED (Halfin-Whitt) regime. If $\beta < 0$, on the other hand, less protection is needed. An extensive numerical study, based on data from an Israeli call center, validates the practical model (arrival-rate uncertainty of order $\lambda^c$, $0.5 < c < 1$, specifically $c \approx 0.8$) and relates it to an alternative well-known Poisson mixture model with an underlying Gamma prior. In an additional numerical study, based on data from an emergency department of a hospital, we get that $c$ is around 0.5. Finally, our Poisson mixture model is incorporated into the $M|M|n + G$ queue, giving rise to the model with a random time-varying arrival rate. The above-derived staffing regimes then give rise to time-varying staffing rules which stabilize the delay probability - in fact, this time-stable performance matches that of a specific stationary queue, at all times, remarkably well.

6. Queueing Systems with Heterogeneous Servers: Improving Patients' Flow in Hospitals

Author: Tseytlin Y. Advisor: Prof. A. Mandelbaum

Abstract:

A patient arriving to the ED undergoes triage, registration, diagnostic testing, basic treatment, and then is either dismissed or admitted to stay, the latter if doctors decide on hospitalization, in which case the patient is transferred to the appropriate medical unit. In this Thesis we shall concentrate in the process of transfer from ED to IW.

Two main problems could arise in the process: patients' waiting times in the ED for a transferal to the IW could be long, and patients' allocation to the wards need not be fair. We shall model patients' flow from the ED to the IW as a queueing system with heterogeneous pools of servers, where pools are wards, servers are beds, and service rates are the reciprocals of ALOS. We shall focus on the issues of fairness and optimality in the sense of average waiting time in the ED, or possible other relevant measures, and ask ourselves the following main question: What routing policy from the ED to the IW is fair and bestperforming, or, how to allocate patients to the wards in a just way while still thriving to minimize waiting time?
7. Improving quality of treatment in the Emergency Department
Author: Weismark S. Advisor: Prof. A. Shtub

Students Projects
1. Improving the Pre-surgical Process in the Hospital
2. Operational Aspects of Transfer the ED to a temporary Location
3. Choosing the Most Effective Operational Model for the ED
4. Patient Flow from ED to Internal Wards: Solving Bottle-Necks and Operational Problems
5. Feasibility Test for Implementation of RFID system in Hospital
6. Comparison of Four possible operational models for ED
7. Mapping the processes in Hadasa ED
8. Operational Aspects of Transfer the ED to a permanent Location
9. Real-Time Location - Tracking Device
10. Fairness in the Allocation of Work among a Hospital’s Maternity Wards, Rambam Hospital
11. RFID-Based Control of a Mass-Casualty-Event

Graduate Students Projects
12. Simulation of Patients Routing from an Emergency Department to Internal Wards in Rambam Hospital
   Authors: Tseytin Y., Zviran A.
13. Research on a Wizard Of Oz simulator for the training of Emergency Department Teams
   Author: Sirkis A.

OCR projects in process
1. Patient Quality of Care – Longitudinal observations and Analysis of Medical Records
2. Human Factors in the design of a New Trauma Room
3. Development of an advanced BI system for an ED, which involves a dashboard and forecasting capabilities
5. Empirical Analysis of an Emergency Department