Learning about Systems Using Machine Learning: Towards More Data-Driven Feedback Loops

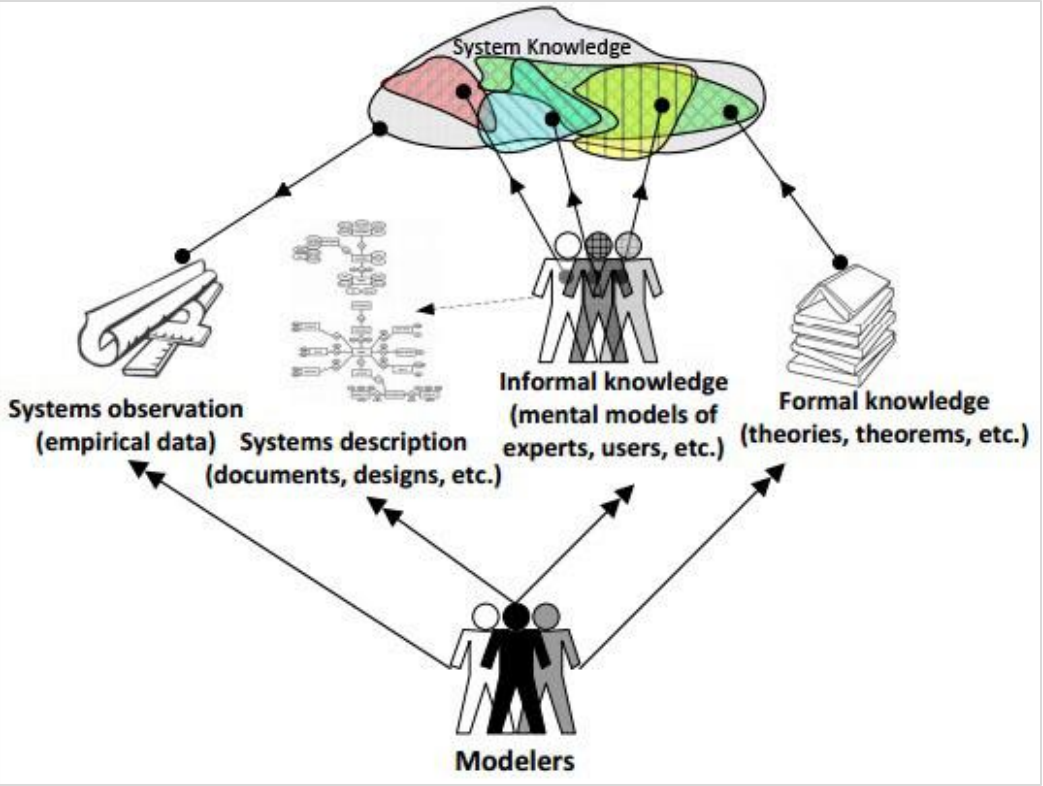
Mahmoud Elbattah, Owen Molloy
m.elbattah1@nuigalway.ie

Integrating M&S with Machine Learning

1.Why?

M&S is he systematic study of modeling processes and simulation processes that describe and transform conceptualisations.[1]

Machine Learning is about learning and deriving knowledge from data.



Sources of System Knowledge.[2]

[1] Padilla, J. J., Diallo, S. Y., & Tolk, A. (2011). Do we need M&S science?. *SCS M&S Magazine*, *8*(2011), 161-166.
[2] Image Source: Huang, Y. (2013). Automated Simulation Model Generation. TU Delft.

2.When?

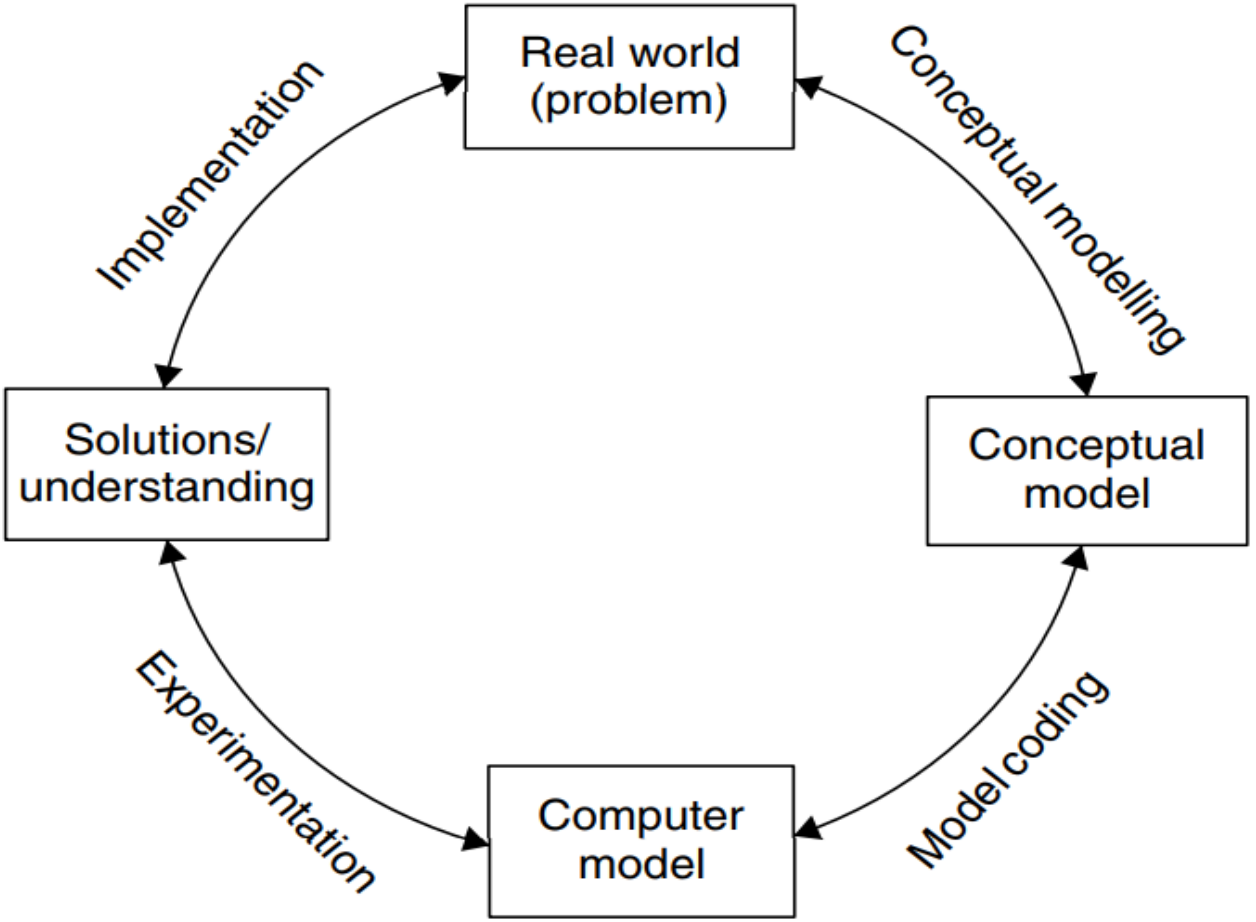


Image Source:
Robinson, S. (2004). *Simulation: The Practice of Model Development and Use*. Chichester: Wiley.

Motivational Questions

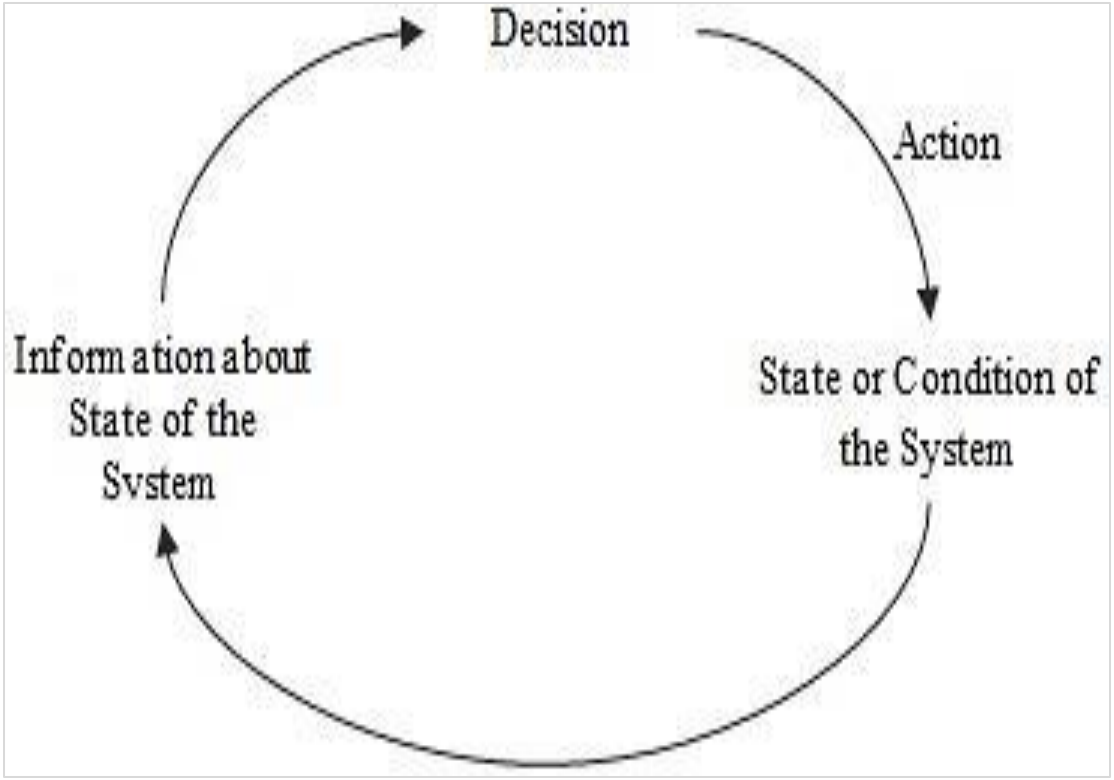
Q1) How can ML be employed to assist the conceptualisation of a system?

Q2) Is it possible to integrate mental models with ML models in a way that supports the learning process to develop based on a more data-driven manner? If so, how?

Q3) Which ML techniques can be appropriate for the perception of a system's structure, or the behaviour involved within a problem?

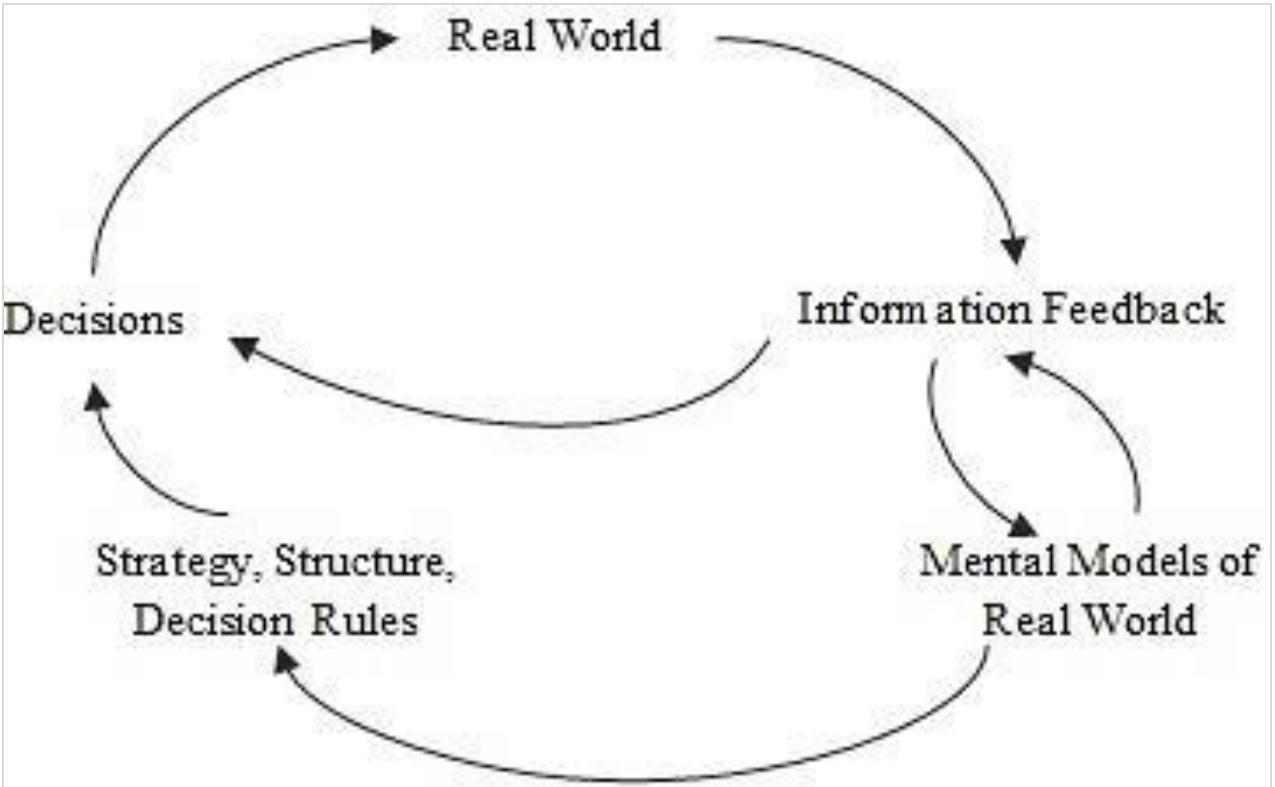
Q4) Can the integration of ML lead to a higher level of confidence in simulation models, indicated by the accuracy of ML models?

Background: Feedback Loop



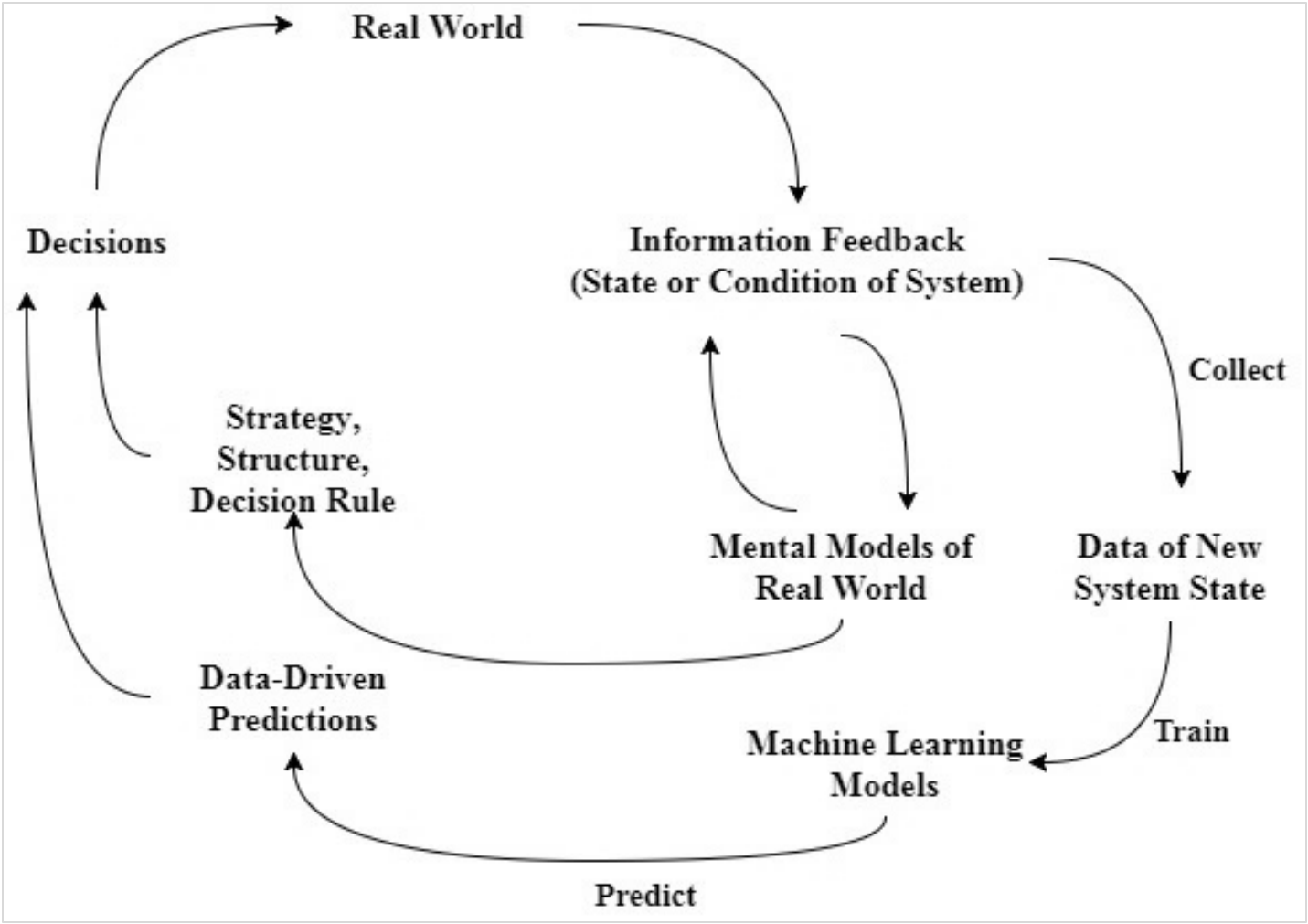
Source: Forrester, J.W., 1968. Principles of Systems, Text and Workbook, Wright-Allen Press-US.

Background: Feedback Loop (cont'd)



Source: Sterman, J. D. 1994. Learning in and about Complex Systems. System Dynamics Review, 10(2-3).

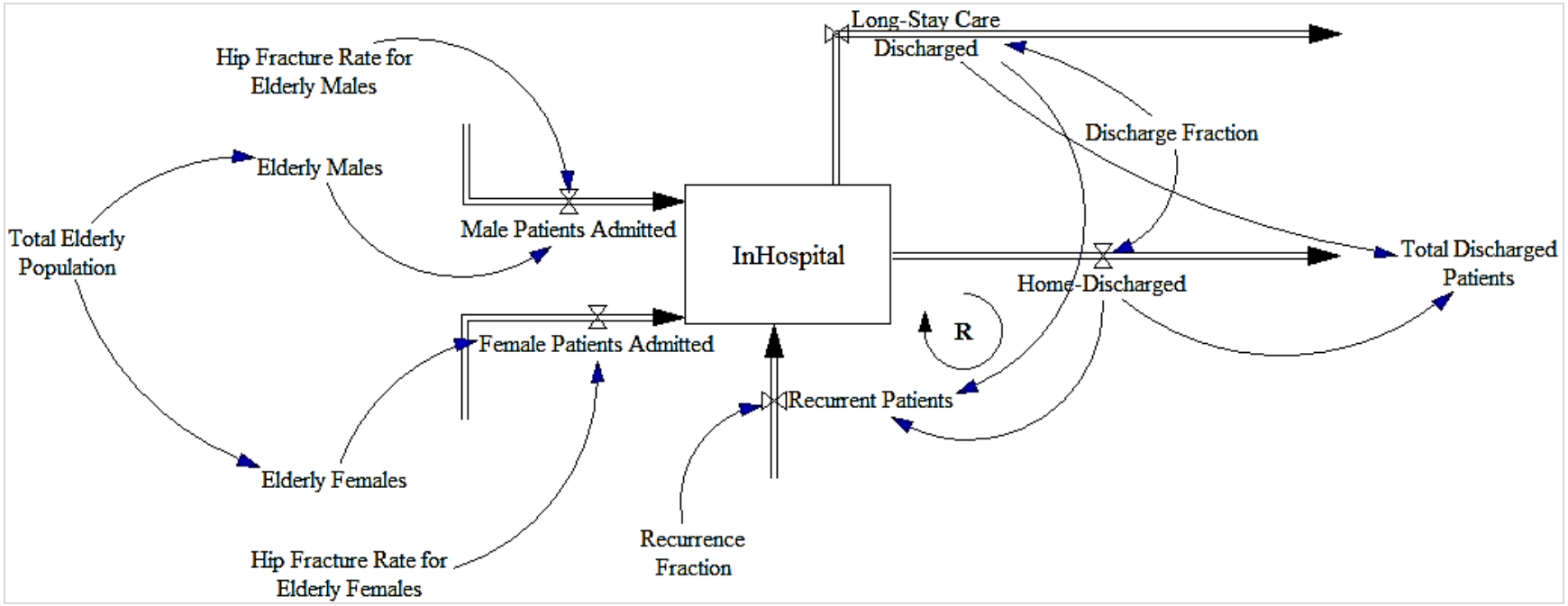
Our Approach: Incremental Learning to Capture Changes in System's Behaviour



Use Case in Helathcare: Data Description

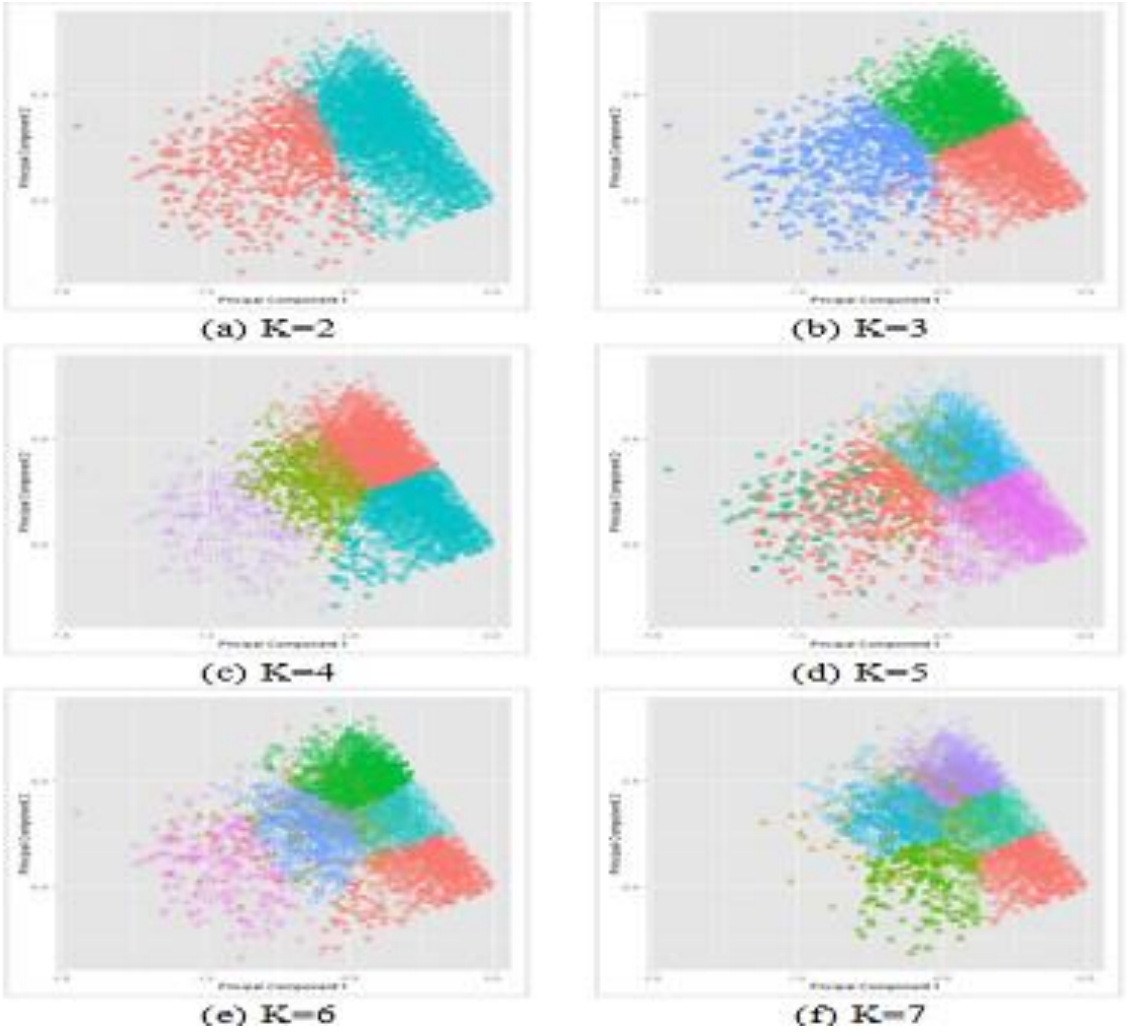
- Irish Hip Fracture Database (IHFD).
- Patient records in the years 2013-2015 (≈8k records)/
- Patients aged 60 and over.
- 38 data fields such as gender, age, type of fracture, date of admission, and LOS.

Modeling the Flow of Patients: Initial SD Model



- What is the expected consumption of hospital resources with regard to the inpatient LOS?
- What is the expected proportion of elderly patients discharged to home, or long-stay care?

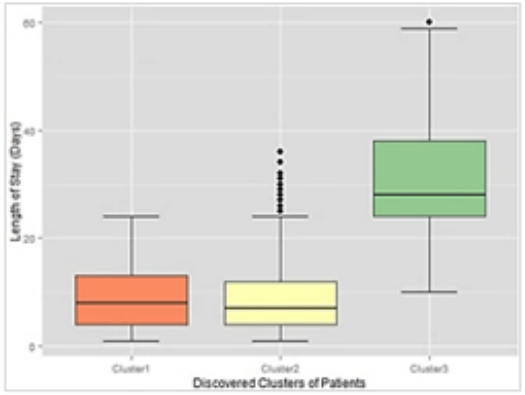
Data-Driven Patient Clustering



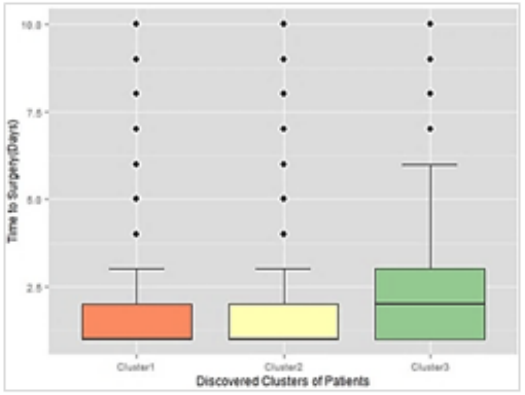
K-Means clustering of patients based on:

- LOS
- Age
- Time to Surgery

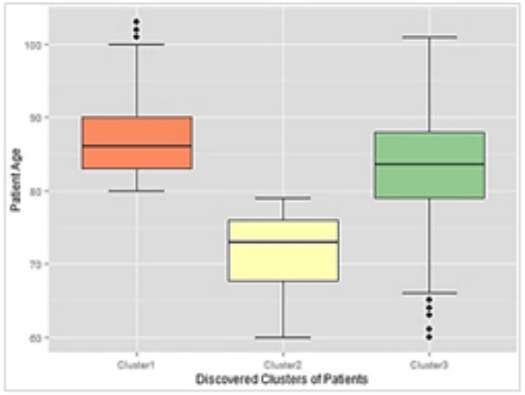
Insights from Clusters



(a) LOS.

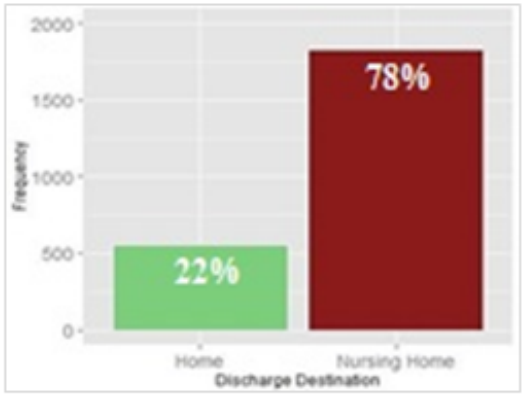


(b) TTS.

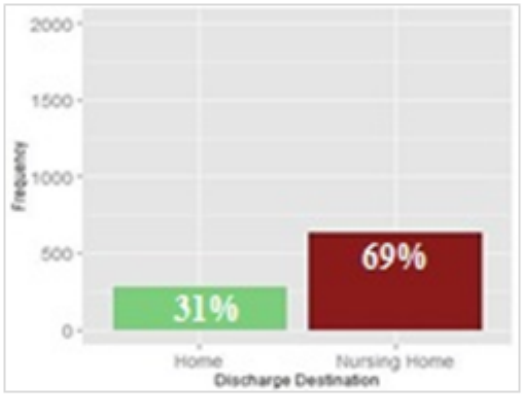


(c) Patient age.

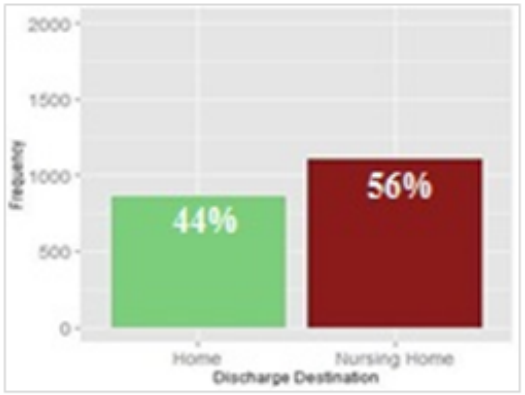
Figure: The variation of the LOS, TTS, and age variables in the patient clusters.



(a) Cluster1.



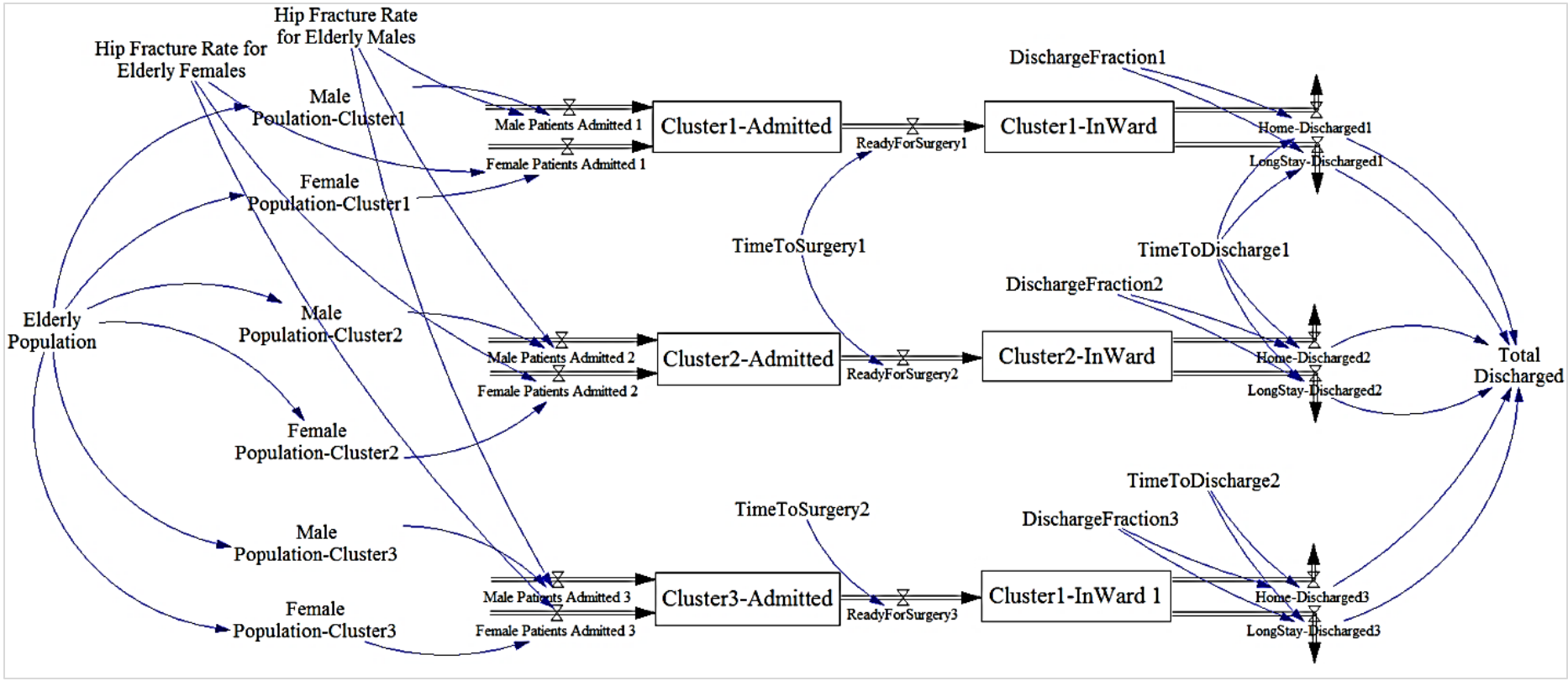
(b) Cluster2.



(c) Cluster3.

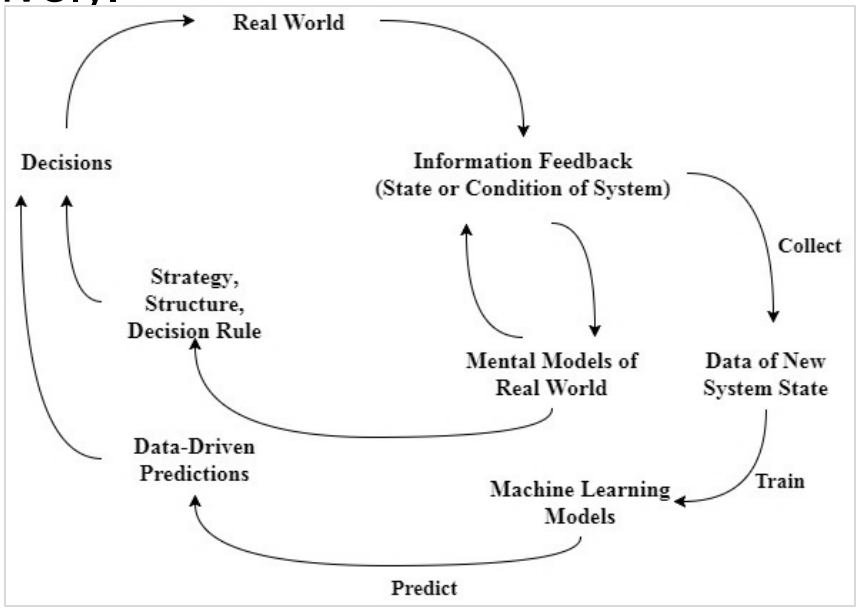
Figure: The variation of discharge destinations in the patient clusters.

Cluster-Based Model



Simulating Data-Driven Feedback

- Simulation new policy to maintain improve care standards:
- Keeping the TTA and TTS within 4 hours and 48 hours respectively.
- Average inpatient LOS to decrease by 20% and 30% in 2014 and 2015 respectively.
- Patients discharged to long-stay residential care to decrease by 5% and 10% in 2014 and 2015 respectively.



Adjusting Patient Clusters

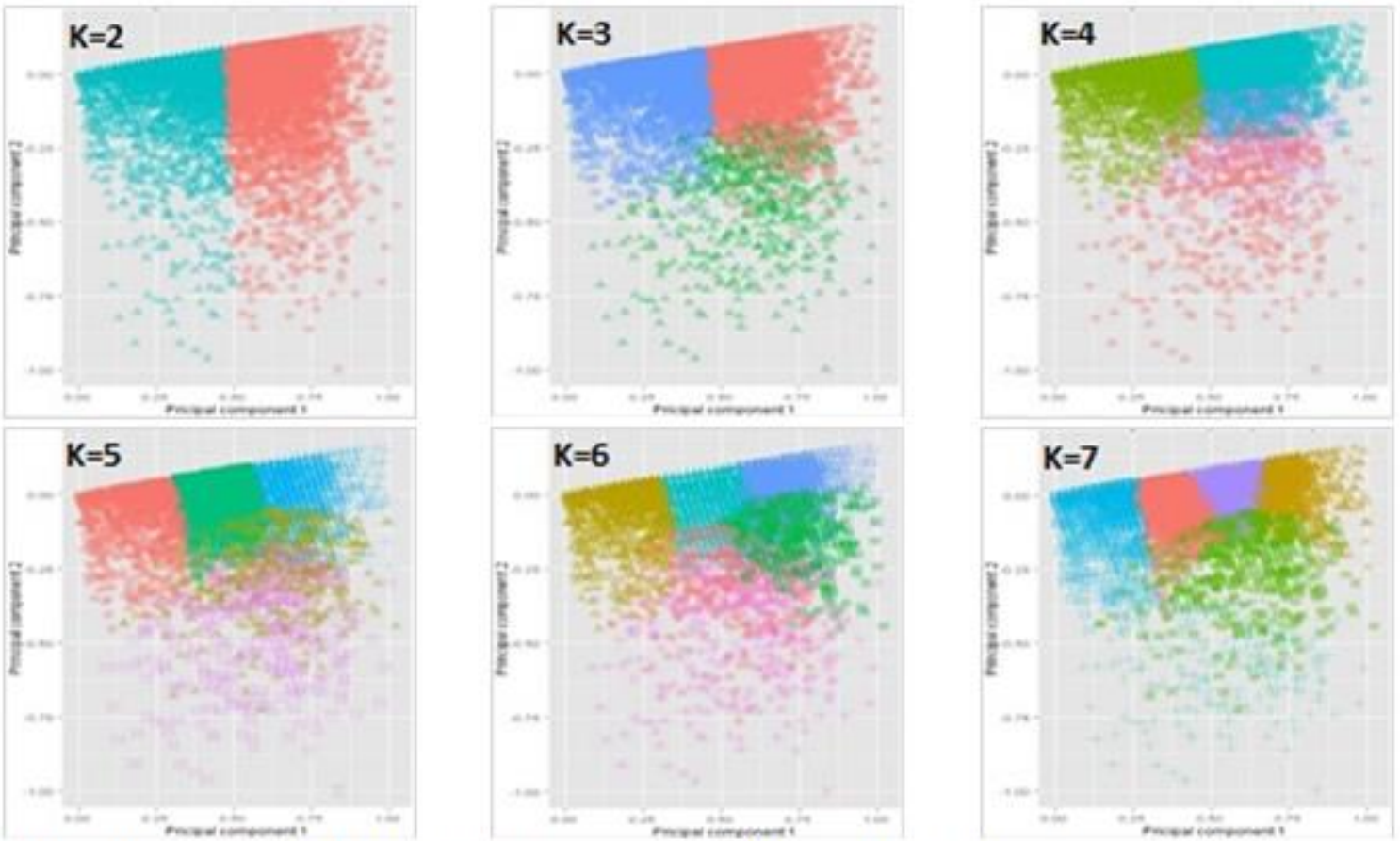
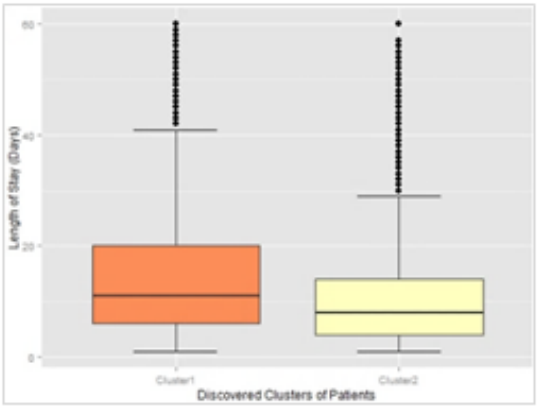
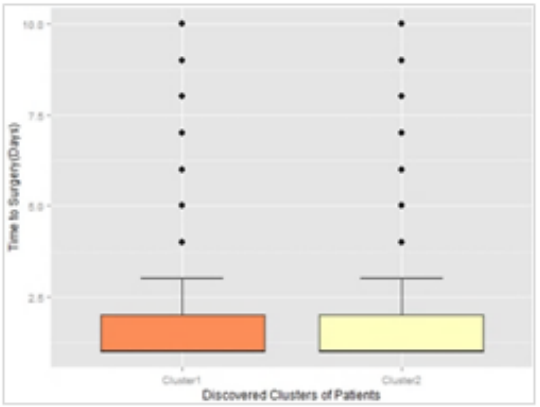


Figure: Visualisation of clustering experiments after applying the new care policy.

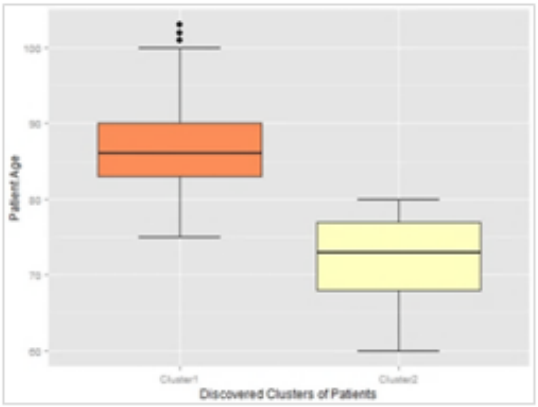
Insights from New Clusters



(a) LOS.



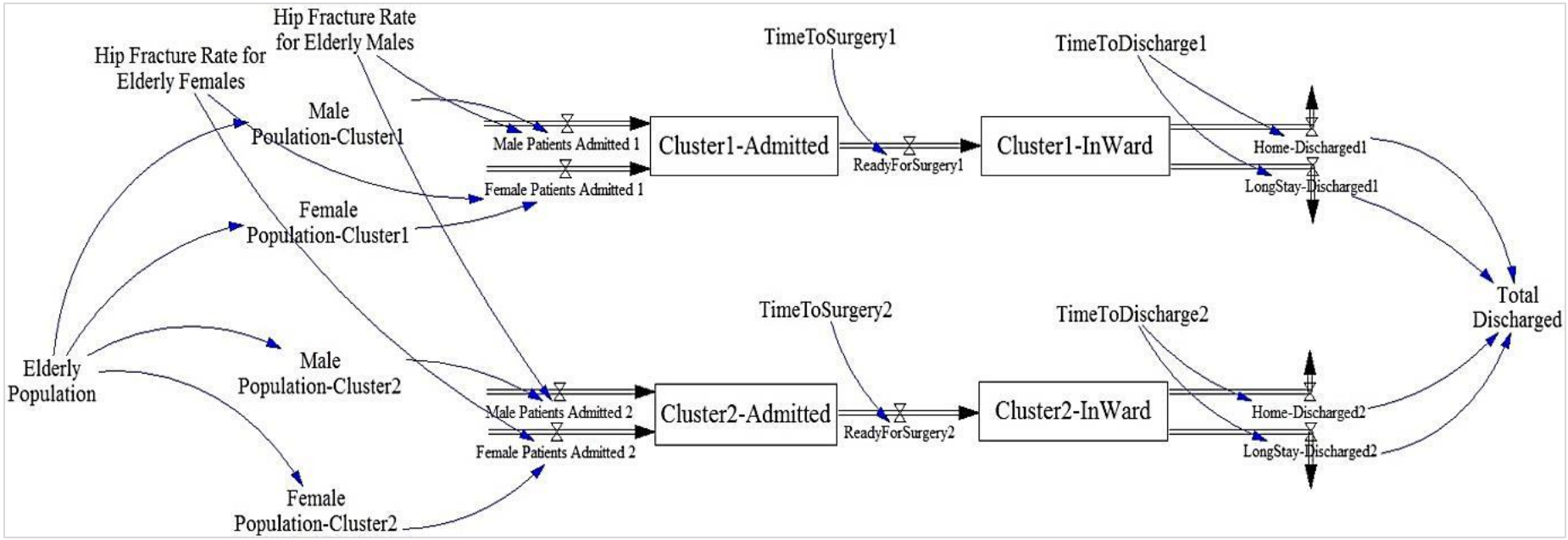
(b) TTS.



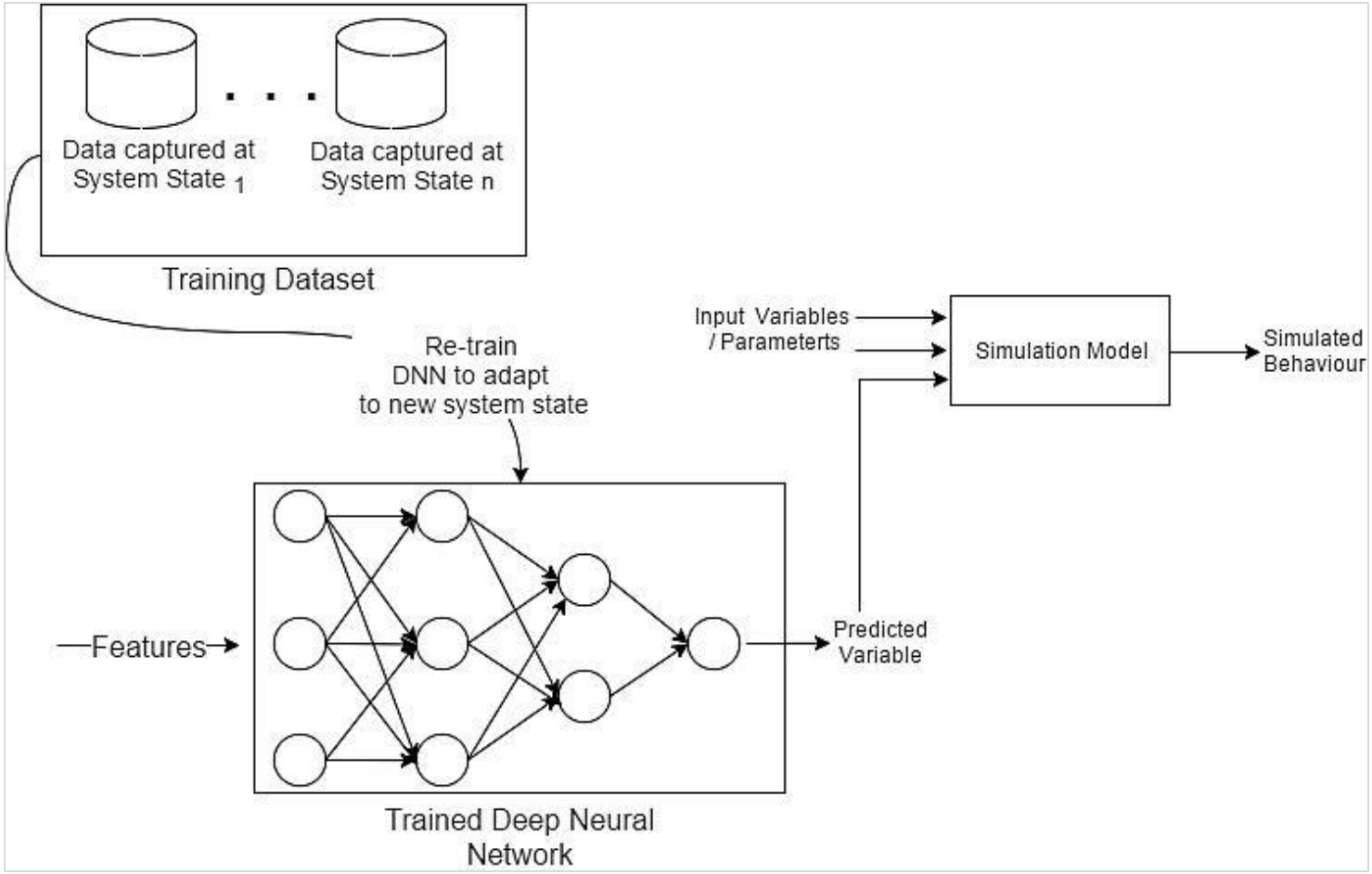
(c) Patient age.

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

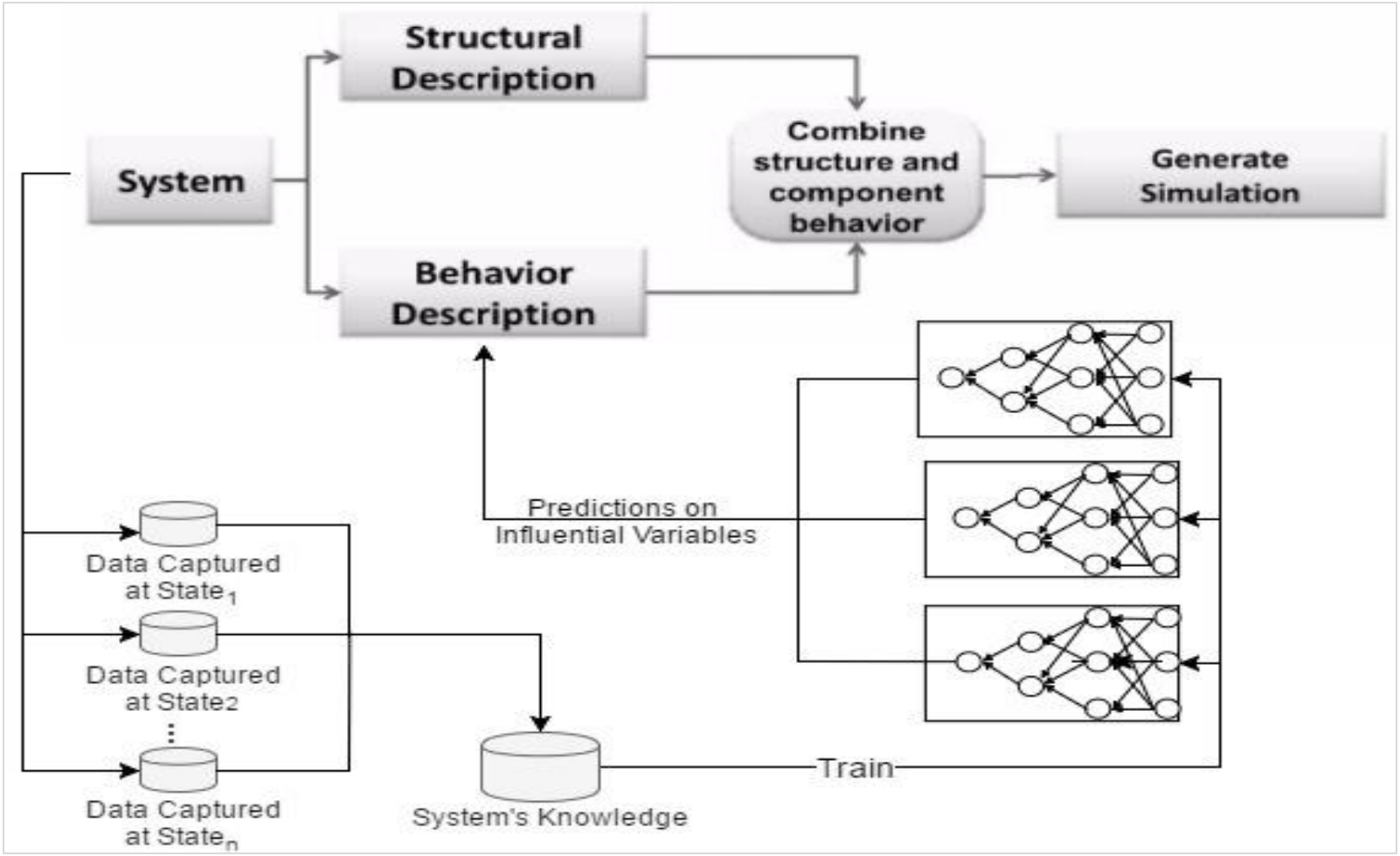
Updated SD Model



Further Directions



Further Directions (Cont'd)



Closing Thought:

- **Herbert Simon, 1983:**
  - Changes in the system that are adaptive in the sense that they enable the system to do the same task(s) more efficiently and more effectively the next time.

- **ML-Aided Simulations:**
  - Changes in the simulation model that are adaptive in the sense that they enable the model to answer the question(s) of interest more efficiently and more effectively the next time.

Source: Simon, H.A., 1983. Why should machines learn?. In Machine learning (pp. 25-37). Springer Berlin Heidelberg.

THANK YOU!

m.elbattah1@nuigalway.ie