

Designing Care Pathways Using Simulation Modeling and Machine Learning

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Main Points

- Background: Value-based Care Delivery (Porter's Strategy)
- A Framework for M&S of Value-based Health System
- Use Case: Pathways Coordination for Hip Fracture Care in Ireland

Background: Value-Based Care Delivery (Porter's Strategy)

Key Issues around Healthcare Delivery

- **Universal Coverage:** Essentially required to support fundamental reorientation of the delivery system around value.
- **Cost Containment:** Financial success for healthcare providers does NOT necessarily mean success for patients.
- **Value of Care :** Usually ill-defined, though it has to be the core issue.

Value: Outcome per unit cost at the output of the end-to-end care delivery value chain (CDVC).

(Michael Porter 2006)

Principles of Value-Based Healthcare Delivery

(Michael Porter 2006)

- Prevention of illness
- Early Detection
- Right diagnosis
- Right treatment to the right patient
- Early and timely treatment
- Rapid cycle time of diagnosis and treatment
- Fewer complications
- Fewer mistakes and repeats in treatment.
- Faster recovery
- More complete recovery
- Less disability
- Fewer recurrences

Better health is the goal, NOT more treatment.

Key Questions

- How to design a healthcare system that can improve patient value?
- How to engineer a dynamic system for healthcare delivery that can sustainably improve patient value?

A Strategic Agenda for Value-Based Healthcare

(Michael Porter 2013)

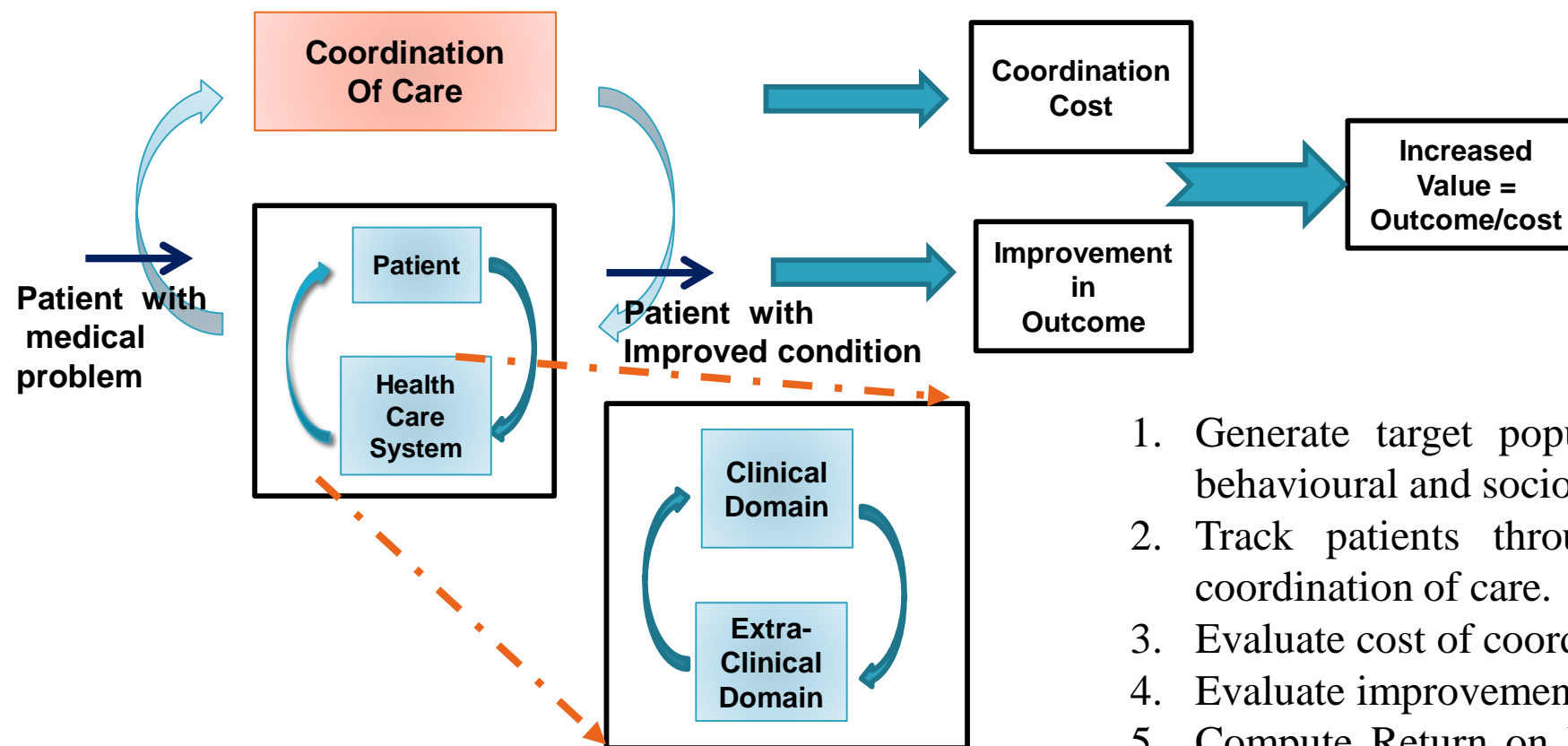
1. Organize into Integrated Practice Units (IPUs)
2. Measure Outcomes and Costs for Every Patient
3. Move to Bundled Payments for Care Cycles
4. Integrate Care Delivery Systems
5. Expand Geographic Reach
6. **Build an Enabling Information Technology Platform**

Our Objective

- Formalize Porter's IPU with System-of-Systems Modeling and Simulation
- Formulate criteria for creation of IPU's viewed as systems
- Many questions, e.g., can a collection of systems with their care delivery value chain be integrated into a viable system?

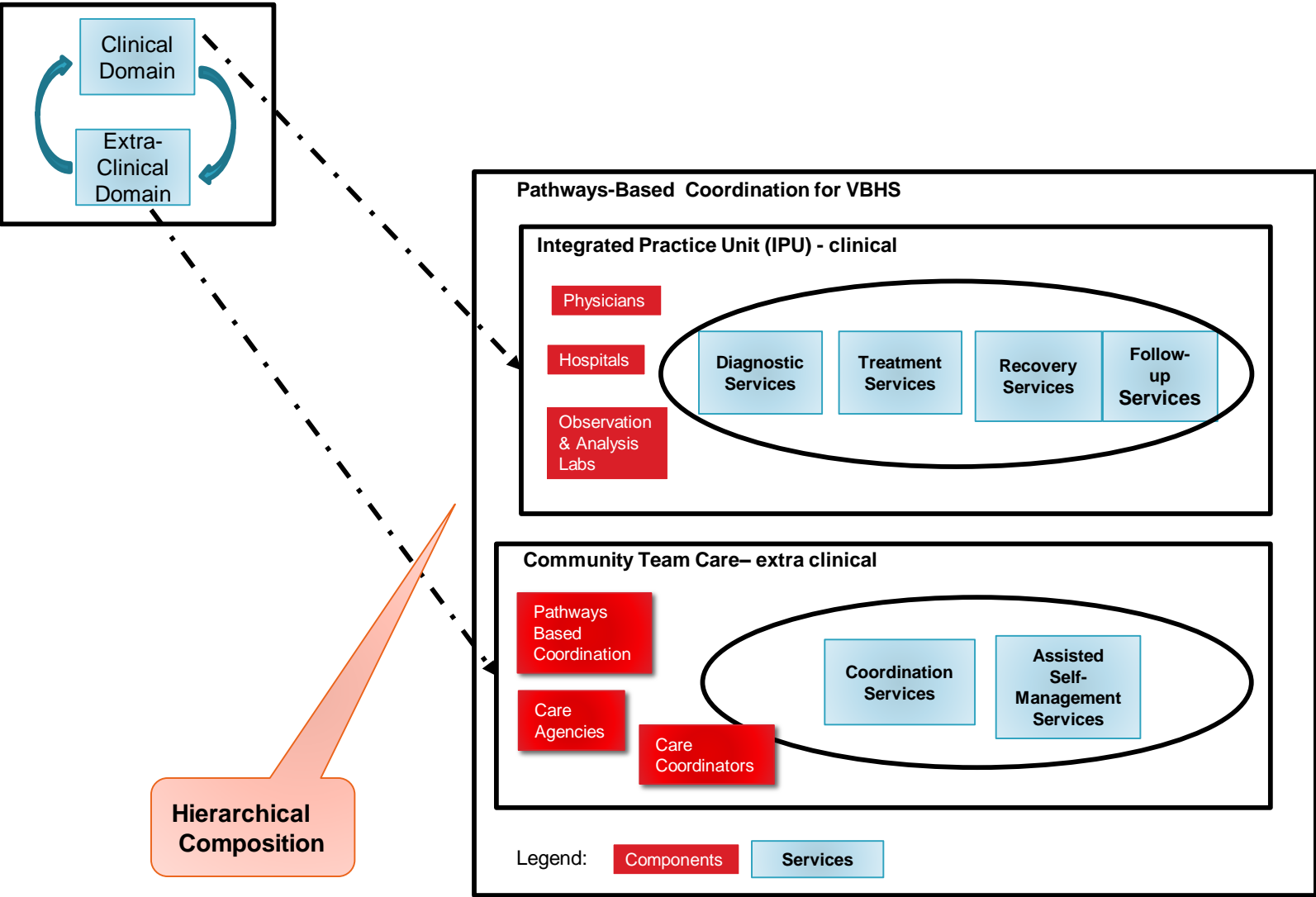
A Framework for M&S of Value-based Health System

M&S Framework of Value-Based Health System

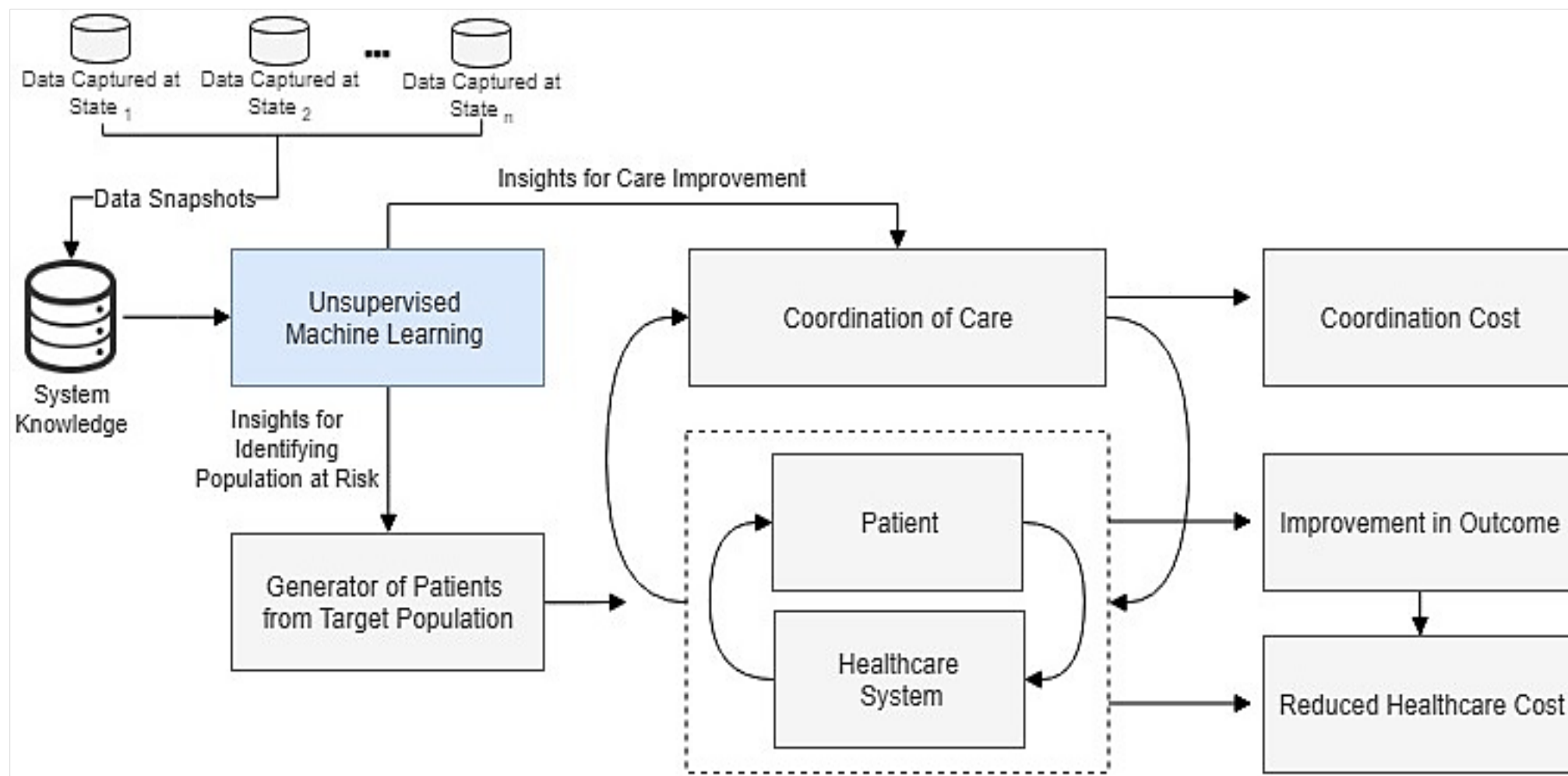


1. Generate target population of appropriate physical, behavioural and socioeconomic characteristics.
2. Track patients through system with and without coordination of care.
3. Evaluate cost of coordination as addition to total cost.
4. Evaluate improvement in outcome and effect on cost.
5. Compute Return on Investment (ROI) = Cost saving per dollar of coordination cost.

M&S Framework of Value-Based Health System (cont'd)



The Role of Machine Learning: Incremental Learning from Data



Use Case: Pathways Coordination for Hip Fracture Care in Ireland

Our Focus: Hip Fracture Care in Ireland

- A good exemplar of elderly healthcare.
- Exponentially increasing with age.¹
- Identified as one of the most serious injuries resulting in lengthy hospital admissions and high costs.²
- Availability of empirical data from the Irish Hip Fracture Database (IHFD).

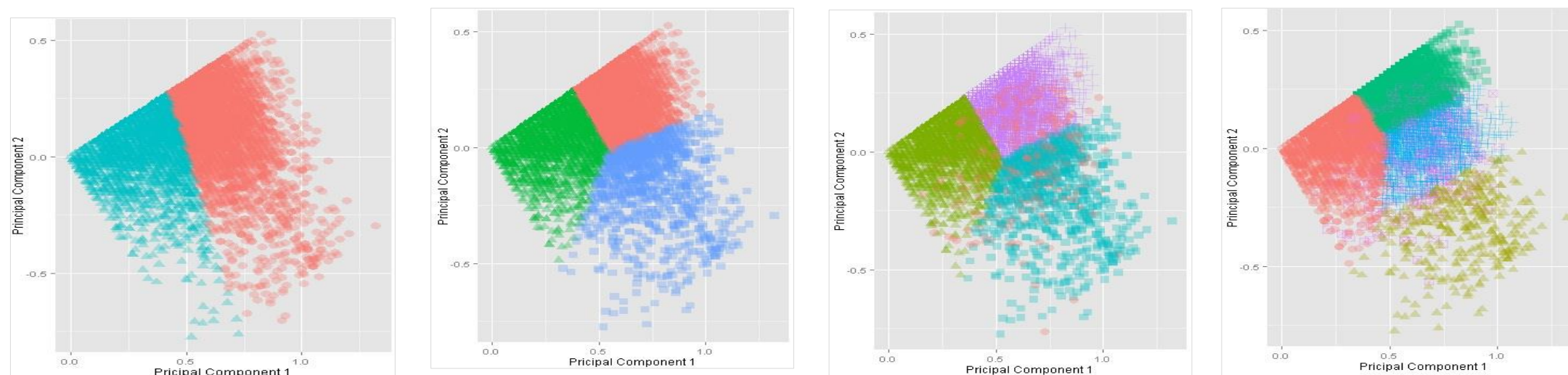
¹ Gullberg, B., Johnell, O. and Kanis, J.A., 1997. World-wide projections for hip fracture. Osteoporosis international, 7(5), pp.407-413.

² http://www.hse.ie/eng/services/publications/olderpeople/Executive_Summary_Strategy_to_Prevent_Falls_and_Fractures_in_Ireland%E2%80%99s_Ageing_Population.pdf

Sources of Data

- Irish Hip Fracture Database (IHFD) (2013-2015).
- Population projections from the Central Statistics Office (CSO).
- Additional population statistics from the Health Intelligence Department.

Learning Patient Clusters from Data

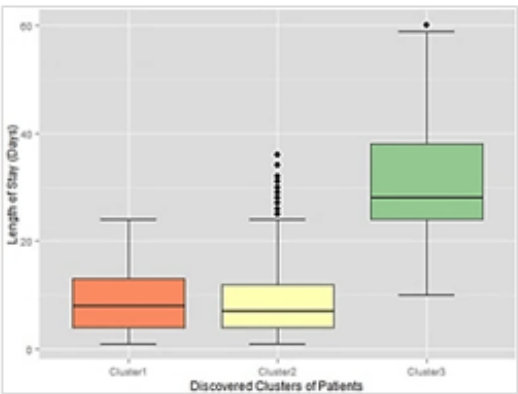


Visualisation of K-Means clustering with K ranging from 2 to 5.

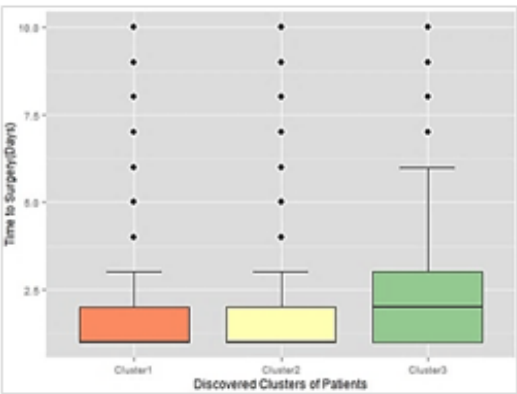
Clustering of patients based on:

- LOS
- Age
- Time to Surgery

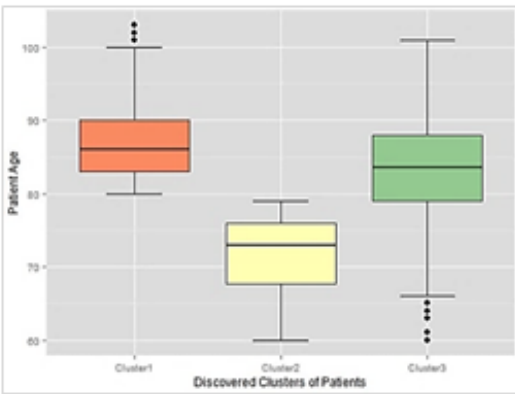
Insights from Clusters



(a) LOS.

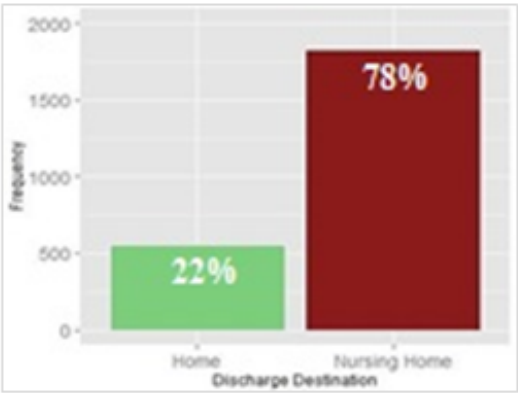


(b) TTS.

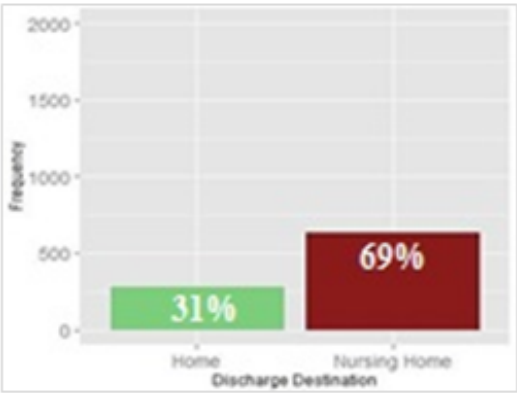


(c) Patient age.

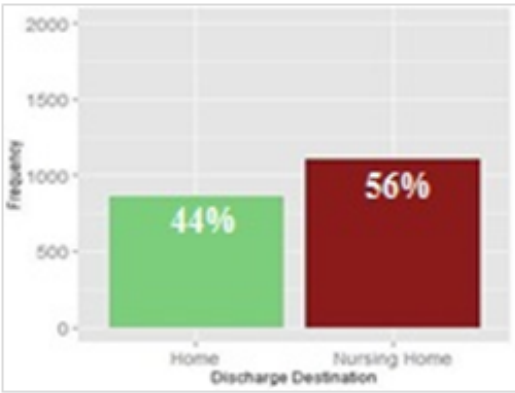
Figure: The variation of the LOS, TTS, and age variables in the patient clusters.



(a) Cluster1.



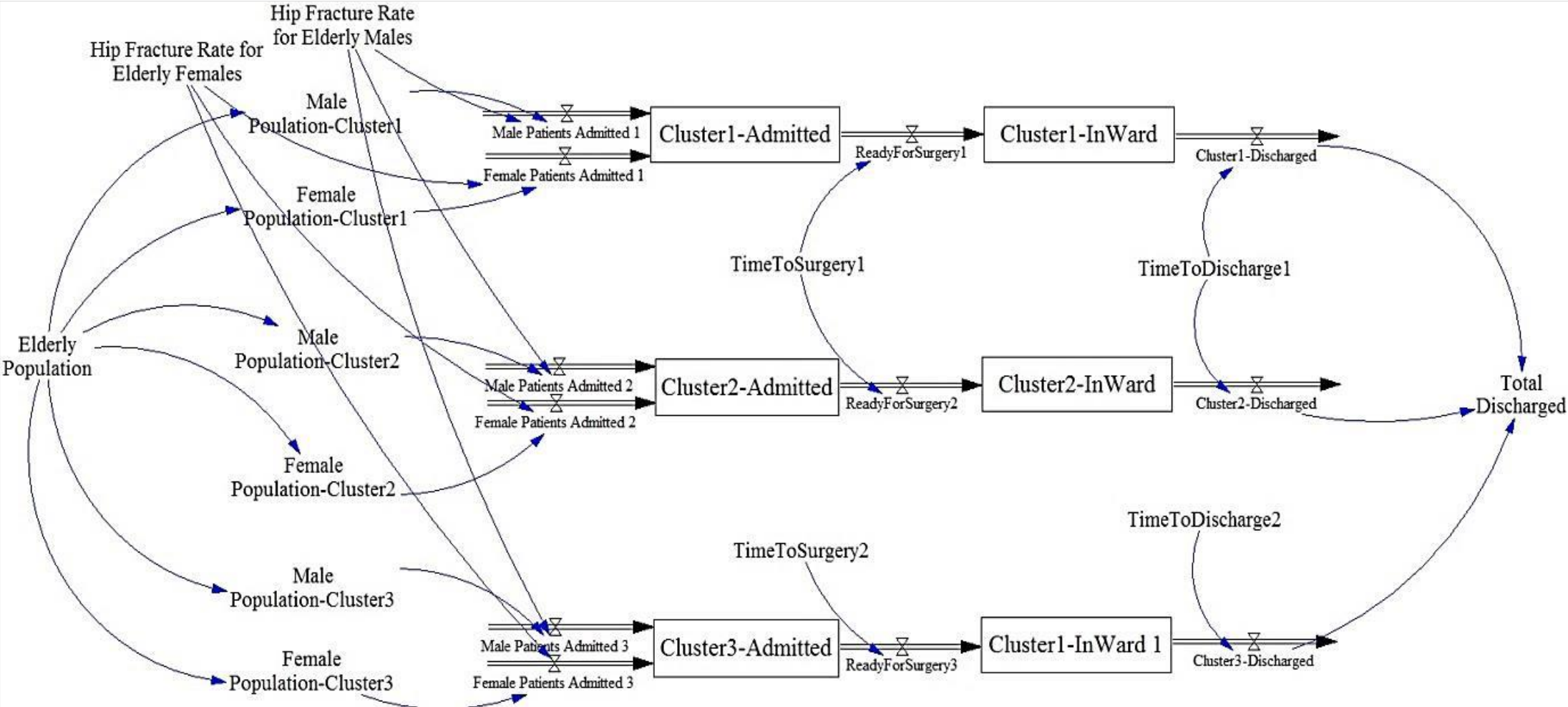
(b) Cluster2.



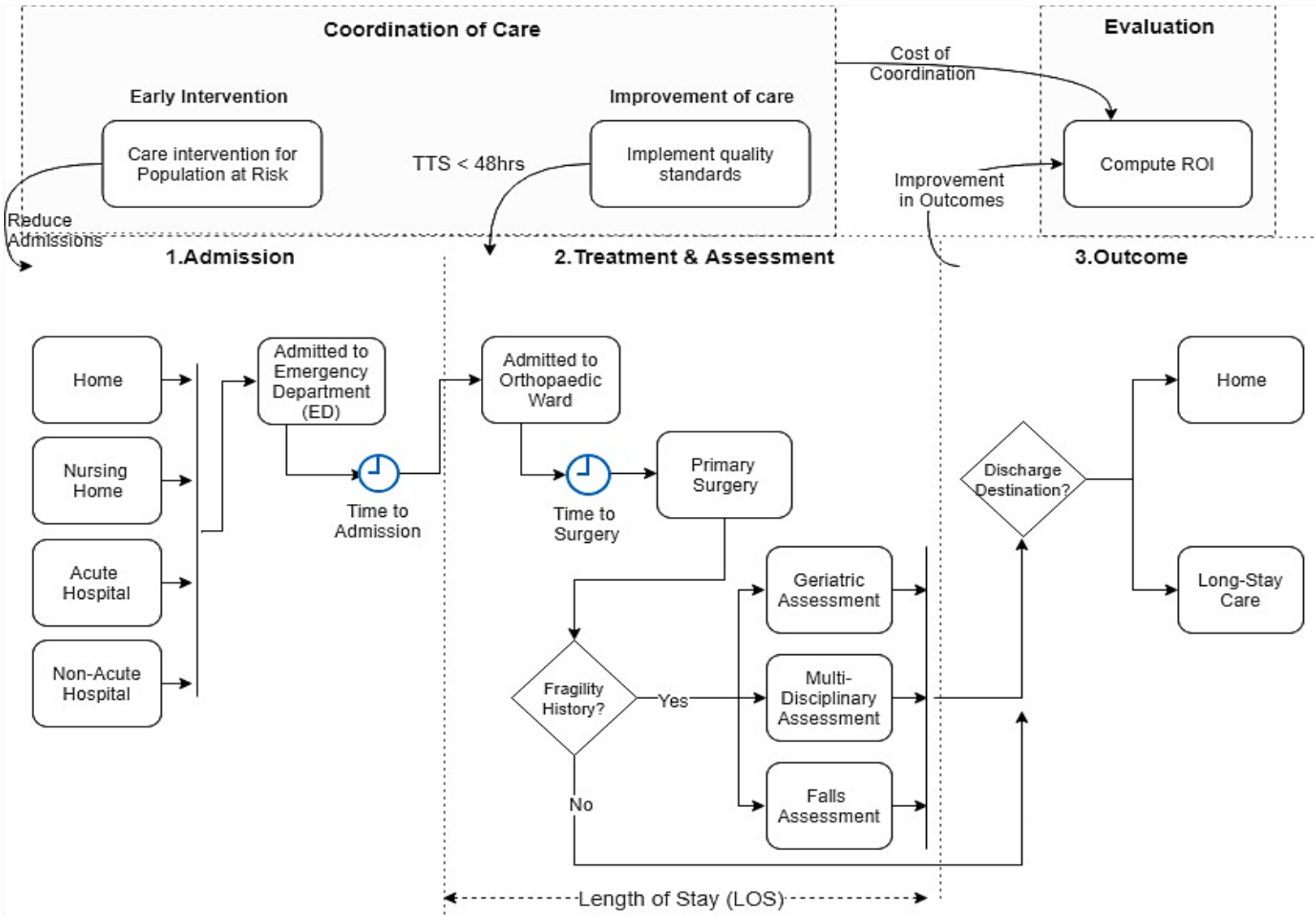
(c) Cluster3.

Figure: The variation of discharge destinations in the patient clusters.

Reflecting Data-Driven Insights on Model Design



Modeling Care Coordination



Summary

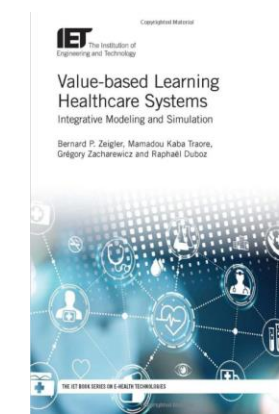
- Health Care Reform is usefully viewed as a Systems Problem.
- Porter's Value-based Health care within a more inclusive Pathways Coordinated Care framework provides needed coordination.
- The proposed framework incorporates M&S with ML for designing pathways and evaluating the ROI of implementation.
- ML can generally be utilised as an assistive artefact within the process of conceptual modeling.

Publications

- Zeigler, B. P., E. L. Carter, O. Molloy, and M. Elbattah. 2016. "Using Simulation Modeling to Design Value-Based Healthcare Systems". In Proceedings of the Operational Research Society Annual Conference (OR58), 6th -8th September, Portsmouth, England.
- Zeigler, B P., (2016) "Discrete Event System Specification Framework for Self-Improving Healthcare Service Systems," IEEE Systems Jnl. [Volume:PP Issue:99](#)
- Zeigler, B P.; Ernest L., et al. (2016) "Guiding Principles for Data Architecture to Support the Pathways Community HUB Model," eGEMs , <http://repository.edm-forum.org/egems/vol4/iss1/1>
- Zeigler, B P.; Ernest L., et al. (2014) "Community HUB Pathways: A Model for Coordination of Community Health Care," Population Health Management, vol. 17, no. 4, pp. 199-201.
- [Zeigler, B P.; Ernest L., et al. \(2014\), Care Coordination: Formalization of Pathways for Standardization and Certification,](#)
- [Innovations Exchange Team, B.P., Zeigler, S. A. Redding. Formalization of the Pathways Model Facilitates Standards and Certification.](#)
- Zeigler, B P.; Ernest L., et al. (2012) "Methodology and Modeling Environment for Simulating National Health Care" 2012 Autumn Simulation Multi-Conference (AutumnSim'12) October 28-31, San Diego,CA..

Value-based Learning Healthcare Systems: Integrative modeling and simulation (Healthcare Technologies)

by Bernard P. Zeigler, Mamadou K. Traore, Grégory Zacharewicz, Raphaël Duboz
The Institution of Engineering and Technology (January 10, 2019)



THANK YOU!

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Care Pathways

- Generally speaking, clinical care pathways (CP) consist of algorithms (usually informally presented as a flow chart with conditional branching) that delineate the overall structure of decisionmaking for treating a specific medical condition. CPs are referenced in the literature under a variety of names such as clinical pathways, critical pathways, and clinical process models, and there is no single, widely accepted definition, although key characteristics have been extracted from over 200 articles (79). Since the introduction in the 1990s, CPs have become widespread in hospital health care management (80).
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- A comprehensive analysis of 27 published studies compared outcomes and costs for hospitals that used clinical pathways with those that do not. It found CP use was correlated with benefits in reduction of in-hospital complications, decreased length of stay, and reduction in hospital costs (81). A recent large scale study for knee surgery found reduction in length of stay and avoidance of treatment complications for hospitals using CPs versus non-users (82). Based on the concept analysis of de Bleser et al. (79), the European Pathway Association derived an all-inclusive definition of CP (83): “A care pathway is a complex intervention for the mutual decision making and organization of care processes for a well-defined group of patients during a well-defined period.”
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- Defining characteristics of CPs include:
 - An explicit statement of the goals and key elements of care based on evidence, best practice, and patients’ expectations and their characteristics;
 - The facilitation of the communication among the team members and with patients and families;
 - The coordination of the care process by coordinating the roles and sequencing the activities of the multidisciplinary care team, patients and their relatives;
 - The documentation, monitoring, and evaluation of variances and outcomes; and