

Patient Flow Monitoring and Control within Emergency Department

Rambam/Technion/IBM open collaborative research

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The Problem

- The rising cost of healthcare services has been a subject of mounting importance and much discussion worldwide
- Overcrowding in hospital Emergency Departments (ED) is perhaps the most urgent operational problem in the healthcare industry
- Overcrowding in hospital EDs leads to excessive waiting times and repellent environments, which in turn cause:
 - ▶ Poor service quality (clinical, operational)
 - ▶ Unnecessary pain and anxiety for patients
 - ▶ Negative emotions (in patients and escorts) that sometimes lead to violence against staff
 - ▶ Increased risk of clinical deterioration
 - ▶ Ambulance diversion
 - ▶ patients leaving without being seen (LWBS)
 - ▶ inflated staff workload



PROMISE Framework

Joint research project between Rambam, the Technion and IBM Haifa Research Lab

- ▶ Leverage Technion's relationship with Rambam hospital

Goal: Combined multi-dimensional improvement of patient care process

- ▶ Clinical
- ▶ Operational
- ▶ Financial

Multi-disciplinary approach:

- ▶ Medical (Rambam)
- ▶ Statistics (IBM, Technion)
- ▶ Operations Research (IBM, Technion)
- ▶ Healthcare informatics (IBM, Rambam)
- ▶ Process improvement (IBM, Technion)
- ▶ Human factors engineering (Technion)
- ▶ Financial (Rambam)
- ▶ Domain specific knowledge in above areas – IBM & Technion

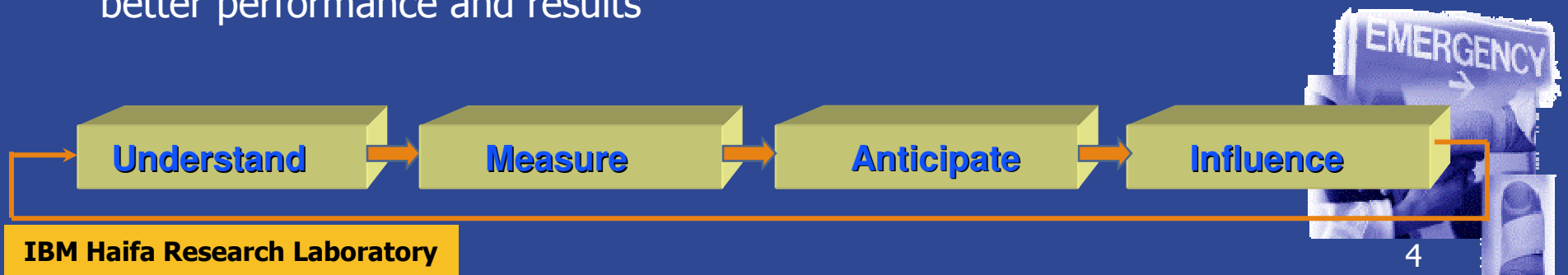
Participation

- ▶ Rambam hospital: Top management including hospital general manager, Prof. Rafi Bayar, ER managers, Dr. Dagan Schwartz & Dr. Shlomi Israelit and IT managers, Sara Tzafrir, Orit Gur
- ▶ Technion: Prof. Avishai Mandelbaum, Prof. Danny Gopher, Prof. Avi Shtub, Prof. Eitan Naveh, Dr. Yariv Marmor
- ▶ IBM: Pnina Vortman, Segev Wasserkrug, Boaz Carmeli, Edward Vitkin, Ohad Greenshpan and Sergey Zeltyn



PROMISE Vision

- End to End Medical **P**rocess **M**onitoring and **O**ptimization **S**ervices
- Based on three main patient care related aspects:
 - ▶ Clinical
 - ▶ Operational
 - ▶ Financial (planned)
- Uses analytical processing for gaining business and clinical understanding
- Provides real time monitoring through RFID and operational dashboards for problem identification, quality assurance and risk management
- Provides optimization, forecasting and what/if type of analysis based on analytical models
- Allows for modifying/improving operational and clinical processes for better performance and results



ED Conceptual Model

Input

Emergency Care

- Seriously ill and injured patients from the community
- Referral of patients with emergency conditions from other providers

Unscheduled urgent care

- Desire for immediate care
- Lack of capacity for unscheduled care in the ambulatory care system

Safety net care

- Vulnerable populations (eg, Medicaid beneficiaries, the uninsured) care
- Access barriers (eg, financial, transportation, insurance, lack of usual source of care)

Ambulance
Diversion

Demand for
ED Care

Throughput

Patient Arrive
at ED

Triage and room
placement

Diagnostic evaluation
and ED treatment

ED boarding
of inpatients

Leaves
without
treatment
complete

Patient
disposition

Output

Ambulatory
care
system

Transfer to
other
facility

Admit to
hospital



Real Time ED Monitoring and Control System

■ Data Collection

- ▶ Collect real-time relevant information from hospital IT systems such as PACS, EHR, ADT, LAB etc
- ▶ Adding RFID based location tracking system for Physicians, Nurses, Patients and other relevant personnel
- ▶ Better utilize historical EHR and operational data from existing IT systems within the hospital

■ Data Visualization

- ▶ Operational dashboard
 - Displays complex behaviors in a simple way
- ▶ Mobile devices

■ Analysis Techniques

- ▶ Mathematical models – service engineering
- ▶ Simulations – for planning and control
- ▶ Machine learning - neural networks, based on historical data
 - Published paper –
Neural Networks Application on Emergency Department Load Measurement



System Architecture

Data Collection

Hospital IT systems

- Admit, Discharge, Transfer
- Electronic Health Records
- Lab request/results
- Picture Archive and Communication System (PACS)

RFID based Location Tracking

- Low level location tracking for patients and care personnel
- Technology dependent capabilities

ED Simulator

- Based on observation
- Will be used, mainly, for design phase e.g. to mimic the RFID system

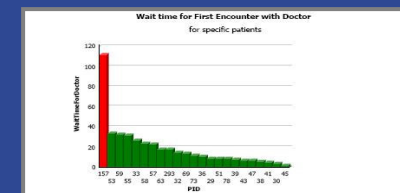
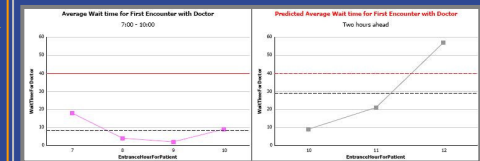
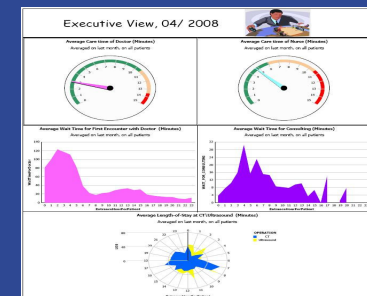
Analysis

Real Time
Event Processing
Network
Rule Based Analysis

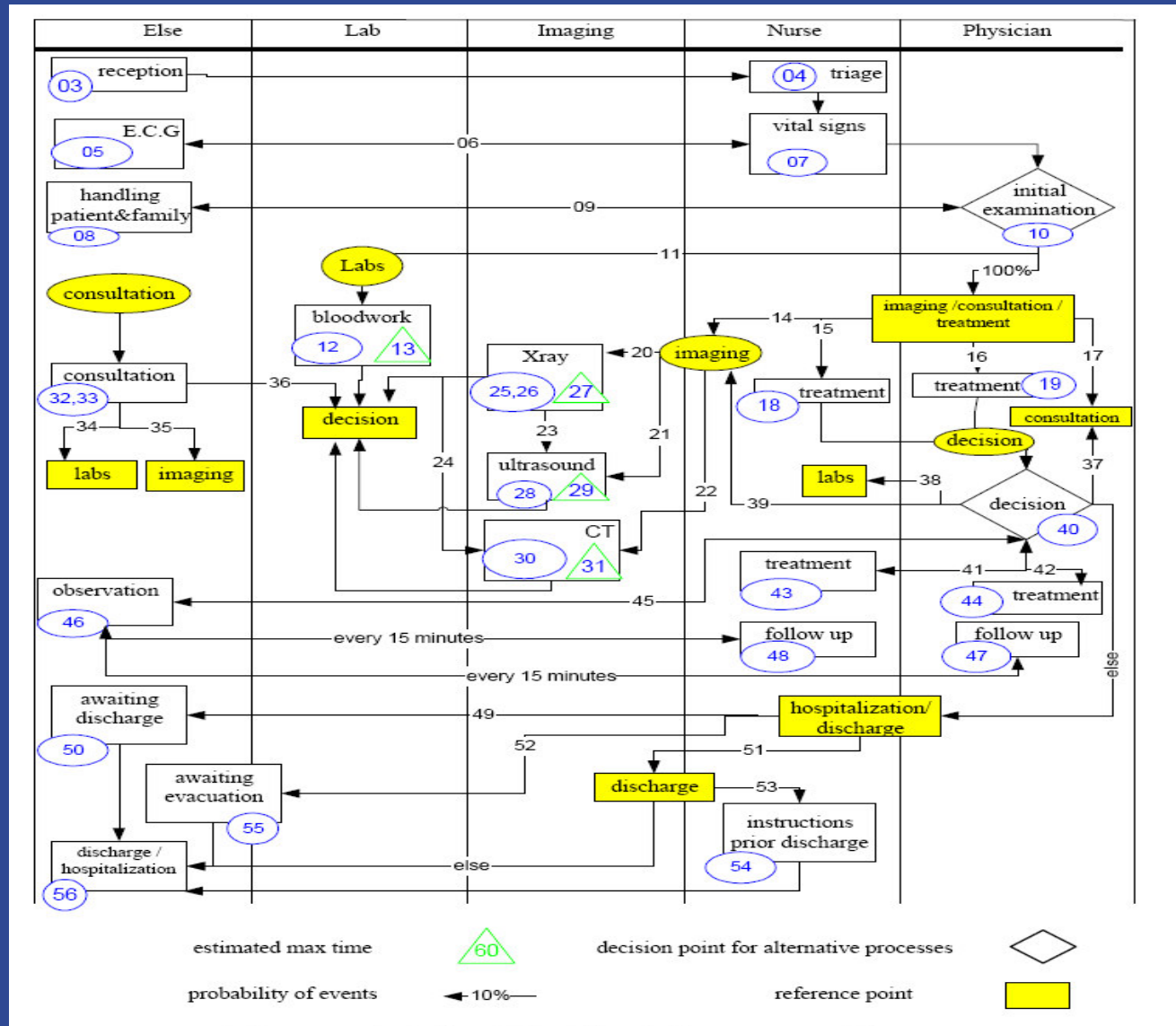
Machine Learning
Algorithms
Analysis of Historical
And Real-time Data

Mathematical Models
e.g. Queuing Theory

Data Visualization



The ED Patient Flow

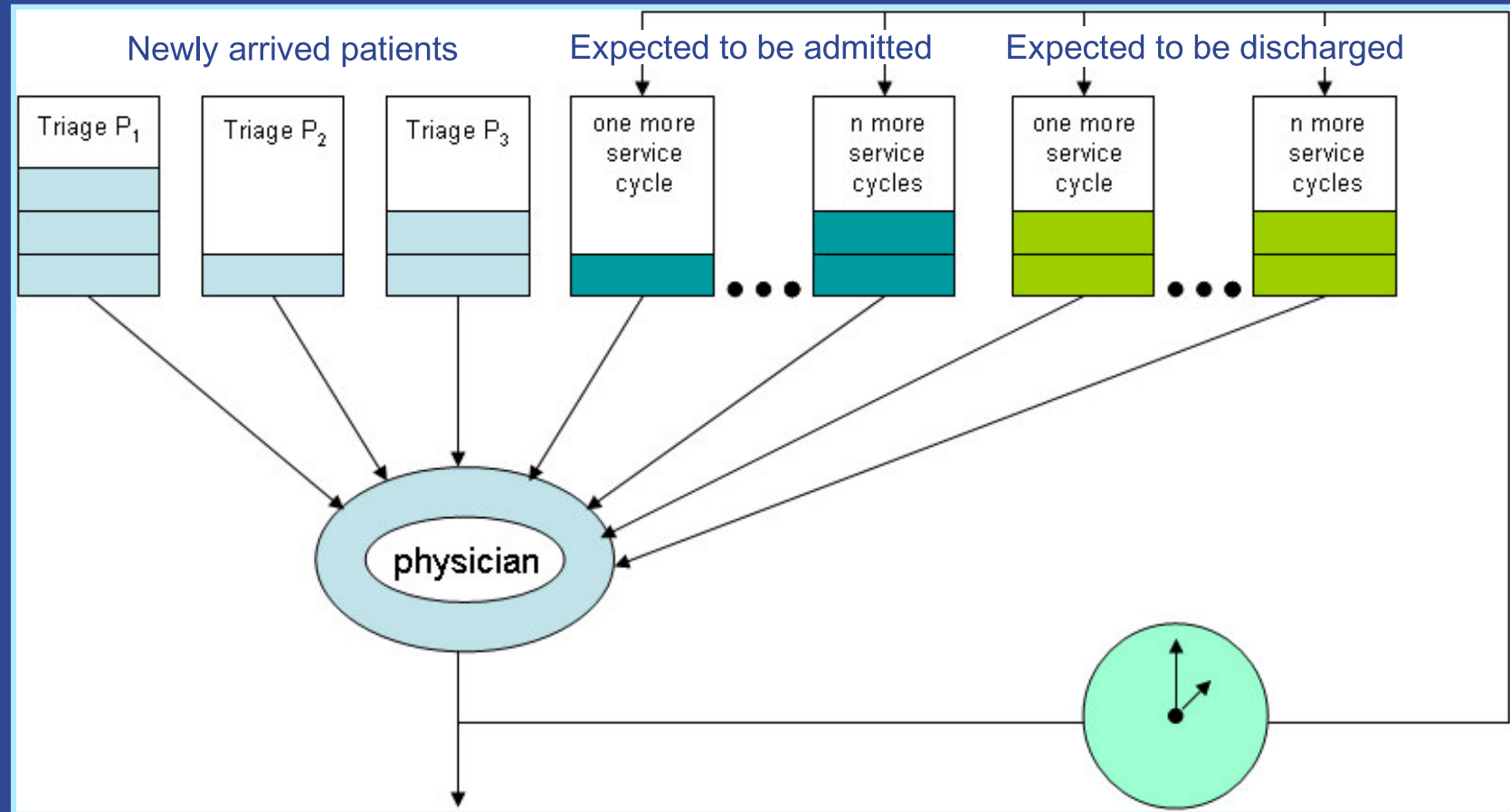


Managing the ED Patient Flow

- Modeling the ED patient flow as a queueing network
 - ▶ Patients – tasks
 - ▶ Care personal – servers (stations)
- Knowing in real-time the next 'station(s)' in the patient's route
 - ▶ Set of alternatives are usually provided by the care personnel
 - No a priory full path knowledge
 - ▶ System may provide decision support
- Deciding upon the 'best' next station (e.g. next physician)
 - ▶ Assuming there are multiple options
 - ▶ Sends patient to the (clinically and operationally) 'best' station
 - ▶ Always make sure there is at least one 'next' station
- Within each 'station' queue deciding upon the next patient to treat
 - ▶ Based on operational, clinical and patient fairness
 - service level agreement
- Predicting capabilities
 - ▶ System is about to get out of the allowed range
 - E.g., capacity is about to be exceeded
- Decision support and what-if analysis
 - ▶ What are the best actions to take e.g. asking for additional physician



Improving the (Naive) First Come First Serve Policy



Searching for the 'Best' Service Algorithm

- Meeting the triage deadlines
 - ▶ Time till first encounter based on clinical severity as being reflected by the triage score
- Reducing the total number of patients at the ED
 - ▶ Serving patients with the least remaining service time
- Give priority for patients that are about to be discharged
 - ▶ Without scurrying appropriate clinical care
 - ▶ Against conventional physician thinking
- Methodology
 - ▶ Adapting Generalized C_μ algorithm
 - Searching for appropriate cost function to reflect the above-mentioned competing conditions
 - ▶ Uses analytic approaches as well as simulation based methods



The Monitoring and Control Dashboard – Example

עמדה	#	גיל	שהייה	A	C	V	E	הוראות	ייעוץ	L	X	US	CT	רופא	אשפוז
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א02	8403759	82	08:55	-	+	×	-	● ●	Im Sur Pl	?	+	✓	?	שפילו	00:55
א03	9467285	36	11:55	-	-	✓	✓	● ●	Nes Ort Py	✓		++	+	מפיס	+01:05
א04	5790468	56	00:35	-	-	✓	-	● ●	Pl On Ort	×	×	?		דגן	+
א05	4566768	76	01:08	-	-	✓	✓			+					
א06	4456826	55	04:55							-				הרשקו	מעבר
א07															
א08	8403759	82	08:55						GY NES ENT					שפילו	00:55
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א10															
א11	5790468	56	00:35						PL /EYE /PED	●		?		דגן	
א12	4566768	76	01:08						✓ EYE /IM						
ב01															
ב02	4456826	55	04:55						GY /PL /SUR					הרשקו	מעבר
ב03	8403759	82	08:55						✓ PED					שפילו	00:55
ב04	9467285	36	11:55						SUR					מפיס	
ב05	5790468	56	00:35						IM					דגן	
ב06	4566768	76	01:08						לוח שוכבים ציבורי						
ב07	4456826	55	04:55											הרשקו	מעבר
ב08	8403759	82	08:55											שפילו	00:55
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ב10	5790468	56	00:35											דגן	

Summary

- Advances in IT technology and usability call for better utilization of computer based monitoring and control systems within hospitals and specifically within the ED
 - ▶ Rambam recently extended their EHR into the ED
- Digital data collection and monitoring open the door for utilizing traditional as well as newly developed operations research and service science and engineering methodologies and techniques within hospitals
- PROMISE is an end-to-end solution for improving ED operational and clinical efficiency by providing forecasting, optimization and operational decision support to care personal and ED managers
 - ▶ Initial capabilities currently under implementation at Rambam

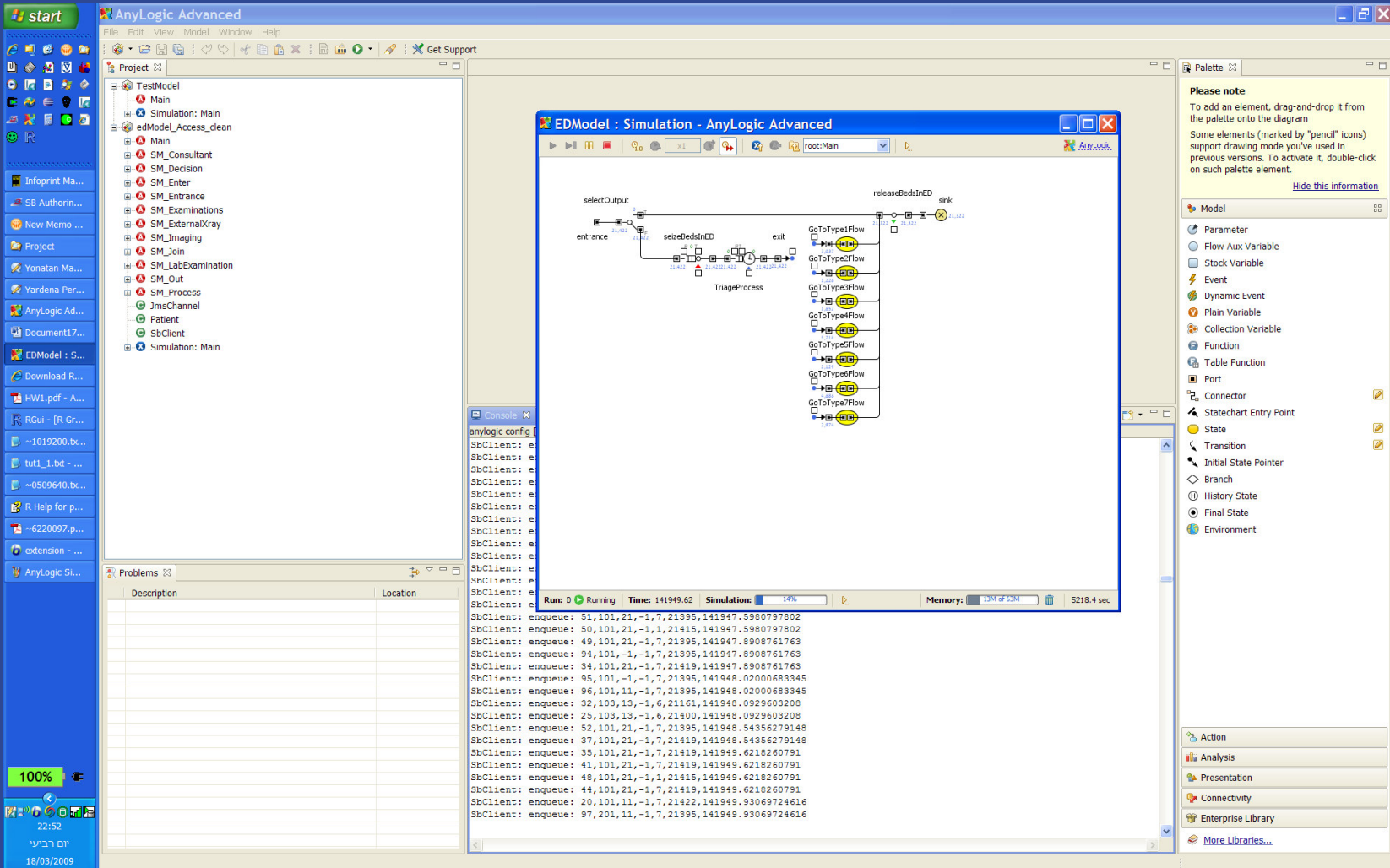


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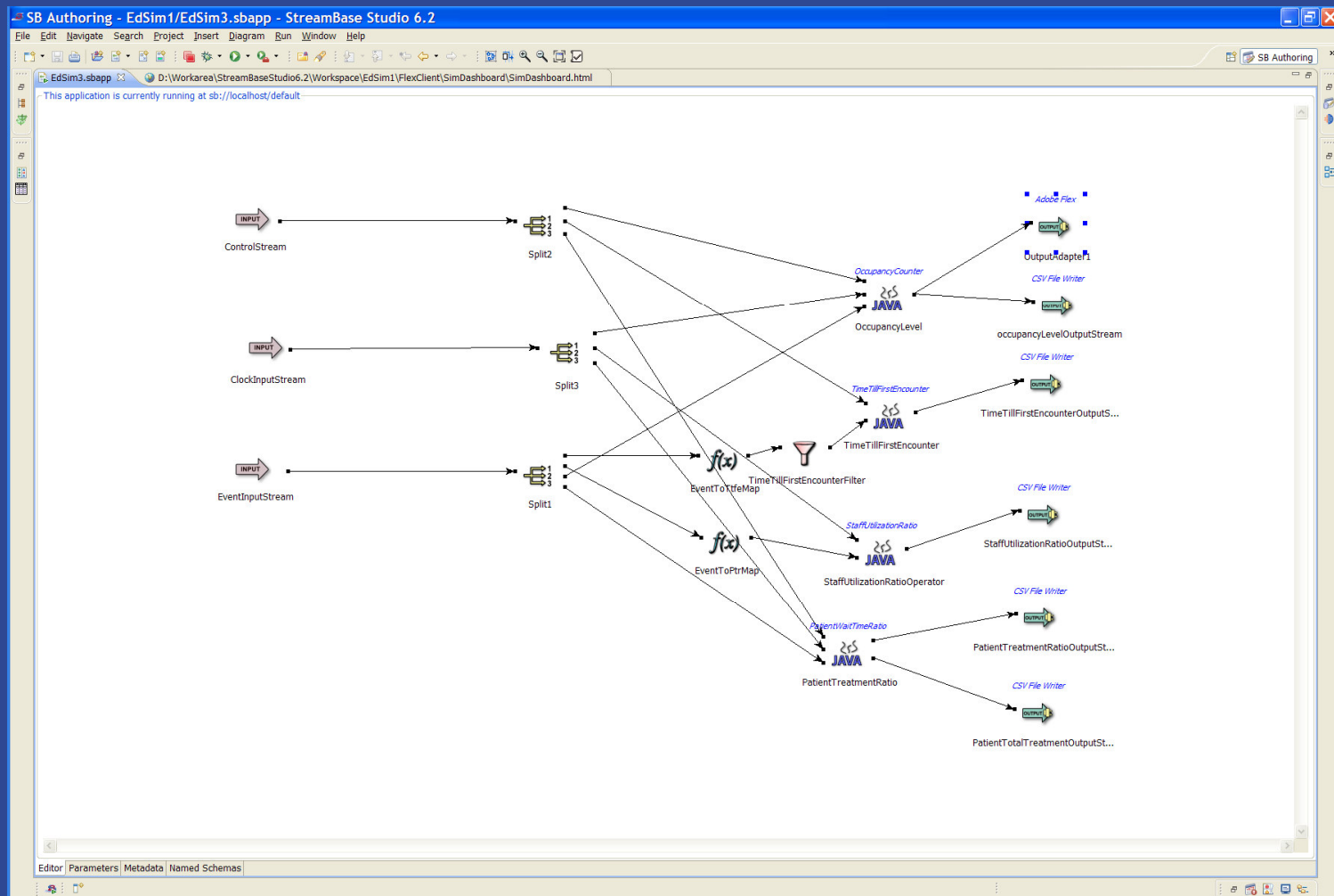
The ED Simulator

We use the ED Simulator (developed by Dr. Marmor) for generating relevant input data into the system



The Event Processing Network

We use the EPN tool for collecting RFID data



The Dashboard – Predicting ED Load

Emergency Department Realtime Activity Monitoring



Emergency Department Realtime Activity Monitoring



Promise

a collection of clinical operations research projects

- Several projects related to patient flow at ED, internal wards and from the ED to the wards
- Operational Research, Queuing Theory, Simulation, Complex Event Processing
- Join work with the Technion and Rambam (leading Israeli Hospital) under an IBM Open Collaborative Research program

