i2SIM-Human

Mathematical Representation of Human Decisions in an System Solution

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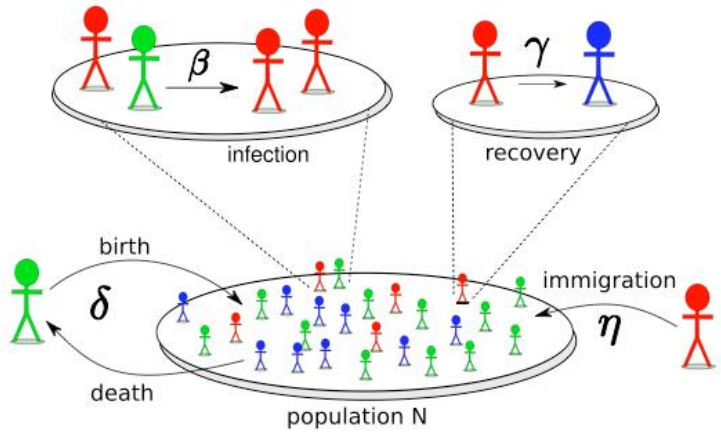
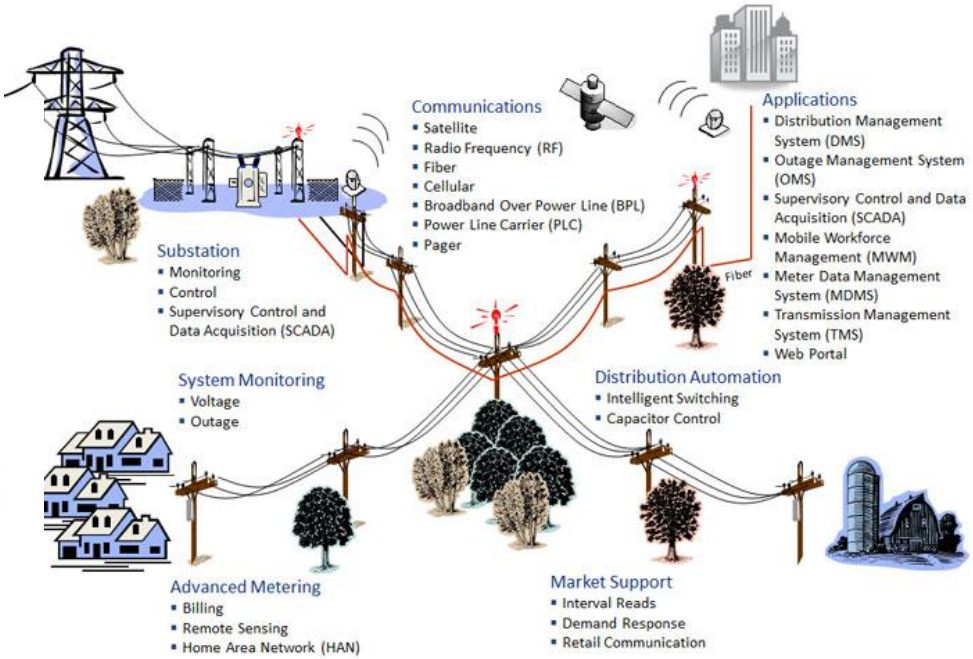
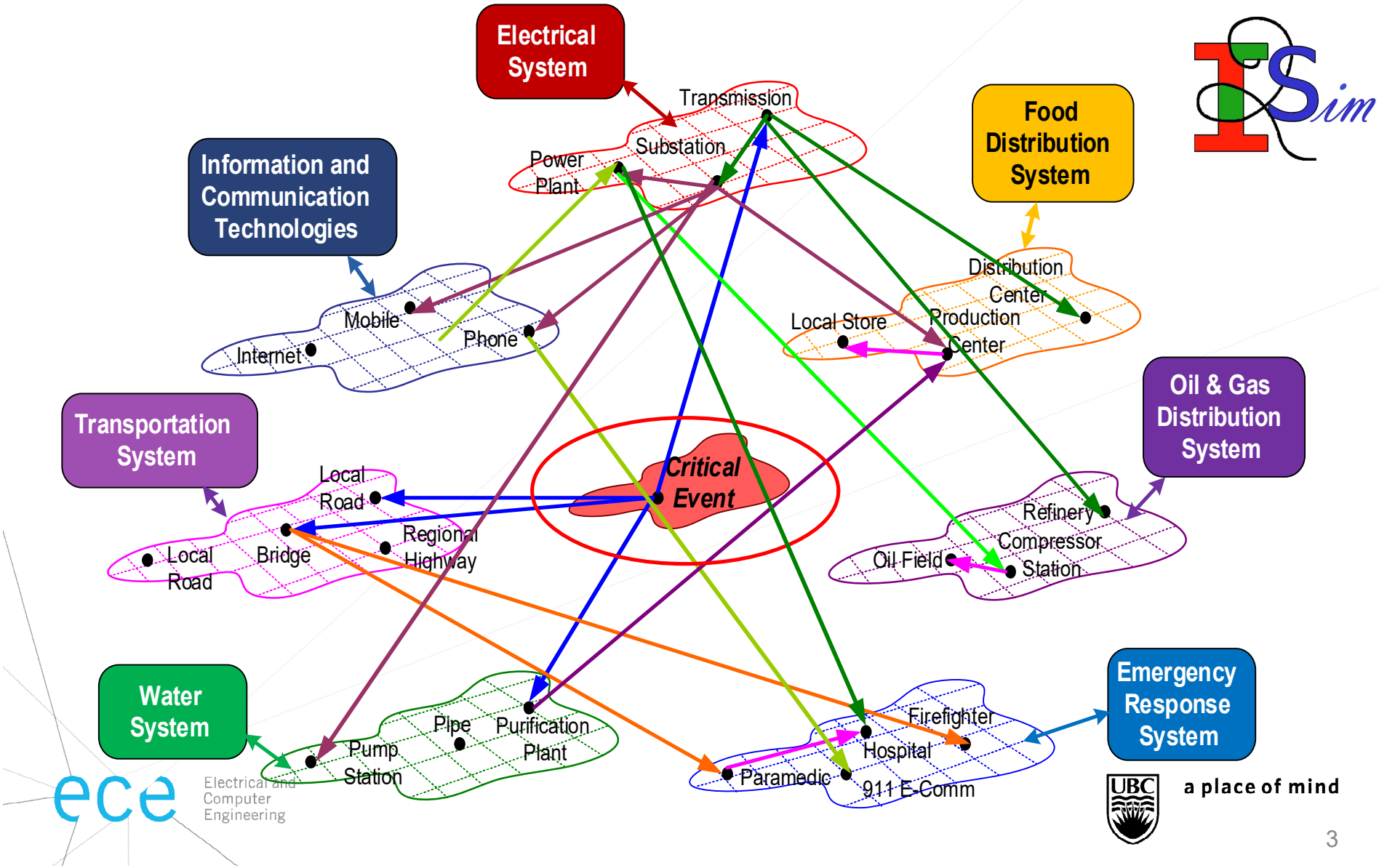
Large Complex Systems

- A complex system is a network of heterogeneous agents with nonlinear behaviour and multiple time scales.

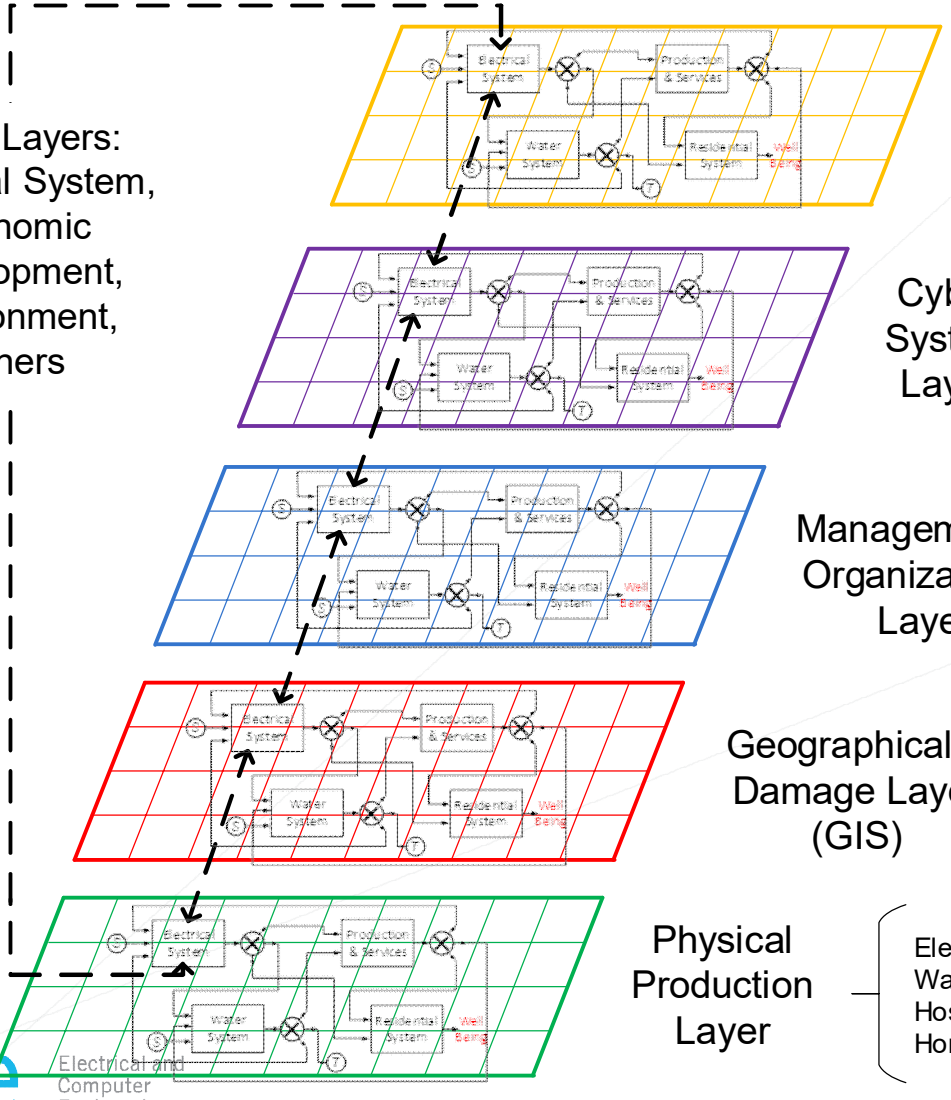




Critical Interdependent (CI) Systems



Physical, Geographical, Management, and Cyber Layers



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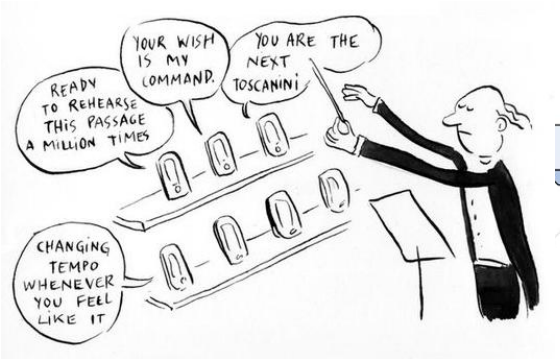
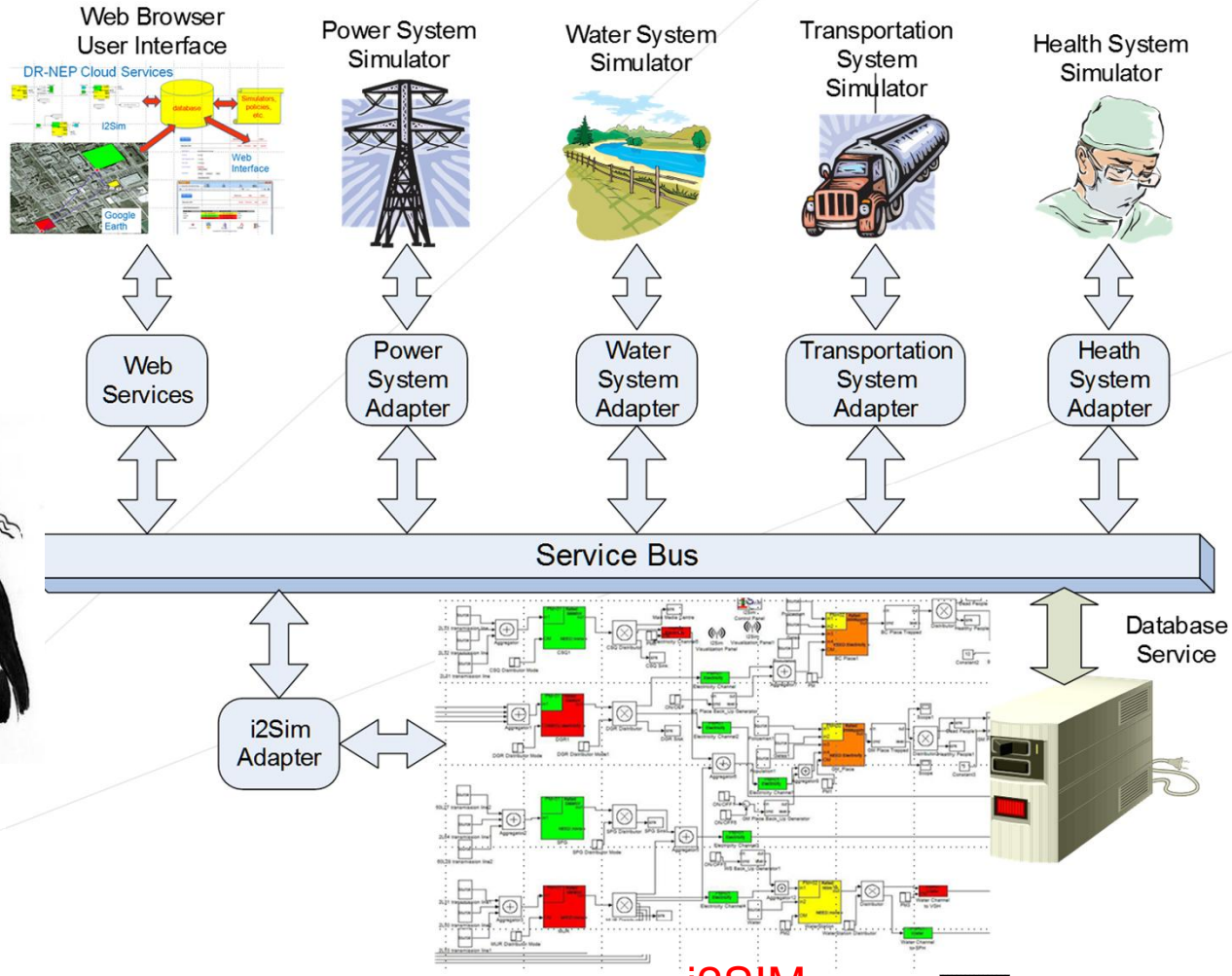
i2SIM Multisystem/Multilayer Simulator

Coordinated Integration





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Quality of Mission (QoM) versus Quality of Individual Services (QoS)

- QoS (Quality of Service) (**reliability**)

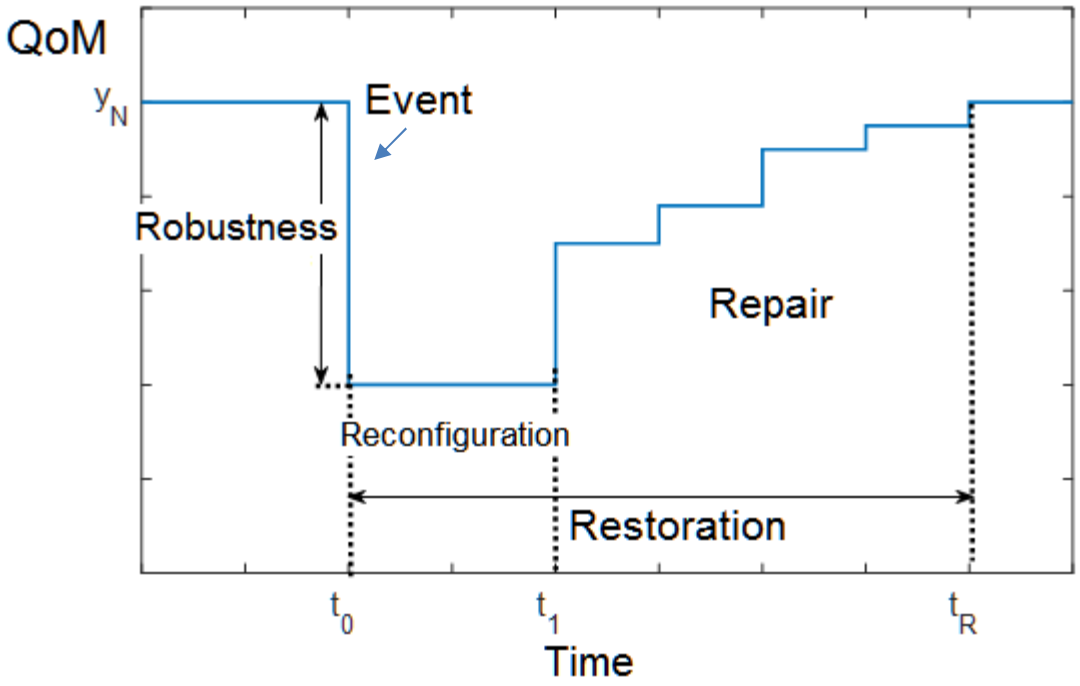
Failures of Equipment and Design

- QoM (Quality of Mission) (**resilience**)

Impact of Failures on the Mission

Quality of Mission (QoM) Index

A disruptive event occurs at t_o. Restoration to an acceptable level achieved at t_R.



$$QoM_{index} = \frac{\int_{t_o}^{t_R} y(t)dt}{y_N(t_R - t_o)}$$

The Quality of Life (QoL) in Smart Cities depends on the recovery actions of multiple interdependent CIs

HRT: Table to relate inputs and outputs

Public Service (HRT)			
y (service) (%)	X1 (elec) (MW)	x2 (water) (ML/ day)	x3 (ICT) (units)
100	180	150	33
75	135	80	30
50	90	50	25
25	45	20	15
0	0	0	0

X

Electrical System (HRT)			
y (elec) (MW)	S1(elec) (MW)	x1 (ICT) (units)	m1 (idam)(%)
600	600	33	100
300	300	22	50
0	0	0	0

S1

m1

X

Well-Being Table Residences (HRT)				
y (WBL) (%)	x1 (elec) (MW)	x2 (water) (ML/day)	x3 (services) (%)	x4 (ICT) (units)
100	200	150	150	33
75	120	130	130	30
50	70	100	90	25
25	30	40	40	15
0	0	0	0	0

Water System (HRT)		
y (ML/day)	S2(ML/day)	x1 (MW)
300	300	30
200	200	20
100	100	10
0	0	0

S2

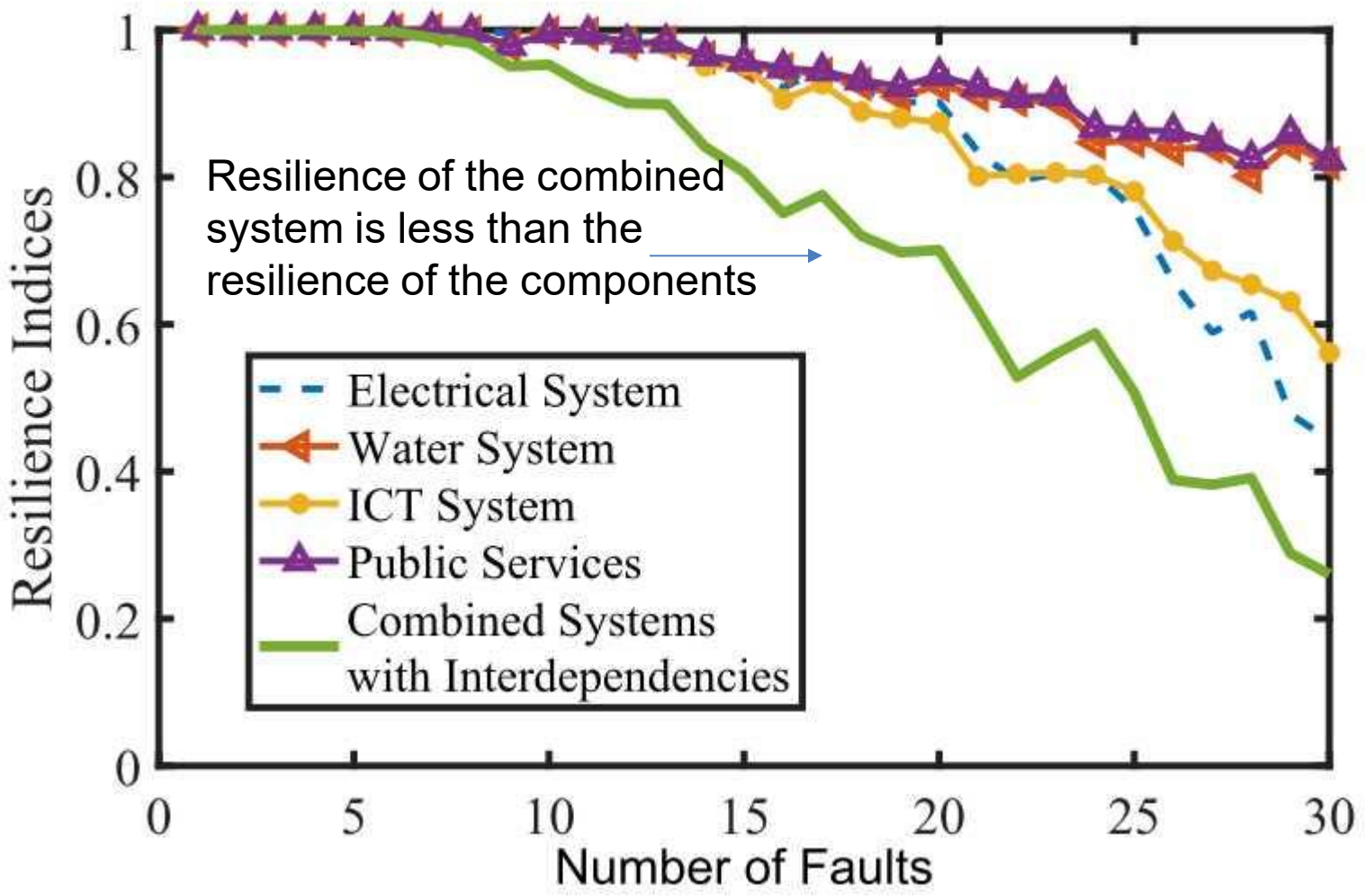
X

ICT System (HRT)		
y (units)	x1(elec) (MW)	m2 (idam)(%)
100	20	100
50	10	50
0	0	0

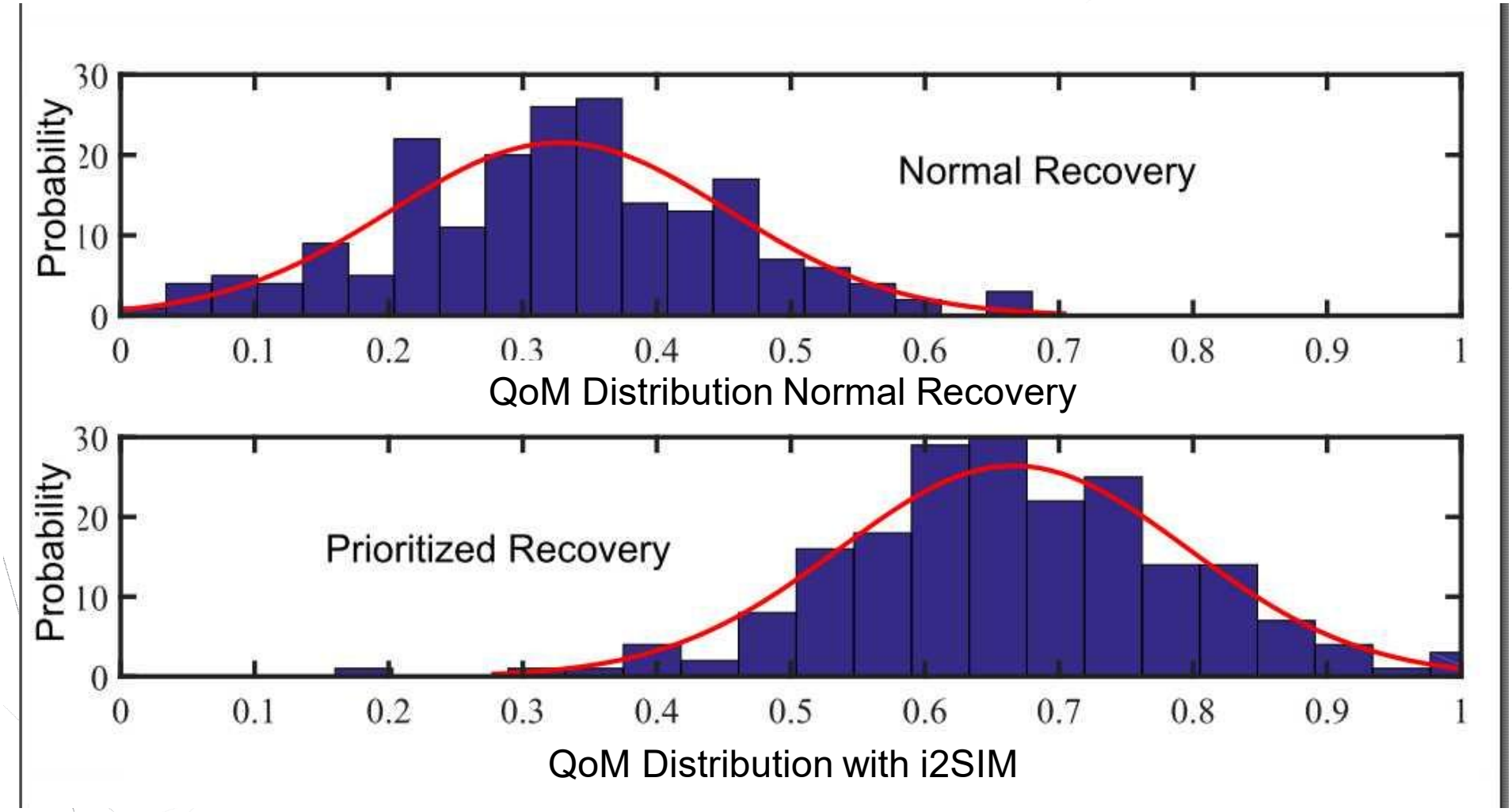
m2

X

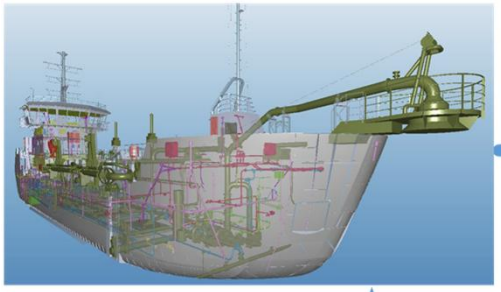
QoM with Interdependencies



QoM Probability Distribution



Human in the Loop



Sensors

Clean Up Data

Extract Parameters

Simulator

Digital Decisions Assistant

Decisions Maker

Modelling Human Experience

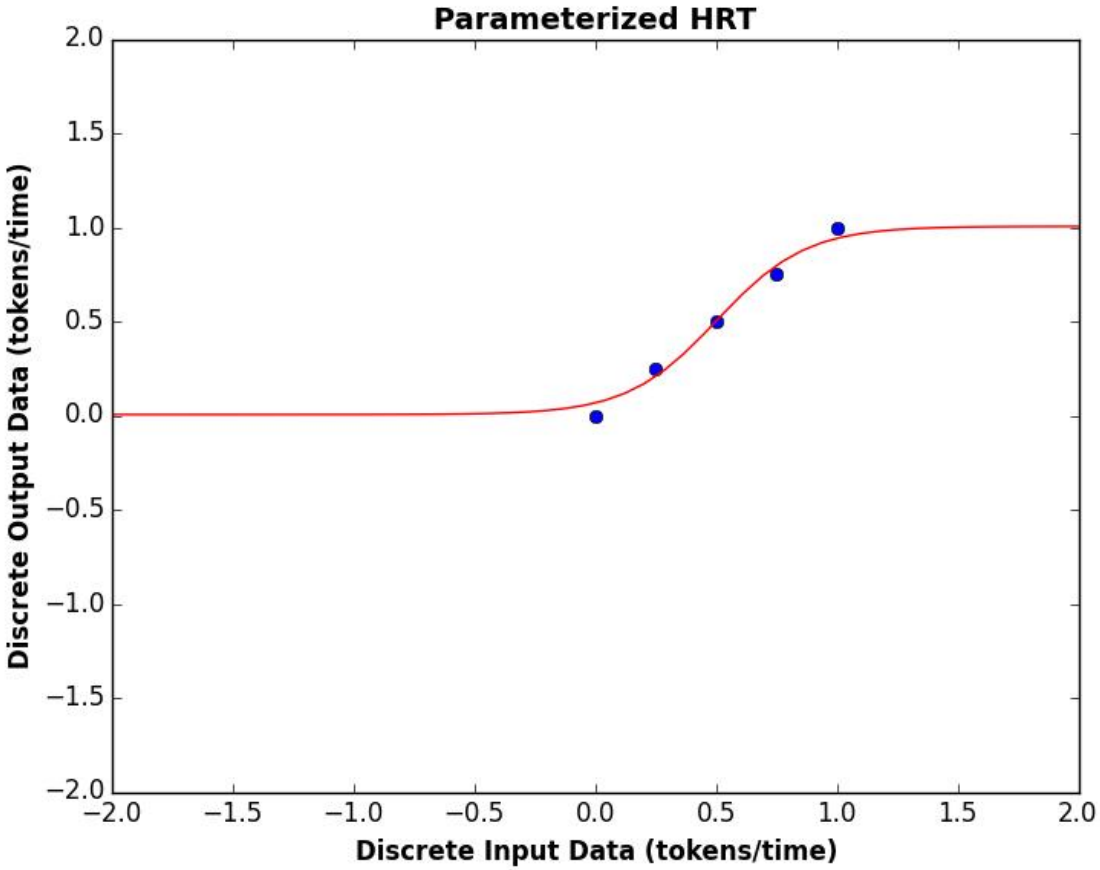
1. i2SIM uses the concept of the Human Readable Table to capture human and physical relationships.
2. For example, the number of patients treated in the ER unit of a hospital depends on the availability of physical quantities: electricity, water, doctors, nurses, etc.
3. How these quantities determine the number of patients treated is known from experience. The manager of the unit knows these relationships.
4. The more experienced the manager, the better he/she will know the relationships.

Manager's Knowledge of ER Unit's Operation Represented in Hospital's HRT

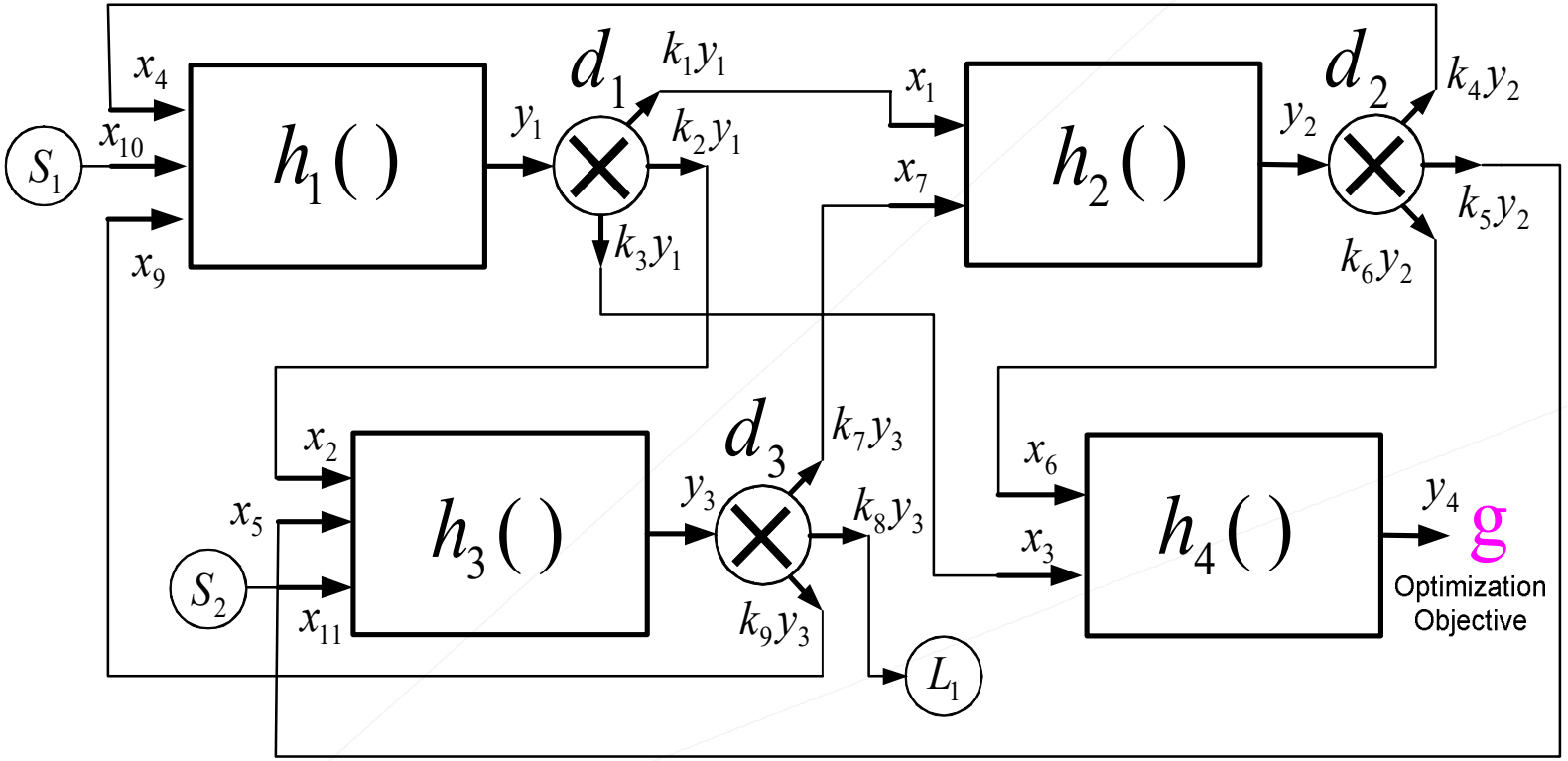
	Management Layer	Engineering Layer	Engineering Layer	Management Layer	Management Layer	Engineering Layer	Management Layer
	y(t)	**$x_1(t)$**	**$x_2(t)$**	**$m_1(t)$**	**$m_2(t)$**	**$m_3(t)$**	**$m_4(t)$**
	Patients per hour	**Electricity (kW)**	**Water (L/h)**	**Doctors**	**Nurses**	**Physical Integrity**	**Doctors Shift Factor**
	20	100	2,000	4	8	100%	100%
Operating Level	16	80	1,000	3	6	80%	75%
→	10	60	600	2	5	50%	50%
	7	40	400	2	3	20%	25%
	0	0	0	0	0	0%	0%

- Table relates inputs to output in a nonlinear manner.
- The Operating Level is determined by the least available resource.

HRT Tables are Parameterized by Analytical Functions



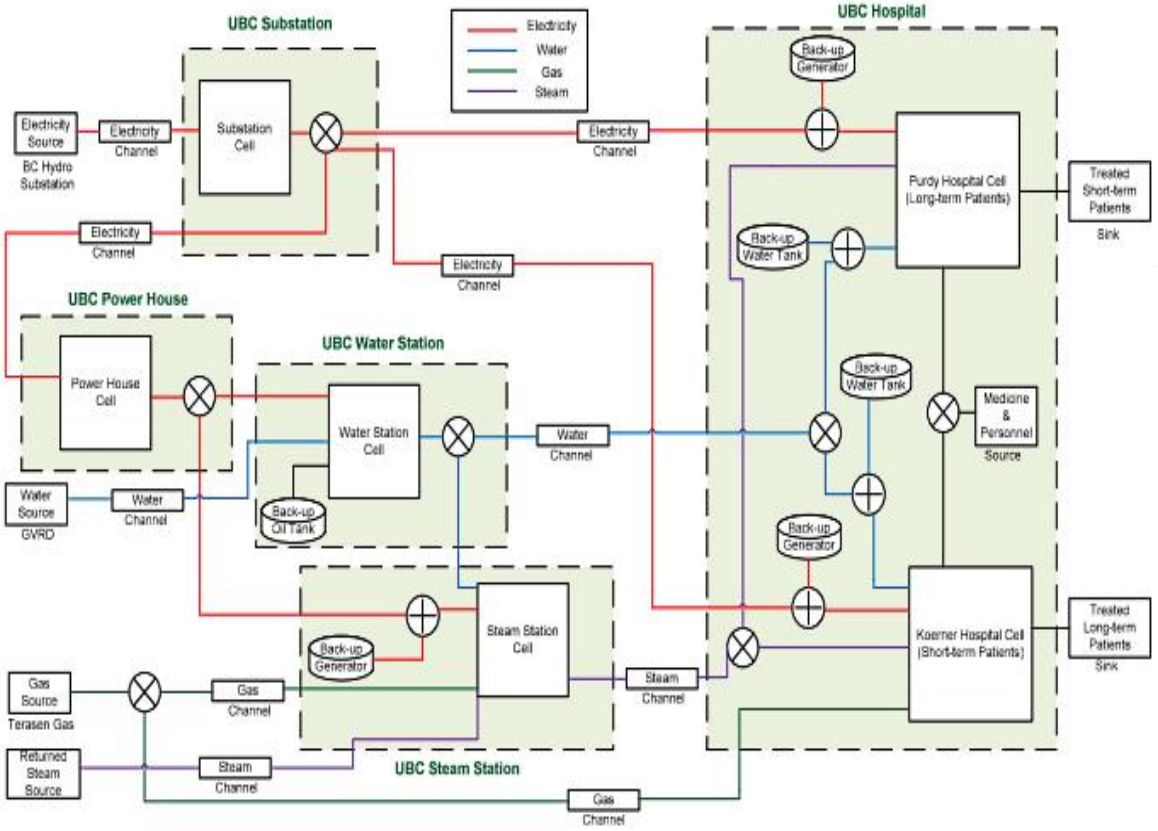
State-Space System Representation



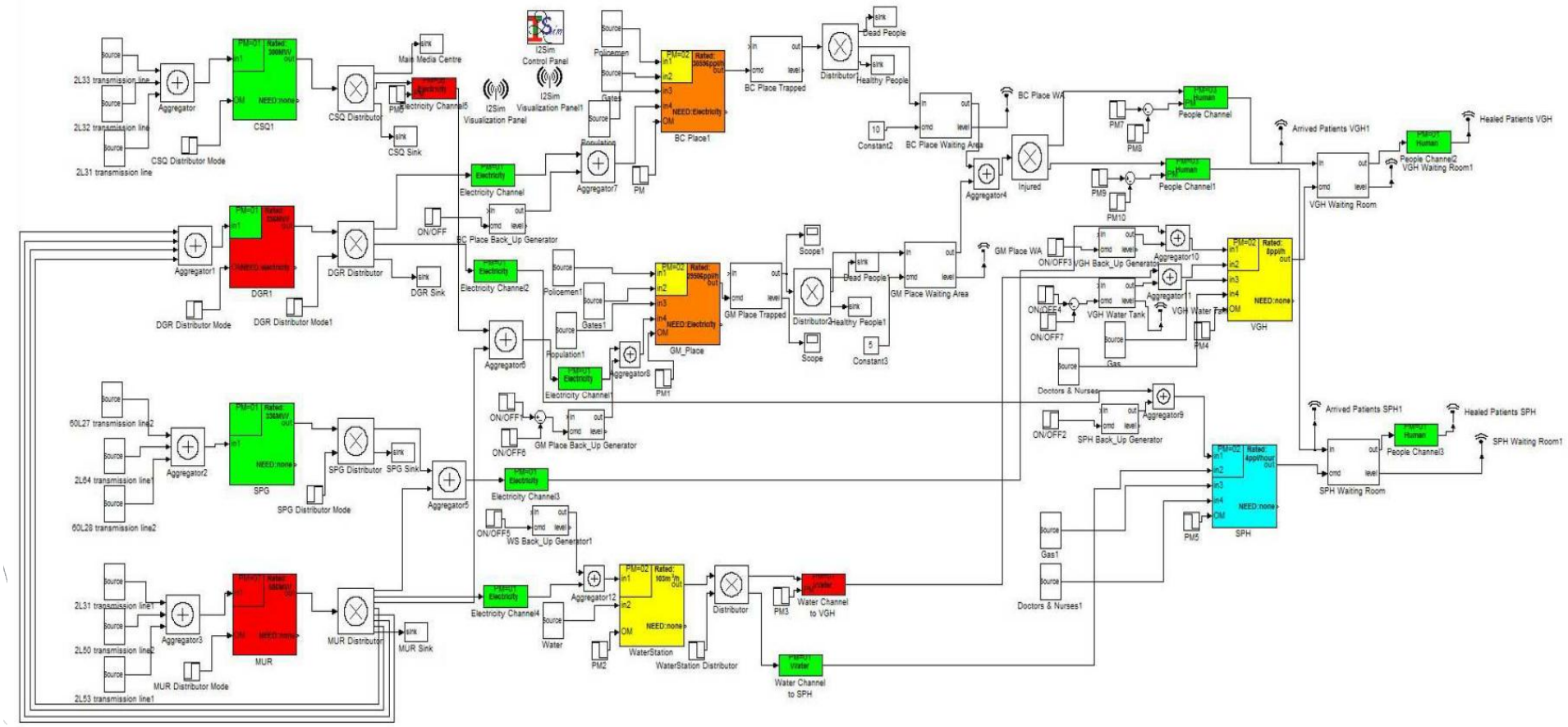
$$\begin{cases} h_i = \min\{ f_i\{x_i\}\} \\ d_i = g\{x_i, k_i\} \end{cases}$$

UBC Campus


Electrical Source
Electrical Substation
Hospital
Water Source 1
Water Pump Station
Other Facility


UBC Substation
Electricity
Water
Gas
Steam
Electricity Source
BC Hydro Substation
Electricity Channel
Substation Cell
UBC Hospital
Back-up Generator
Purdy Hospital Cell (Long-term Patients)
Treated Short-term Patients
Sink
Back-up Water Tank
UBC Power House
Power House Cell
UBC Water Station
Water Station Cell
Water Channel
Back-up Oil Tank
Water Source
GVRD
Medicine & Personnel
Source
Steam Station Cell
Gas Source
Terasen Gas
Gas Channel
Steam Channel
Returned Steam Source
UBC Steam Station
Koerner Hospital Cell (Short-term Patients)
Treated Long-term Patients

Vancouver 2010 Winter Olympics



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DRDC Project

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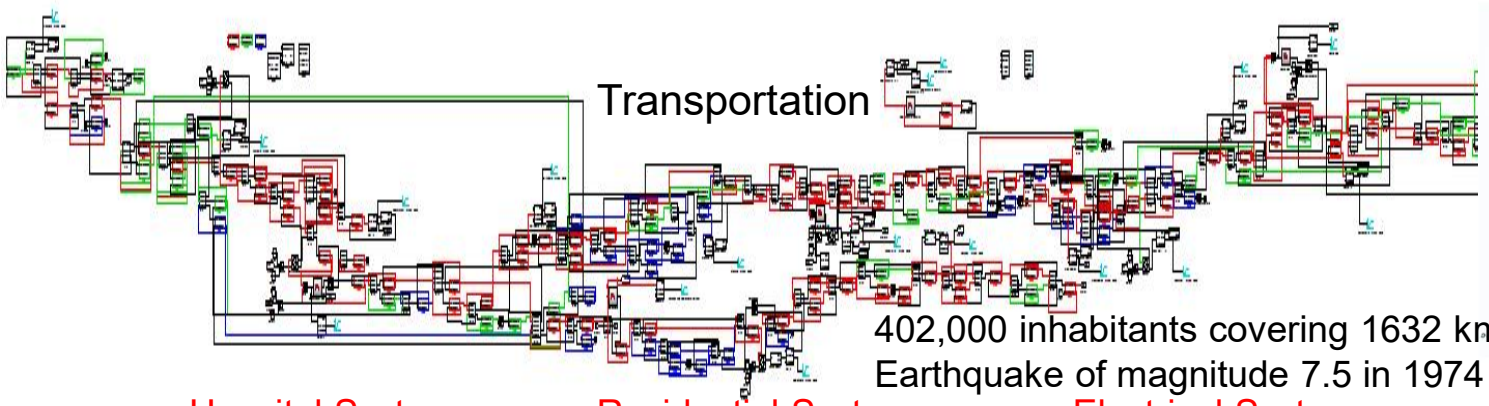
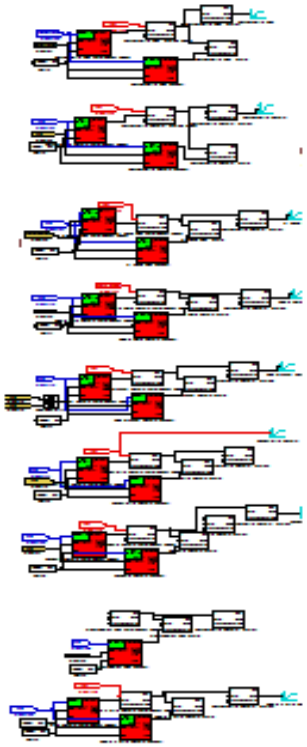
Guadeloupe Island Earthquake 1974



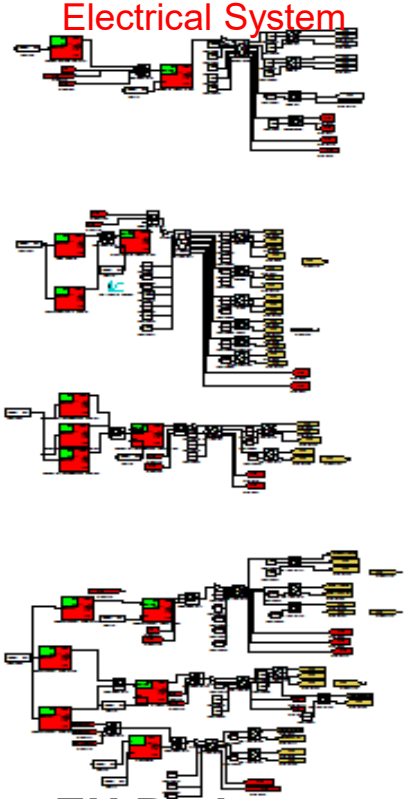
402,000 inhabitants covering 1632 km²
Earthquake of magnitude 7.5 in 1974

Hospital System

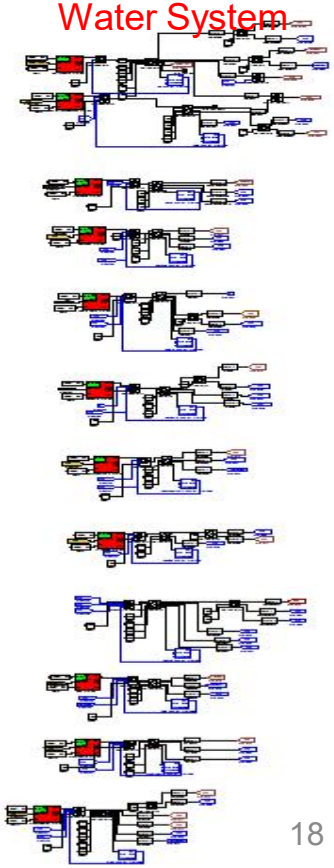


Residential System

Electrical System

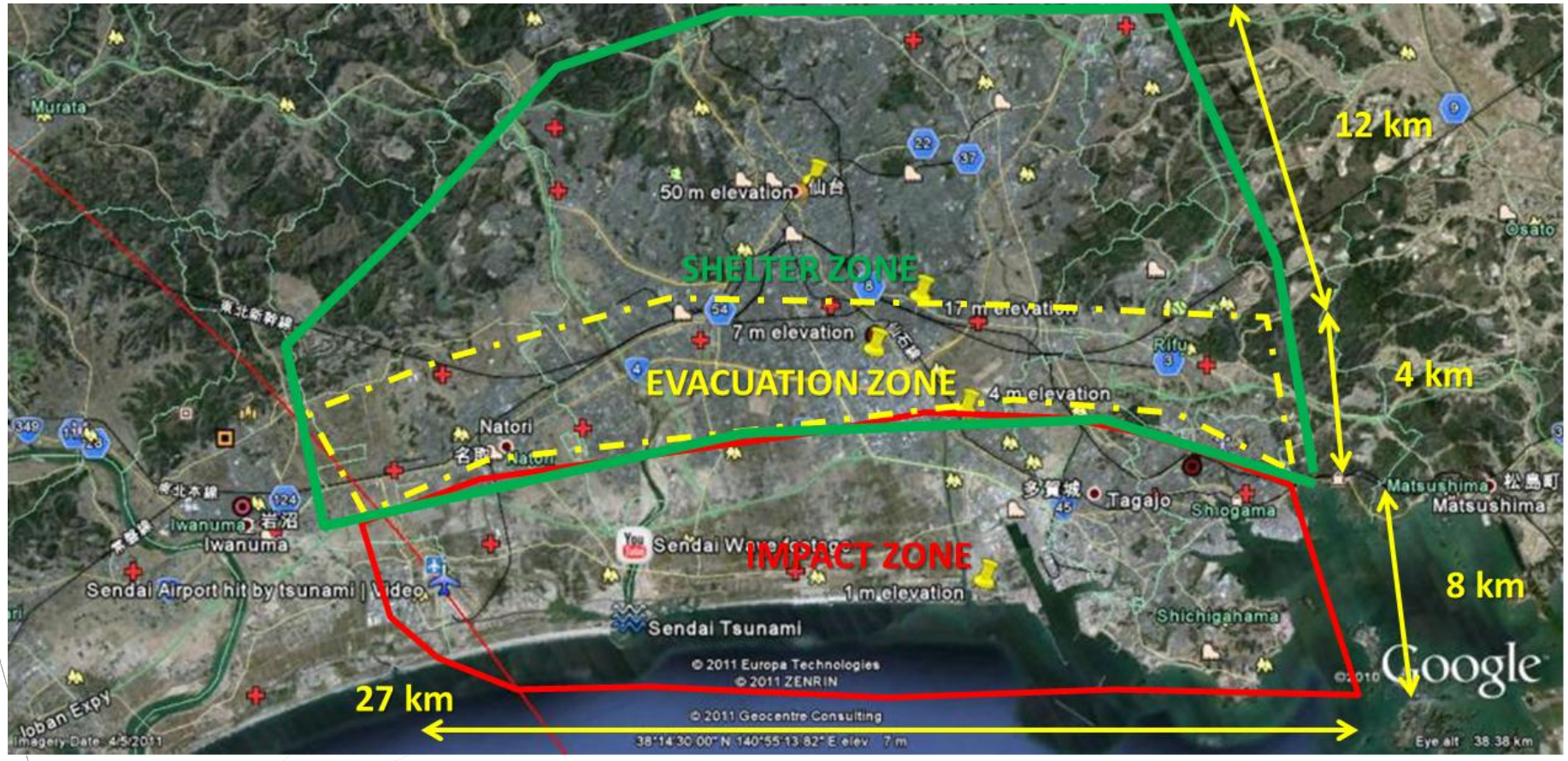


Water System

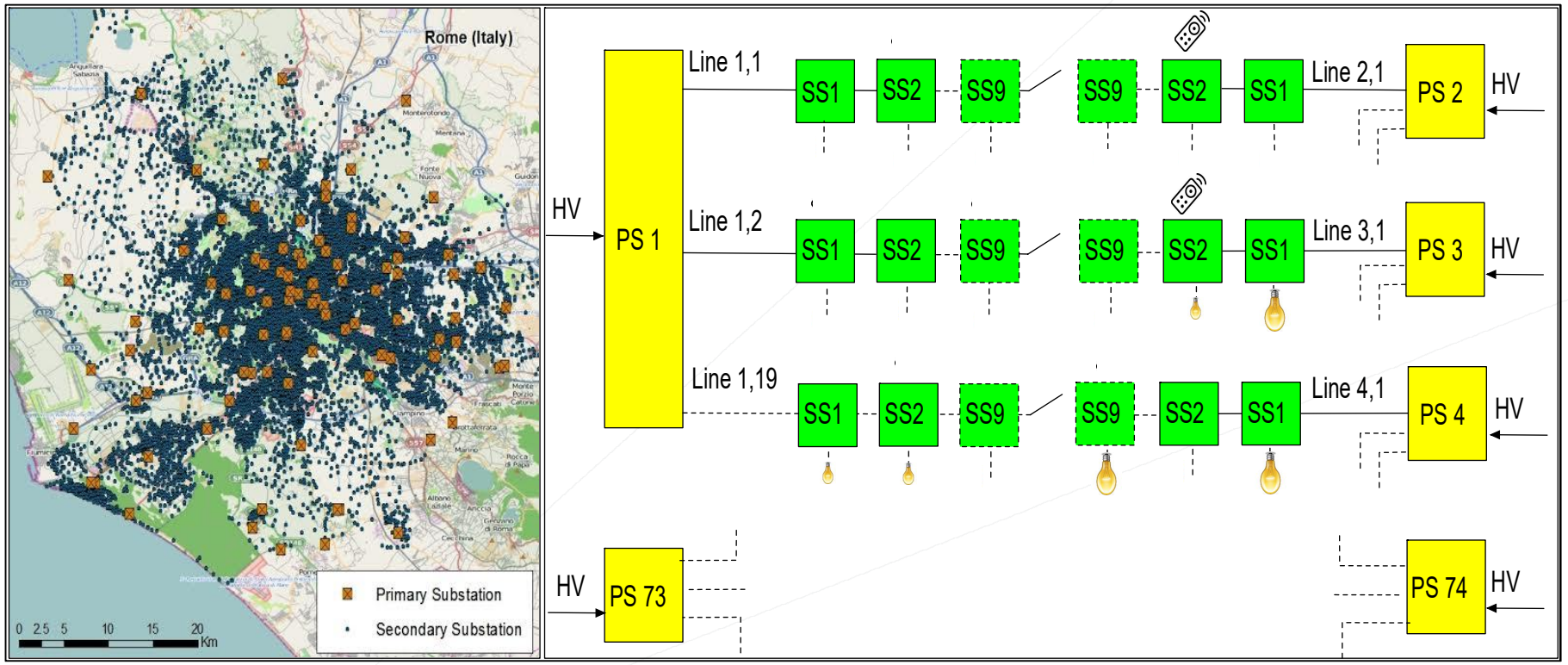


MATRIX fp7 EU Project

Japan Sendai Earthquake 2011



City of Rome Electrical System



1.6 million customers, 74 HV substations, 13,500 secondary substations

CIPRNet fp7 EU Project

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Thanks