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Using Simulation Modeling to Design Value-Based Healthcare Systems

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Full-Text Available at

- https://www.researchgate.net/publication/308138628_Using_Simulation_Modeling_to_Design_Value-Based_Healthcare_Systems

Conference Paper | Full-text available

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Bernard Phillip Zeigler · Ernest Carter · Owen Molloy · Mahmoud Elbattah

Main Points

- ***Modeling and Simulation Framework***
  guides design, development, and evaluation of architectures
  to produce ***value (end-to-end outcome/cost)*** in health care.

- ***Value-Based Health Systems*** (VBHS)
  comprise both clinical (medical) and
  extra-clinical (social, transitional) care subsystems.

- Reforming/Improving VBHS depends on
  implementing a ***holistic learning health information infrastructure*** that
  supports human decision making about protocols, processes, and procedures that work together to support the value-based paradigm.

- ***Pathways-based*** VBHS architecture
  coordinates ***clinical and extra-clinical services*** to at-risk populations and
  assures ***goal attainment, accountability, and pay-for-performance.***.

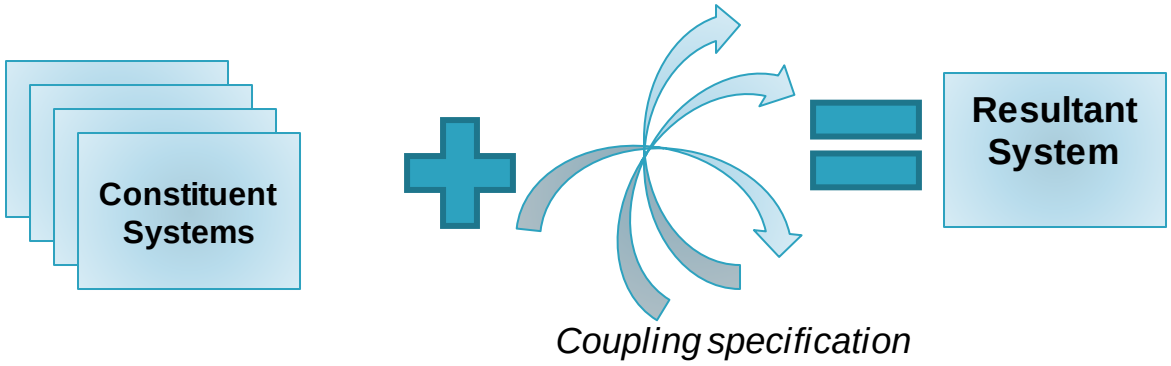
Overview

- Background: Health System Modeling and Simulation Framework
  - System Theory and Systems-of-Systems (SoS)
  - Discrete Event Systems Specification (DEVS) modeling and simulation framework
  - DEVS formalization of Health Systems SoS
  - Modeling and Simulation Environment Implementation
- Fixing Healthcare System: Value-Based Care (Porter's Strategy)
- Pathways-Based Coordination of VBHS
- Use Cases
  - (USA) : Pathways Coordination in Low Birth Weight Prevention
  - (Ireland): Pathways Coordination in Hip Fracture Care

BACKGROUND: SYSTEM MODELING AND SIMULATION

Wymore's Mathematical System Framework*

- Composition of Systems – *constituent systems* and *coupling* specification result in a system with structure and behavior emerging from their interaction
- Closure under coupling – resultant is a well-defined system just like the original components



*Tuncer I. Ören and B. P. Zeigler, "System Theoretic Foundations of Modeling and Simulation: A Historic Perspective and the Legacy of A. Wayne Wymore", SIMULATION September 2012 vol. 88 no. 9 1033-1046

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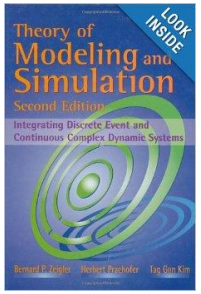
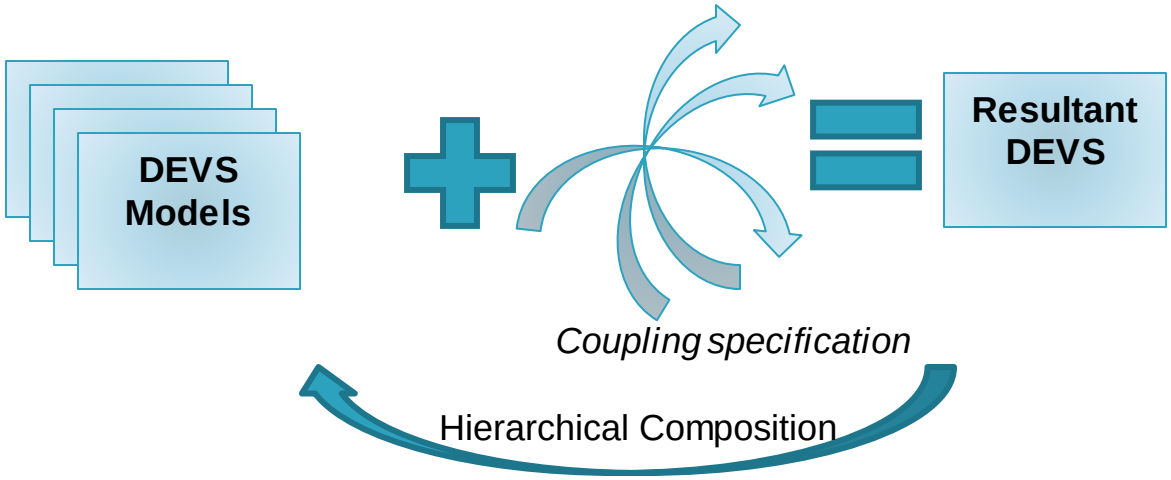
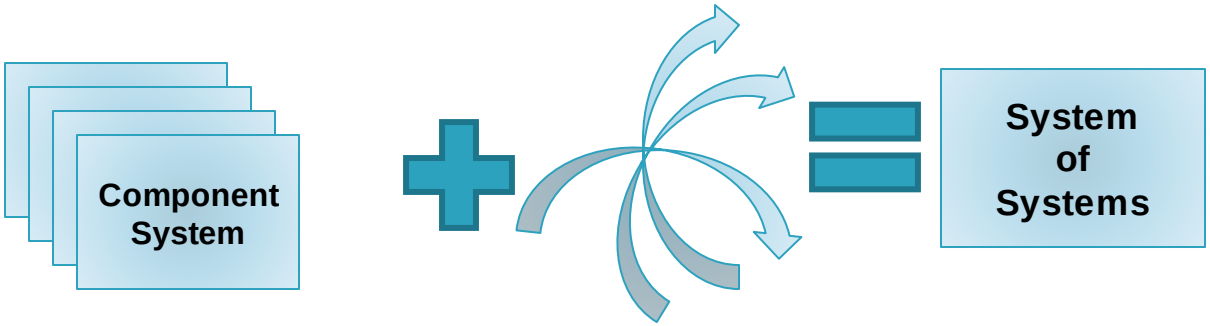
Discrete Event System Specification (DEVS) Formalism

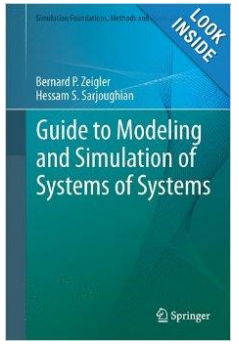


- DEVS Atomic and Coupled Models specify Wymore Systems
- Composition of DEVS Models – *component* DEVS and *coupling* result in a DEVS with structure and behavior emerging from their interaction
- Closure under coupling – resultant is a well-defined DEVS just like the original components



MS4 Systems DEVS IDE Support of Systems of Systems*



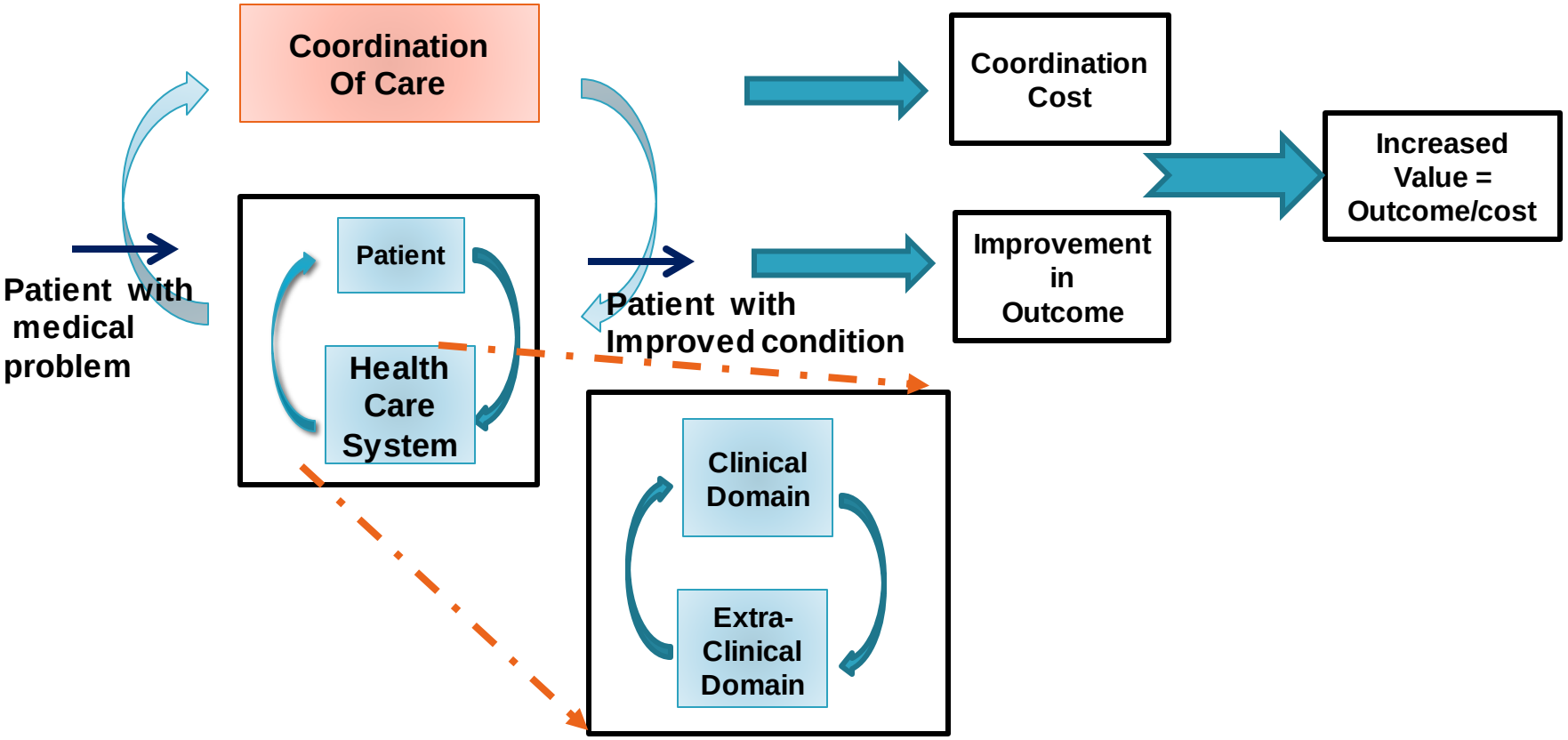


- System of Systems (SoS) – composition of systems - *component systems* have legacy properties e.g., autonomy, belonging, diversity
- Coupling has properties e.g., connectivity, coordination
- Structural and behavioral properties characterize resulting SoS such as fragmented, competitive, collaborative, coordinated

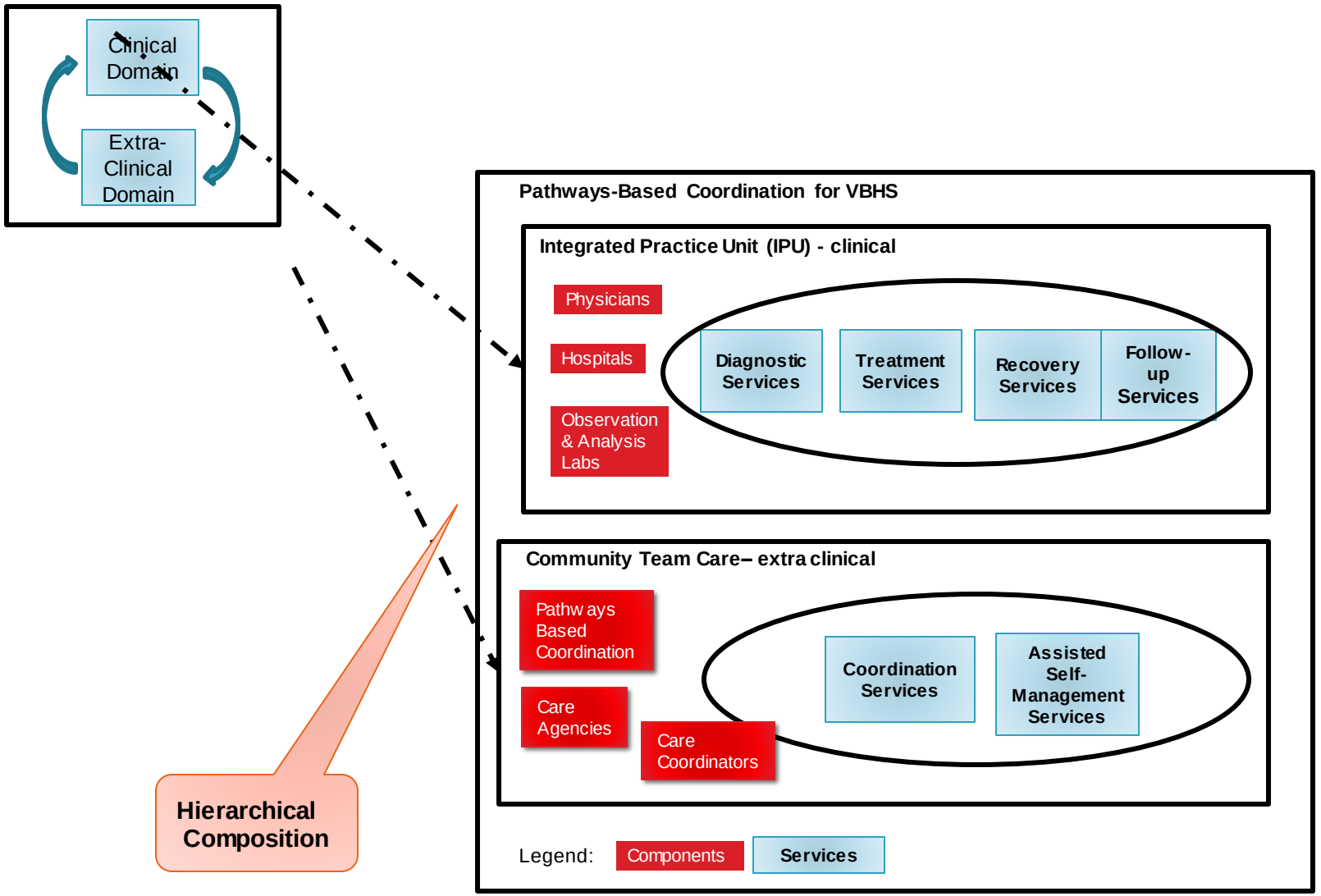
* Guide to Modeling and Simulation of Systems of Systems, Bernard P. Zeigler and Hessam S. Sarjoughian, Springer; 2013 edition (December 28, 2012)

VALUE-BASED HEALTH SYSTEM (VBHS) MODELING AND SIMULATION FRAMEWORK

Value-Based Health System (VBHS) Modeling and Simulation Framework (1)



Value-Based Health System (VBHS) Modeling and Simulation Framework (2)



MS4 Systems DEVS Integrated Development Environment (IDE)

- DEVS provides computational basis for modeling and simulation using Wymore's system framework
- DEVS Multi-formalism systems support enables discrete event and continuous models in same simulation environment
- MS4 IDE supports working directly with systems engineering models and concepts
- MS4 IDE supports implementation of VBHS in web-based cloud environments

http://www.ms4systems.com

FIXING HEALTHCARE SYSTEM: 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)*

Porter, M.E. and Teisberg, E.O., 2006. Redefining health care: creating value-based competition on results. Harvard Business Press.

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.

Porter, M.E. and Teisberg, E.O., 2006. Redefining health care: creating value-based competition on results. Harvard Business Press.

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

Porter, M.E. and Lee, T.H., 2013. The strategy that will fix health care. *Harv Bus Rev*, *91*(12), p.24.

Our Objective

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

USE CASES

Use Case: Healthcare In Ireland: Current and Future Status

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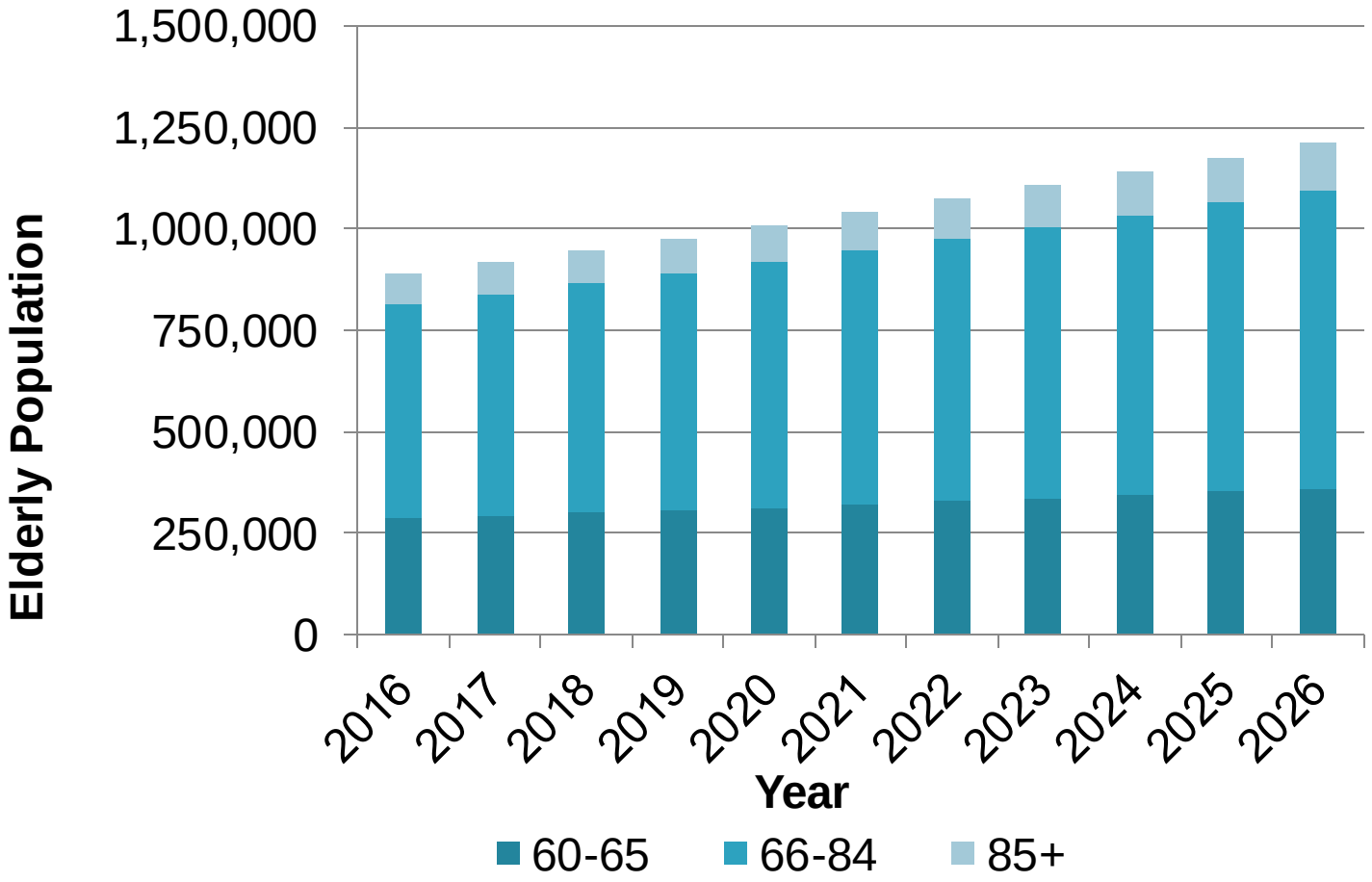
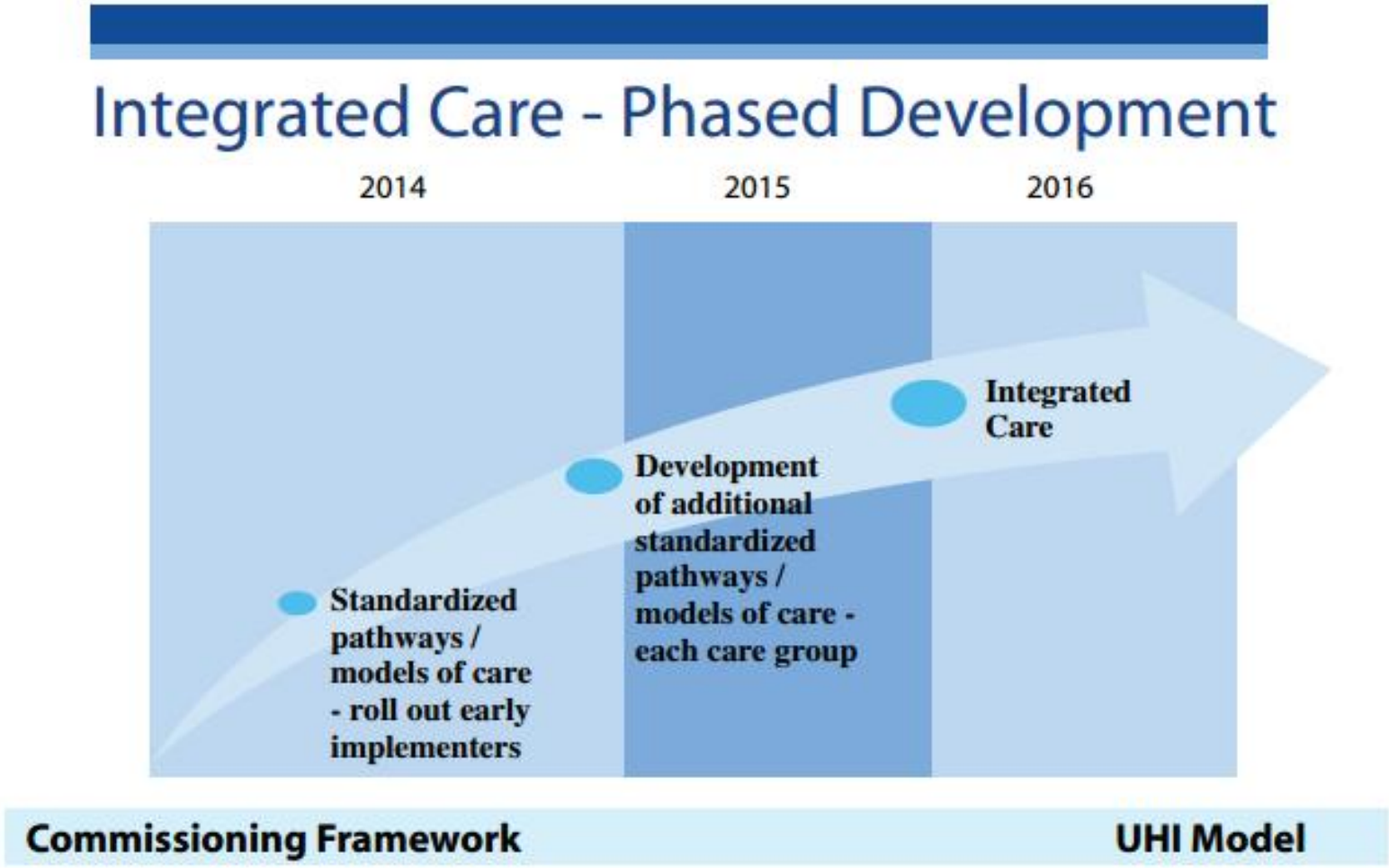
Prospective Challenge: Population Ageing



Source :http://www.cso.ie/en/statistics/population/

Transitioning Towards Value-Based Care



Source: http://www.hse.ie/eng/services/publications/corporate/CHO_Chapter_1.pdf

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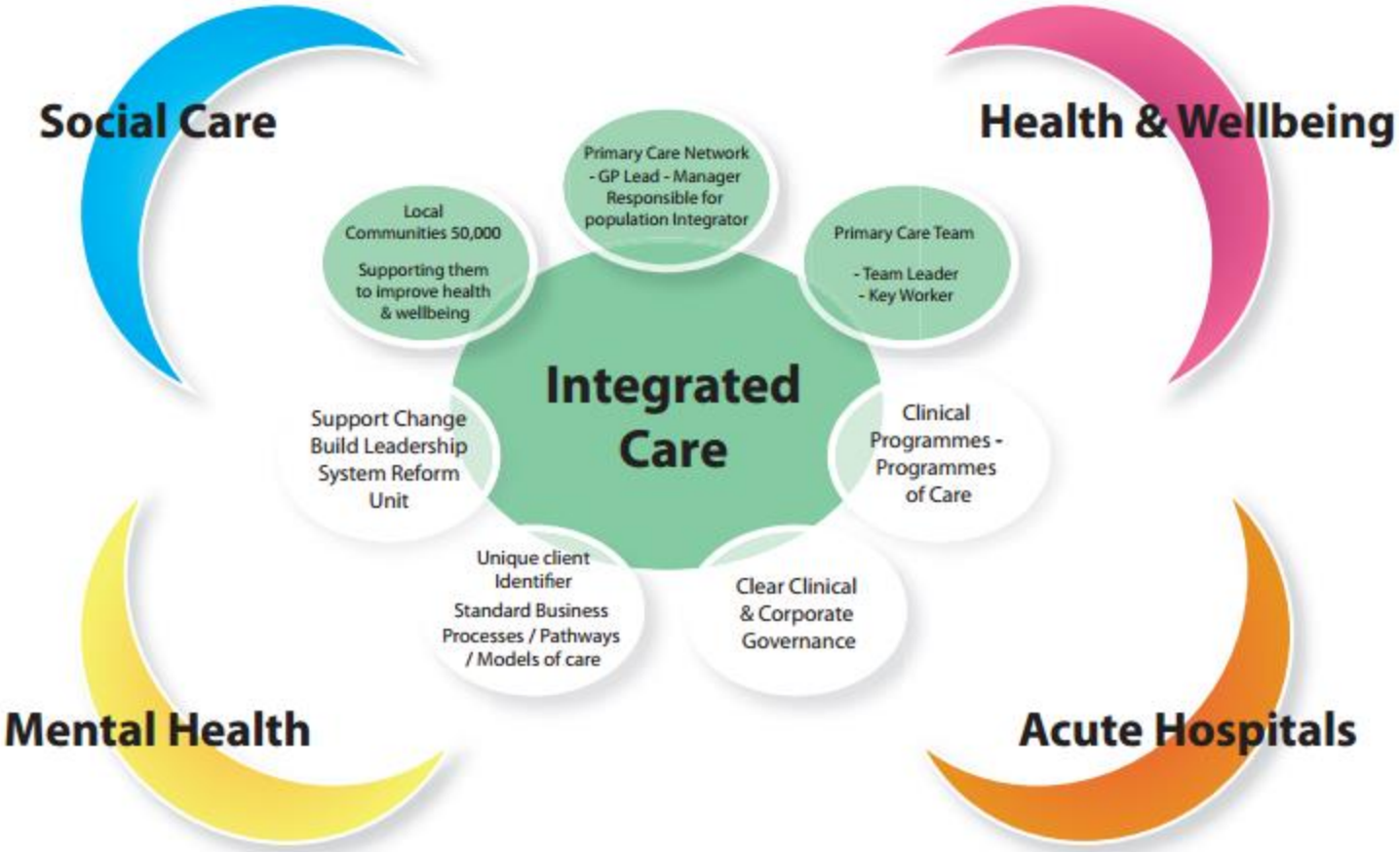
Transitioning Towards Value-Based Care (cont'd)



Source: http://www.hse.ie/eng/services/publications/corporate/CHO_Chapter_1.pdf

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Strategic Framework: National Hospital Groups

1. Dublin North East
2. Dublin Midlands
3. Dublin East
4. South/South West
5. West/North West
6. Midwest

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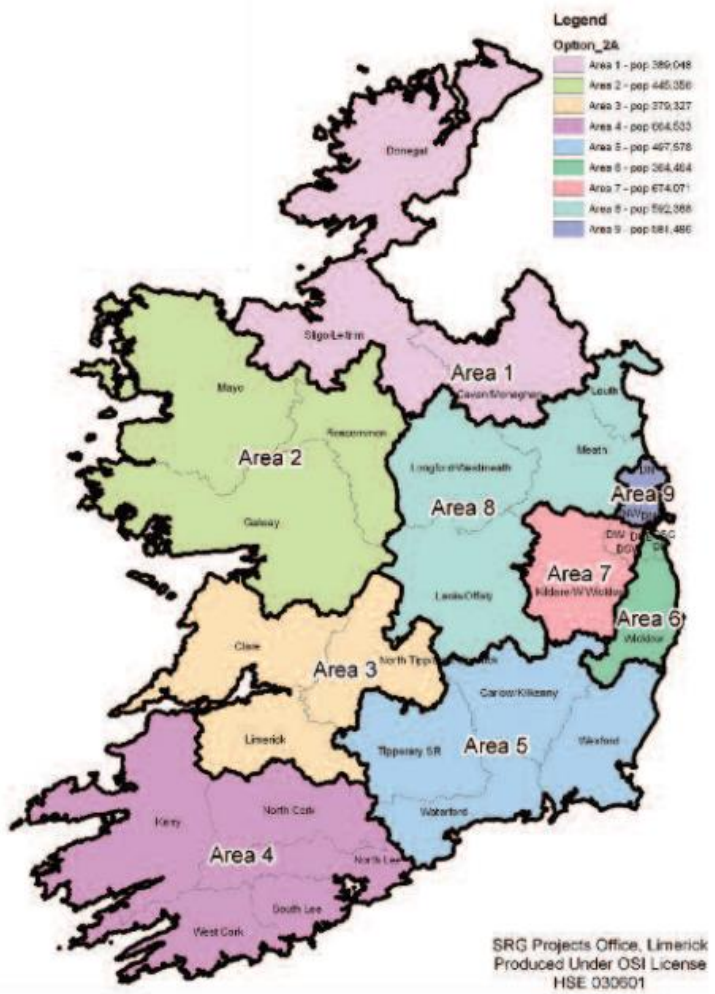
Strategic Framework: Community Health Organisation (CHOs)

CHO1 - Population 389,048
CHO2 - Population 445,356
CHO3 - Population 379,327
CHO4 - Population 664,533
CHO5 - Population 497,578
CHO6 - Population 364,464
CHO7 - Population 674,071
CHO8 - Population 592,388
CHO9 - Population 581,486



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 through the Irish Hip Fracture Database (IHFD).

Sources :1 Gullberg, B., Johnell, O. and Kanis, J.A., 1997. World-wide projections for hip fracture. Osteoporosis international, 7(5), pp.407-413.
2http://www.hse.ie/eng/services/publications/olderpeople/Executive_Summary_Strategy_to_Prevent_Falls_and_Fractures_in_Ireland%E2%80%99s_Ageing_Population.pdf

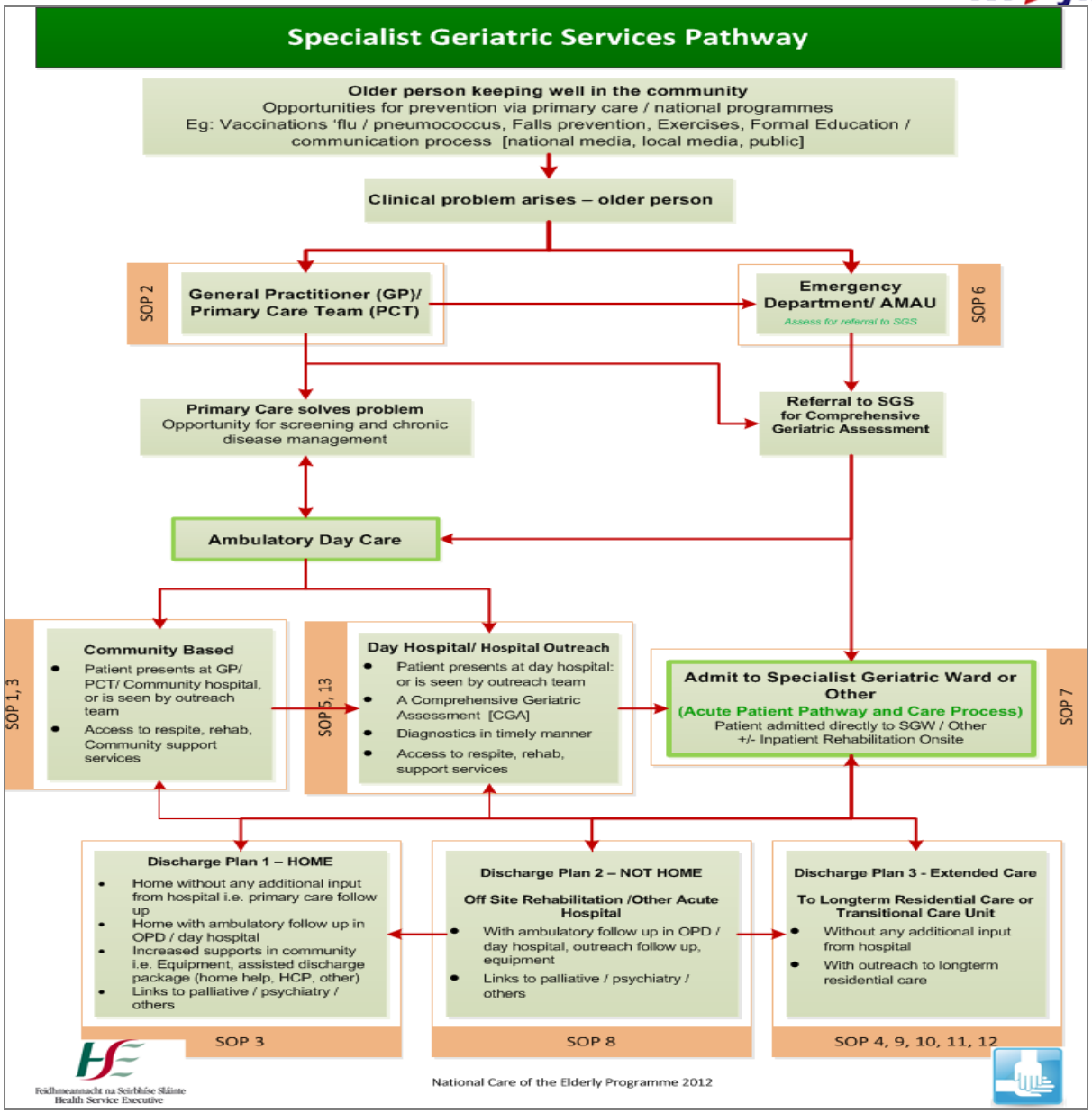
Our Objective

- Assessing the implications of the co-ordinated pathway on the hip fracture care scheme in terms of outcomes and cost, using the MS4 modeling and simulation framework.

Sources of Data

- Irish Hip Fracture Database (IHFD). (Year 2013-2014)
- Population projections from the Central Statistics Office (CSO).
- Additional population statistics with respect to CHOs from the Health Intelligence Department.

Co-ordinated Pathway for Early Intervention and Treatment



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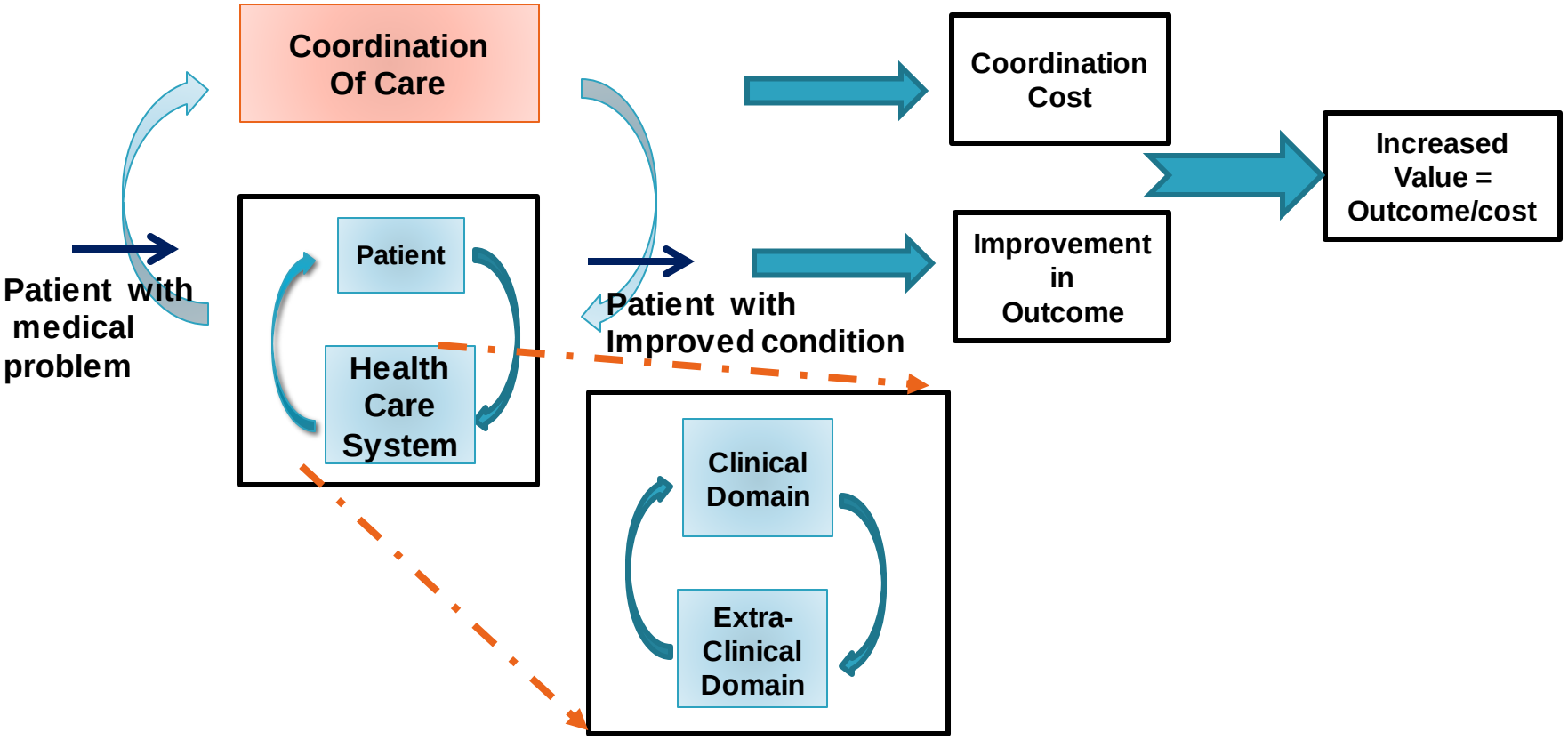
Value-Based Health System (VBHS) Modeling and Simulation Framework



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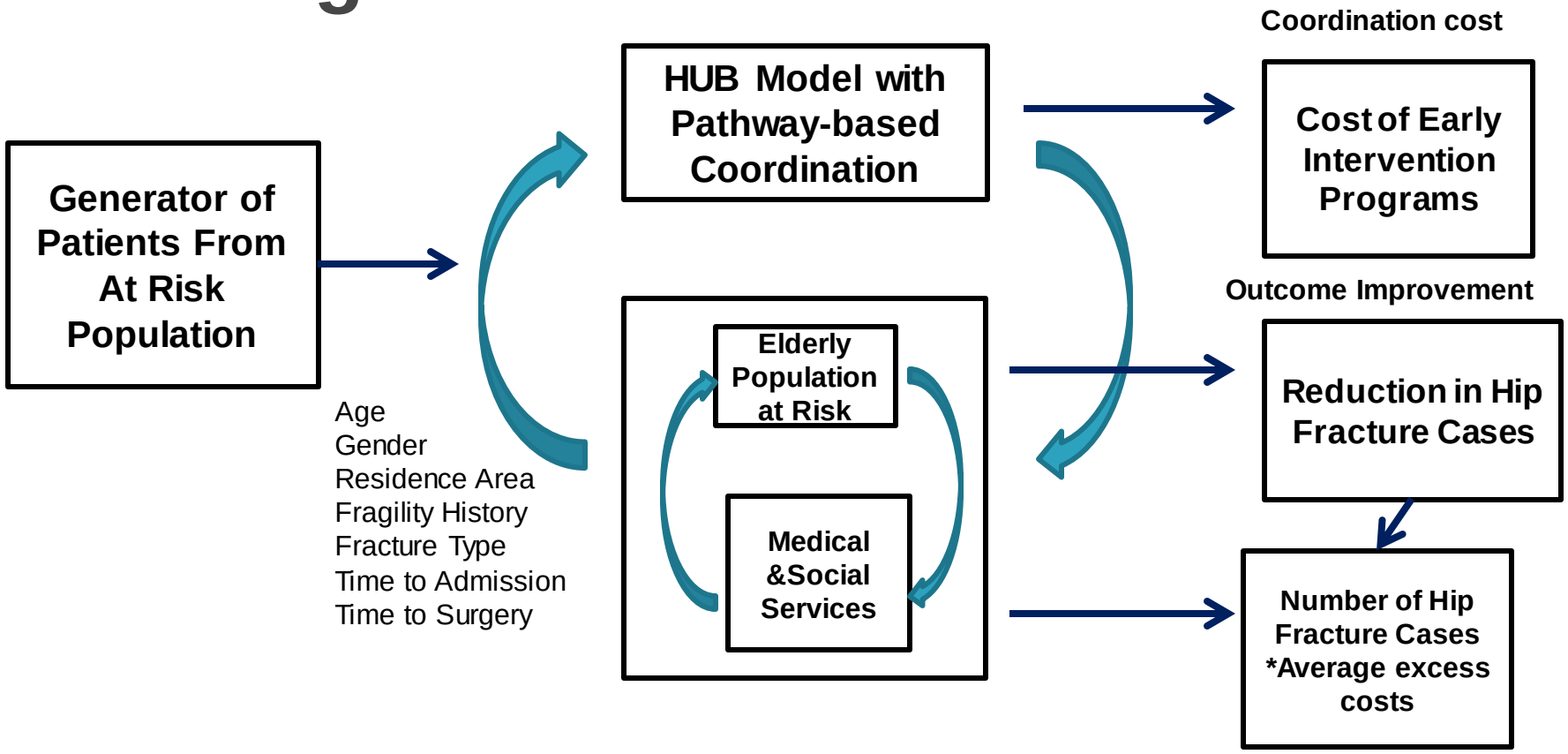
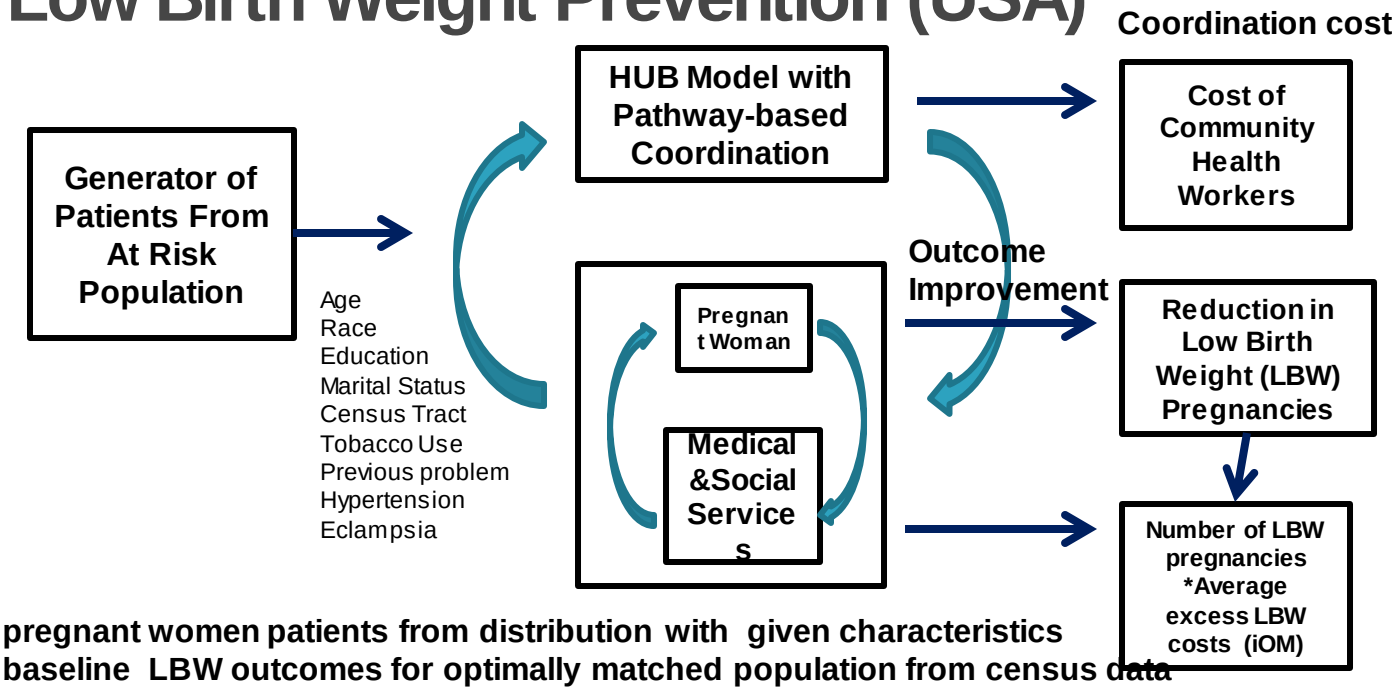
Modeling Framework



- Generate elderly population at risk from distribution with given characteristics
- Compute baseline hip fracture outcomes for optimally matched population from census data
- Track patients through system with Pathways coordination
- Evaluate cost based on outcome-based-compensation
- Evaluate outcome improvement vs baseline - simulation generated patients
- Evaluate reduction in total cost as savings from reduced hip fracture injuries
- Compute Return on Investment = cost saving per dollar of coordination cost

Use Case : Pathways Community Care Coordination in Low Birth Weight Prevention (USA)



- Generate pregnant women patients from distribution with given characteristics
- Compute baseline LBW outcomes for optimally matched population from census data
- Track patients through system with CHW-implemented Pathways coordination
- Evaluate cost of CHWs based on outcome-based-compensation
- Evaluate outcome improvement vs baseline - simulation generated LBWs
- Evaluate reduction in total cost as savings from reduced LBW pregrancies
- Compute Return on Investment = cost saving per dollar of coordination cost

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.
- Formalized this framework using System-of-Systems (SoS) theory expressed in the DEVS Modeling and Simulation methodology.
- MS4 Modeling and Simulation Environment based on DEVS supports design and implementation in a systems engineering approach.

Closing Thought

- "The key challenges facing healthcare providers in future years are perhaps more organisational and logistical than medical and scientific advances".

(Sally Brailsford & Jan Vissers 2011)

Source :Brailsford, S. and Vissers, J., 2011. OR in healthcare: A European perspective. *European journal of operational research*, *212*(2), pp.223-234.

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Publications

- 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..

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Youtube Videos

- Formalizing Porter's Integrated Practice Unit with System-of-Systems Modeling and Simulation
- Extra-Clinical Care Coordination: Pathways Community HUB Model Continuing From: Formalizing Porter's Integrated Practice Unit with System-of-Systems Modeling and Simulation.
- The Role of Modeling and Simulation in Coordination of Health Care.
- Modeling and Simulation for Engineering of Self-Improving Service Systems of Systems: Barriers and Prospects
- Pathways-Based Client Engagement Support

THANK YOU!

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