Innovative Healthcare Modeling Methodology based on System Dynamics and State Transition Diagrams

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Outline

* Lean Healthcare, Kaizen and Six Sigma are rapidly transforming healthcare operations from 'new ideas' to a 'way of life'.
* The concepts of Lean are fairly straightforward, applying the tools to daily work can be counter-intuitive and thus require a credible model to be effectively applied.
* In traditional lean approach consultants take advantages from Value Stream Mapping, the adoption of 5-S and Visual Controls as well as batch reduction and cellular flow.
* Often these activities took very long time to be adopted mostly due to internal change resistance and lean implementation projects struggle for achieving their goals.
* In order to control budgets while ensuring proper level of assistance to their citizens a NHS requires modeling the various clinical processes (such as surgery, clinics, nursery) Modeling & Simulation Experts often propose both very detailed and high fidelity discrete-events models and approximate Systems Dynamics micro-world.
* In the authors experience none of such approaches definitively proven their superiority and a mixed approach has to be adopted.
* This paper presents an innovative approach where Systems Dynamics and State Transition Diagrams are integrated building a flexible and general model able to reproduce complex healthcare operations in a tradeoff between complexity and flexibility. The papers presents a complete case study applied to real life hospital. Methodology is presented and discussed.

Introduction

* Healthcare organizations are large, complex and adaptive.
* They show both ‘detailed’ complexity (large number of elements) and ‘dynamic’ complexity (many interconnections).
* At the same time have long processes crossing several organizational boundaries each with different cultures, accounting systems and performances measures. (*NHS Confederation, Issue 10, Oct. 2009*)

Lean Management in Health Care

* Incidents and quality problems claims to redesign health care systems such as: hospitals, clinics and hospices.
* One of the most used concept for such innovative design is Lean Thinking.
* Lean Thinking evolved from a tool designated to improve shop-floor performance in automotive to a complete management approach able to address many sectors including Health Care.
* However, application to health care has been limited and focused mainly on operational aspects using original lean tools.
* **Health Care requires to pay more attention to socio-technical aspects that are unique in a holistic approach.** (Joosen et al. 2009)

Lean Principles

* Lean Thinking is focused on standardization, inventory reduction and process performances improvement in order to create Value for the customer.
* Value is the capability of deliver exactly the customized “product” within a minimal time between request and response at the lowest possible “price”.
* In this way is possible to identify Value-Adding operations and Non Value-Adding ones.

* Various tools, first pioneered in Toyota, were eventually used in health care with notable results (Nelson-Peterson & Leppa 2007):
  * Reducing waste in inventory;
  * Reducing waiting times;
  * Improving Productivity;
* Some times these process improvements directly contributed to better quality care (*Jones et al. 2006*):
  * Reducing complications;
  * Reducing iatrogenic infections;

Lean Principles (2)

* Womack & Jones establish the 5 (operational) principles placing customer value and waste reduction at the center of Lean Thinking.
* At the same time some Authors pointed out that process improvement and customer value came at the expenses of the working conditions of the employees.
* For any Lean effort to succeed both operational and socio-technical aspects have to be addressed (De Treville & Antonakis, 2006).

	Five Principles of Lean Thinking
1	Provide the value customers actually desire
2	Identify the value stream and eliminate waste
3	Line up remaining steps to create continuous flow
4	Pull production based on customers consumptions (needs)
5	Stay over in pursuit the perfection

Critichal Aspects in Lean Thinking

* Lean has the potential to make jobs more simple and repetitive (standardization).
* These jobs may no longer be challenging to highly trained physicians.
* Such reduced complexity make possible for these jobs to be executed by less highly trained professionals.
* In this way more time is available to physicians to deal with more complicated patients.
* Making jobs too simple or repetitive may lead to resistance and anxiety.
* ***How a system that promote standardization can still be attractive to motivate workers?***

Towards a Systematic Approach

* In an effective application of Lean Thinking principle to health care two levels of intervention should be be addressed:
  * Operational: improve the process (traditional view)
  * Socio-technical: improve the quality of the work (innovative view)
* Introducing a Care Pathway have to lead both shorter admission times, maintaining a positive organizational climate while achieving better outcome rather than trading off a shorter admission time at expenses of workers' satisfaction (Ballè et al. 2007).
* Value, in health care, consists in a 'bewildering array of value-concepts, reflected in a plethora of quality measures and frameworks' (Young & McClean, 2008).
* This issues requires a model to be understood and properly managed.

Modeling & Simulation

* A manager's most important task is to create an environment where interaction among team members lead to a level of performance that can not be achieved by individual members alone (Berwick, 2003).
* Our limited ability to understand multiple interconnection among operational, social and technical variable requires the use of a quantitative model to manage complex adaptive organizations.
* Traditional techniques are mostly based on spreadsheets, static models with a limited transparency of assumptions.
* Innovative techniques require a way to test ideas before use as effective solutions.
* **Systems Dynamics (SD) is the origin of the current trend of 'whole systems thinking' in health and social care providing a set of thinking skills and a set of modeling tools.**

Systems Dynamics

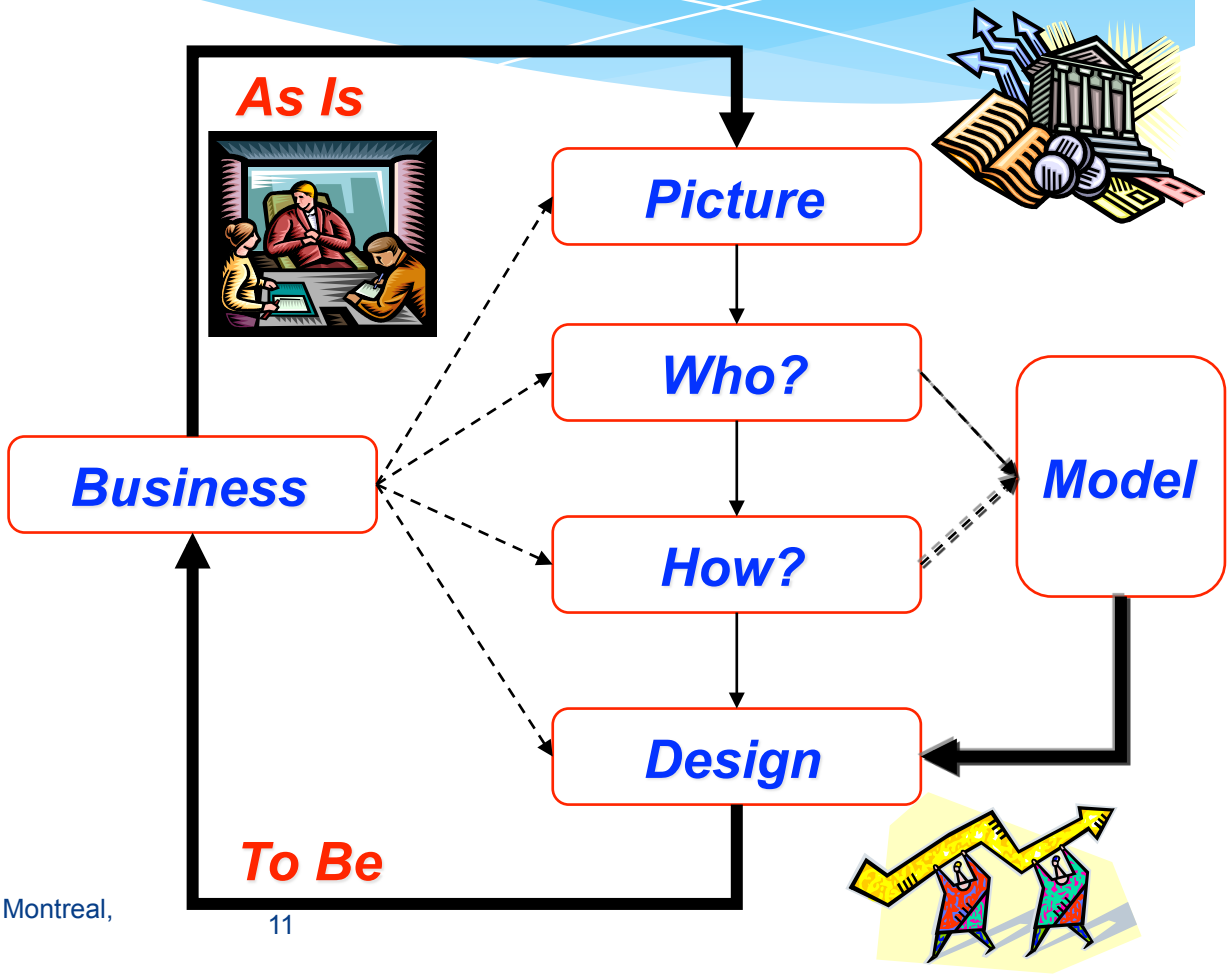
* Developed at MIT in the fifties, System Dynamics is a methodology that focuses on the internal structure of a system, underlying its feedback loops, cause-effect relations and delays.
* Instead of Discrete Event Simulation, that build bottom-up, System Dynamics is able to capture complexity from a top down approach that is much suitable for data driven applications.
* Using system dynamics is possible to see not just events, but also patterns of behavior over time.
* System Dynamics is also a powerful tool to support strategic Decision Making Processes.

Modeling Methodology

General methodology is based on the following 5 steps:

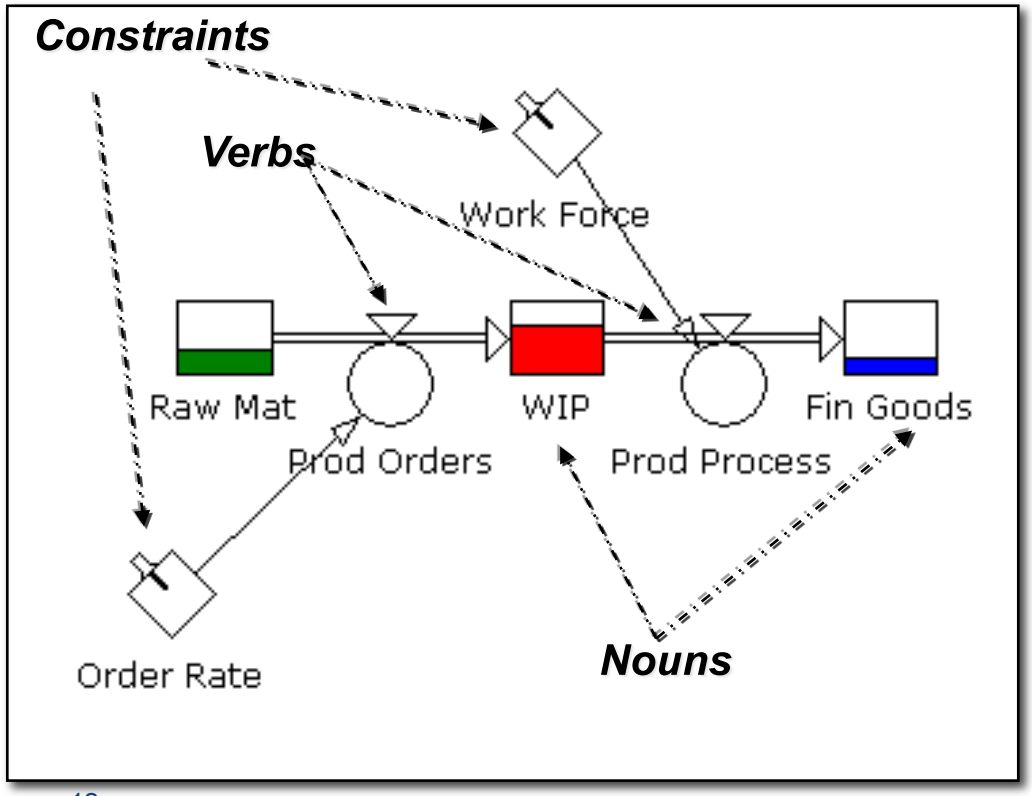
1. Understand Business (schema/as-is)
2. Identify Entities(nouns)
3. Identify Rules and Processes (verbs)
4. Create a model of the value's chain (model)
5. Improve the Business (design/to-be)

The entire model is based on 2 building blocks: stocks and flows.



SD Building Blocks

* The main building blocks of a SD model are Levels and Flows.
  * **Levels** are somewhat static or inactive. They have memory and they change only through the actions of flows. Without flows, levels would never change, and there would be no dynamic behavior.
  * **Flows** are action variables that create the dynamics of the system. They make level increase or decrease.
* Dynamic behavior can also occur with no feedbacks, because it is simply the result of flows accumulating in levels.



Creating the Model

* Theory of Constrains is another modeling approach that try to identify the limiting conditions of an economic system based on the following assumptions.
  * ***Business is a system and follows the system's theory.***
  * ***In every system exists a limited set of constraints that prevent business development.***
* To improve system's performances is necessary to identify such constraints and properly manage them.
* Starting from quantitative measures made on the system and using Operation Management's practices
  * Is necessary to work on the human resources learning mechanisms, overcoming cognitive limits in order to achieve better performances and to improve the overall utilization of the physical assets.

Process Modeling

Process Simulation

Performances Measurements

General Model for Health Care

* Based on the premises the general model has to address the following points:
  * Should be kept as general as possible
  * Should be completely Data Driven
  * Should reach a credible level of detail
  * ***Should model the standardization effect over the work organization (socio-technical aspect)***
  * ***Should model the learning curve of human resources in improving the performances (operational aspect)***
  * ***Should provide support to investigate over the effect of variability (natural and artificial)***

Addressing variability

* Natural variability is needed to effectively deal with individual differences between patients and their needs.
* Artificial variability is related to controllable factors in management of health care systems.
* Both variability have to be implemented in the model since, counter-intuitively, artificial variability may have a greater influence on health outcomes than natural variability.
* In literature (McManus et al. 2003) is found that the number of scheduled admissions (artificial variability) had a greater impact on overcrowding on an intensive care unit than the number of unscheduled admissions (natural variability).

Powersim Studio 8™

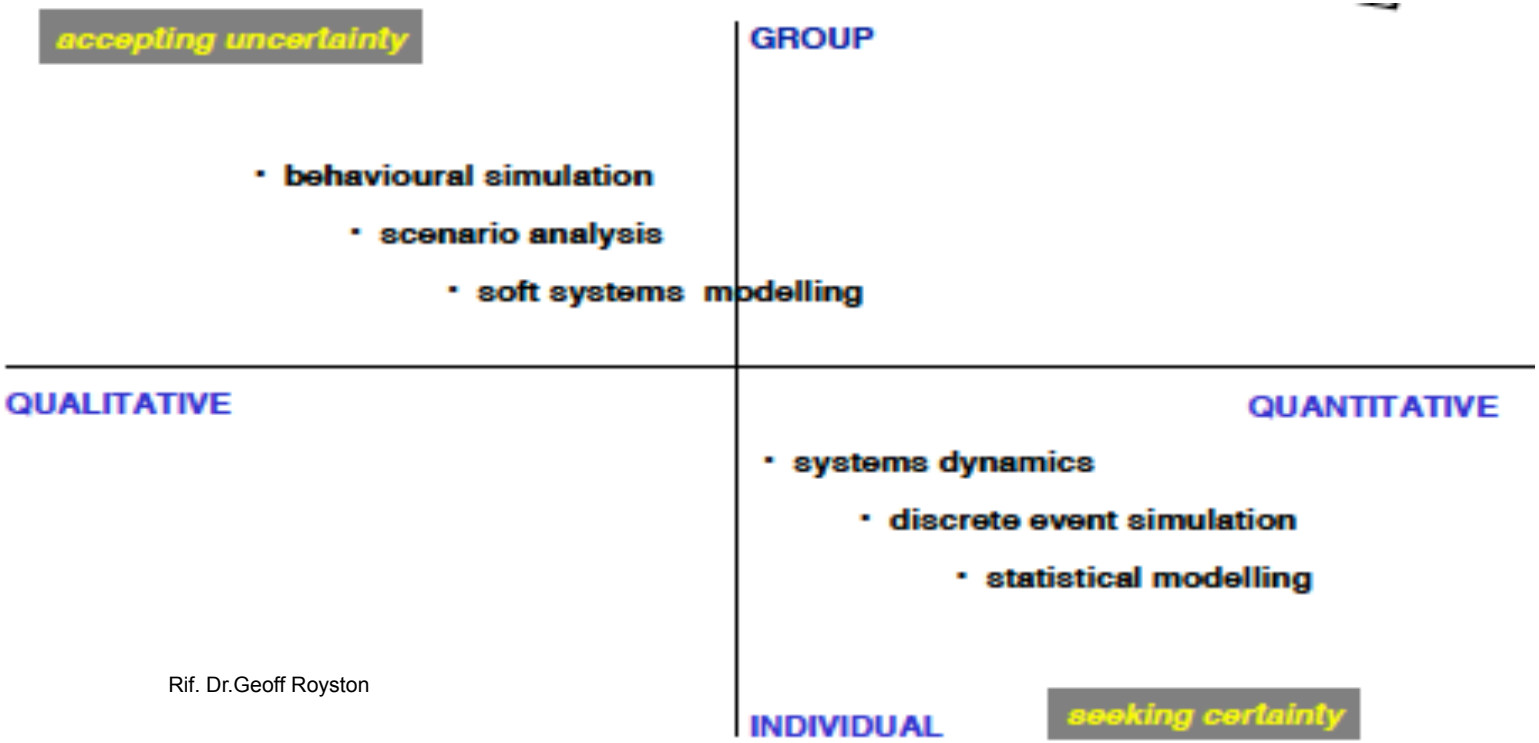
* Powersim™ is a Norwegian software house worldwide leader in the design and distribution of Business Simulation products.
* Powersim Studio 8™, differing from other System Dynamics software, is more rigorous (for instance, regarding units of measure), provides and Optimization module and a Risk Analysis tool, and can be interfaced with ERP, database and dataset coming from various sources.
* One of the most important aspect in the identification of the suitable SD modeling tool is its ability in defining vectored (layered) models.
* Powersim Sudio 8™ introduce also the possibility to study the effect of variability by cloning the current simulation into different scenarios.

General Considerations towards Modelling

* Necessity to optimize general organization about Healthcare systems, and the reducing of financial effort; have brought healthcare policy makers to consider different approaches more lean thinking orientated.
* Several methods more important, consider different aspects to enhance systems efficiency.

General Considerations towards Modelling

* Below, positions of main modelling utilized.



Rif. Dr.Geoff Royston

Modeling Approach

* Working in different big General Hospitals, we have utilized principally two approaches:

1. *Discrete Events Analysis* (pediatrics Hospital "G.Gaslini" Genoa)
2. *Systems Dynamics + State Transition Diagram* (General Hospital "Galliera" Genoa)

Using Discrete Event Simulation

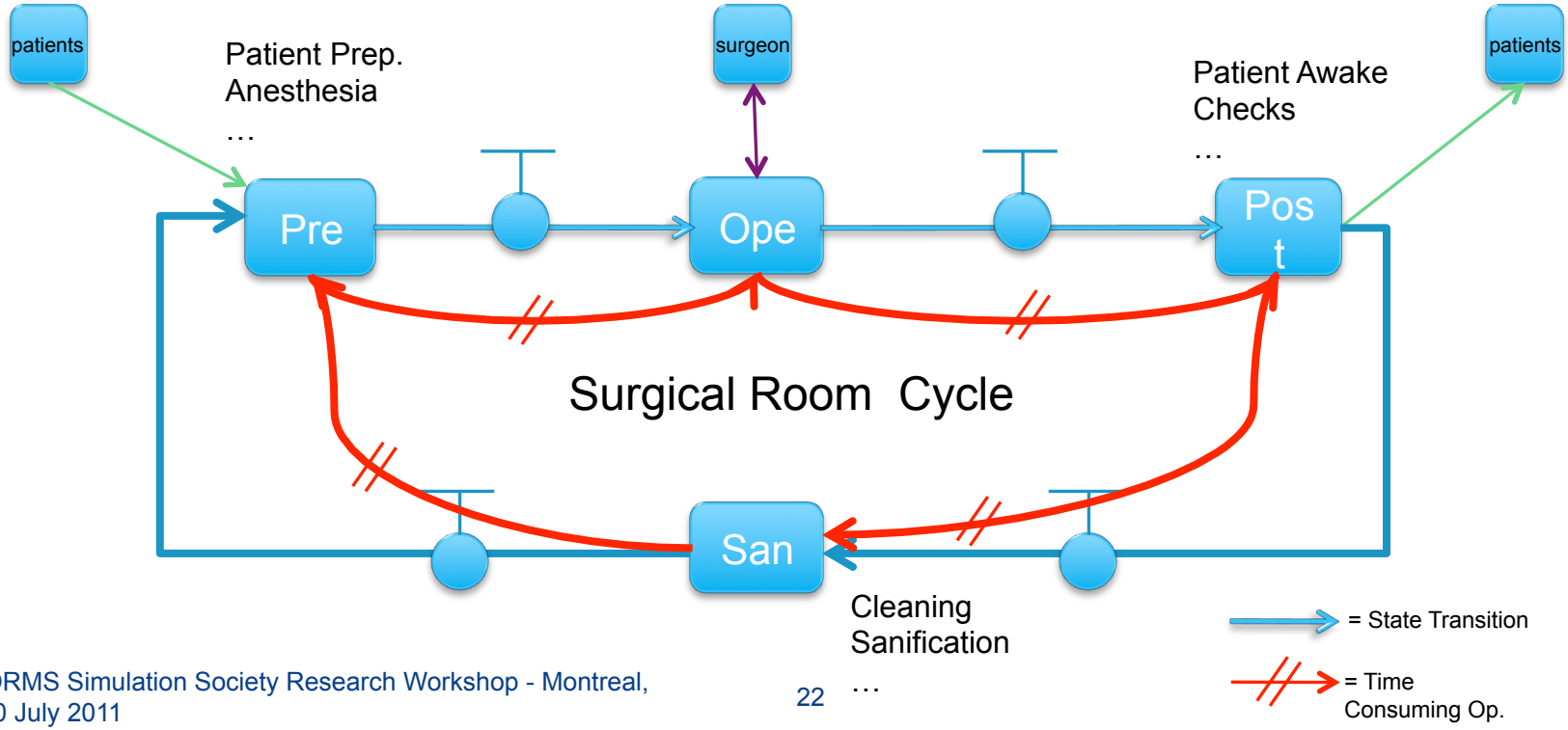
* In the *Case 1* (*discrete events analysis*) the main focus of the model was set to precision resulting in a very long Validation Campaign that stolen most of the work usually used for What If analysis.
* Discrete Event modeling is very useful when the system is a Laboratory, or a Surgical Room or generally a very detailed and measurable process.

Using Systems Dynamics

* In the *Case 2* (System Dynamics + *State Transition Diagram*) the goal is a more general model that gives a classification of the human behavior able to build a general process vision on Healthcare organization that represent the basis where new strategies and new organizations are tested before put to work.
* The aim of the model is not to working only on timing optimization of the various process but is most a way to create a new vision for the organization.

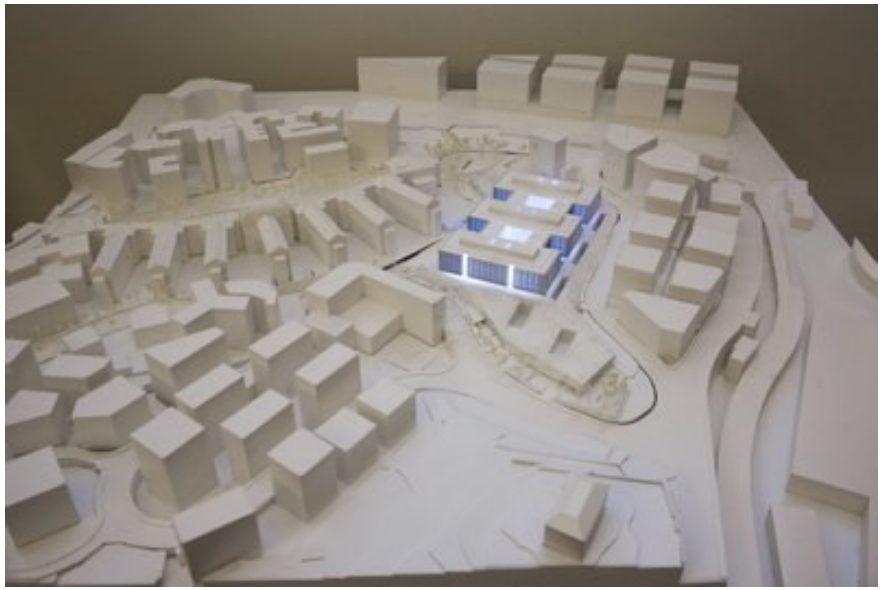
An Example: Surgical Room Organization

* The following is an example of state transition diagram in the systems dynamics approach on Operating Room Department



HospiX™ General Model

* HospiX™ was designed and implemented by DIPTEM in order to serve as general reference model for supporting the adoption of Lean Principle in one of the Genoa's big hospitals.
* The transition to Lean Health Care was established in coincidence with the development of the Hospital new buildings: new buildings leads to new operations.



HospiX™ General Model (2)

* The model is built using SD and is divided in three major schema:
  * Process: designed to capture the operational logic;
  * Human Resources: designed to model the socio-technical aspects;
  * Lean: designed to link Process and Human Resources with the Lean Healthcare principles and targets, identifying relationships and behaviors.
* Beside these three modules two other schema are used:
  * Stats: devoted to collect results and to prepare for KPI analysis;
  * GUI: it is the main controlling point of the simulation model and is used to control all the scenario variables.

Create a Vector Based Model

* Diagnosis-related group (DRG) is a system to classify hospital cases into one of approximately 500 groups, also referred to as DRGs, expected to have similar hospital resource use, developed for Medicare as part of the prospective payment system.
* The original objective of DRG was to develop a patient classification system that related types of patients treated to the resources they consumed.
* As of October 1, 2007 with version 25, the CMS DRG system re-sequenced the groups: DRG are now known as MS-DRG.
* Starting from Oct 1st the current version is MS-DRG 27, last position is 999 ().
* Since in Hospitals organization is roughly based on Department (DEP) the entire simulation is modeled over the two dimensions DRG and DEP.

A Case Study: Future Hospital

* The simulation was built using:
  * 11 DEP (1 for each Departement)
  * 25 DRG
* Average IAT was set to 22 pat/day per DEP
* DEP_DRG Time matrix [11x25] was set using results from IBM Cognos 8 BI extracting data of the last 2 years patients records;
* ***Productivity improvement was set to +10%***
* ***Operational improvement was set to +15%***
* ***Standardization was set to -20%***
* ***Time to reach the goal was set to 3 months***
* ***Uniform variability (+/- 10%) was added***
* ***New Schema of Surgical Room Organization was set based on the previous figure.***

* Hospital is currently organized to provide:
  * First Aid, (60,000 pat/yr)
  * Day Hospital (100,000 pat/yr)
  * Surgery (20,000 pat/yr)
  * Medical Care (25,000 pat/yr)
* Organization is based on 11 Departments and 68 Operative Units (OU).
* Hospital treats approx. 25 DRGs.

Results

- ***Surgeons Ut% move from 48% to 75%***
- ***With 12 more shifts of Anesthesiologist more than 123 nursery shift were saved***

Conclusions

* Health Care may get lots of benefits from the adoption of the Lean Thinking.
* However Lean Health Care has some difficulties in order to be adopted: tradeoff between Operational and Socio-Technical objective is just one of the examples.
* Lean Health Care needs a model in order to test ideas before use as effective solutions.
* The model should be general and completely data driven in order to be configured and used in a very short timeframe.
* The use of SD has proven to be very effective in the modeling of a complex Hospital especially thanks to its ability in capture complexity in a friendly manner.
* A practical implementation of the proposed approach has been presented and discussed demonstrating the practical use of the methodology.