Modeling the Drift to Unsafe State

Connecting STAMP and System Dynamics

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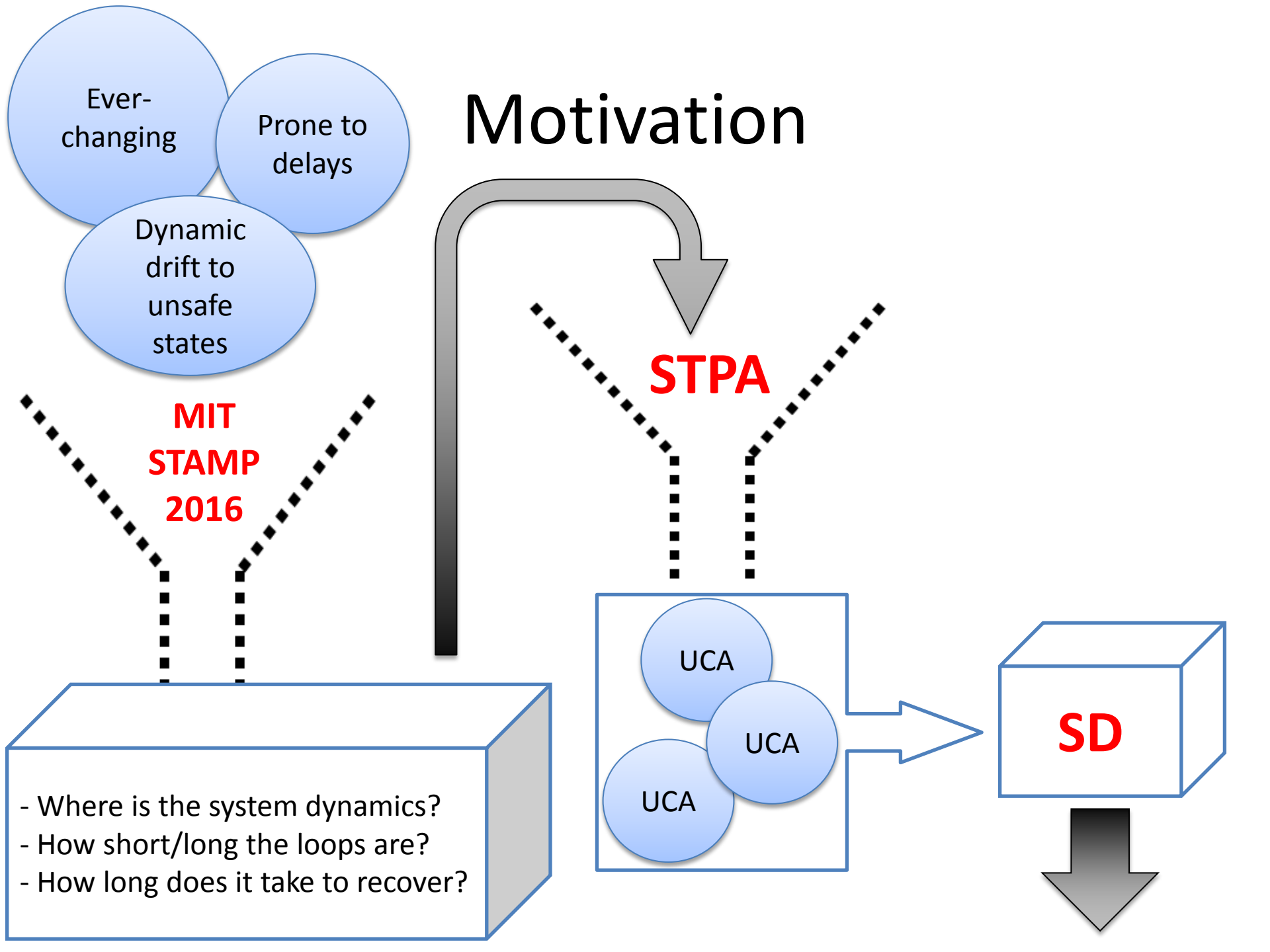
Aim

The study explores the impact of each of the unsafe control actions (UCAs), as well as of their combination, on the dynamics of drift from safe to unsafe states

Motivation


Ever-changing
Prone to delays
Dynamic drift to unsafe states
MIT STAMP 2016
STPA
UCA
UCA
UCA
SD
- Where is the system dynamics?
- How short/long the loops are?
- How long does it take to recover?

Outcome

- By manipulating the UCA variables:

(1) understand how long it takes for the system to drift to unsafe state,

(2) which UCAs lead to the quickest drift,

(3) which UCAs interact

- Dynamic analysis of a healthcare process with the STPA results as an input to the SD model

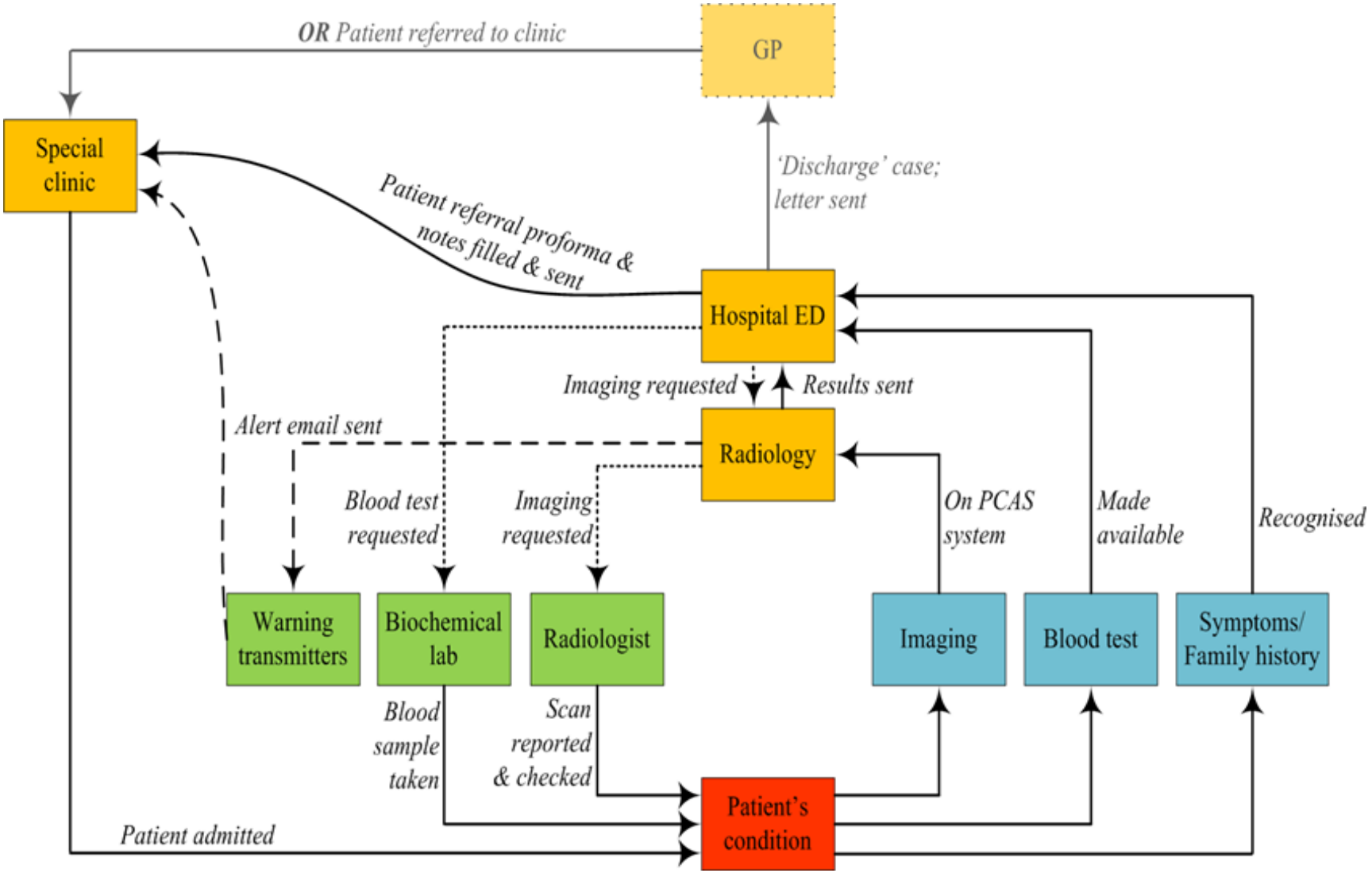
Previous work with STAMP & System Dynamics

- DuLac, N. PhD Thesis 2007
  - "A framework for dynamic safety and risk management modeling in complex engineering systems"
  - http://hdl.handle.net/1721.1/42175
- Coutier, M. MS Thesis 2010
  - "A case study of Vioxx using STAMP"
  - http://hdl.handle.net/1721.1/59557
- Leveson, et al 2012
  - Leveson, Nancy, Matthieu Couturier, John Thomas, Meghan Dierks, David Wierz, Bruce M. Psaty, and Stan Finkelstein."Applying System Engineering to Pharmaceutical Safety." Journal of Healthcare Engineering 3, no. 3 (September 1, 2012): 391-414.

STPA Results

- Accident: *Deaths or deterioration of condition, while waiting to see specialist*
- Hazard: *Waiting time to see specialist extends too long*
- CAs: Hospital ED (7); GP (2); Radiology (2)
- 50 UCAs in total; 3 UCAs are used as variables in the SD model for demonstration

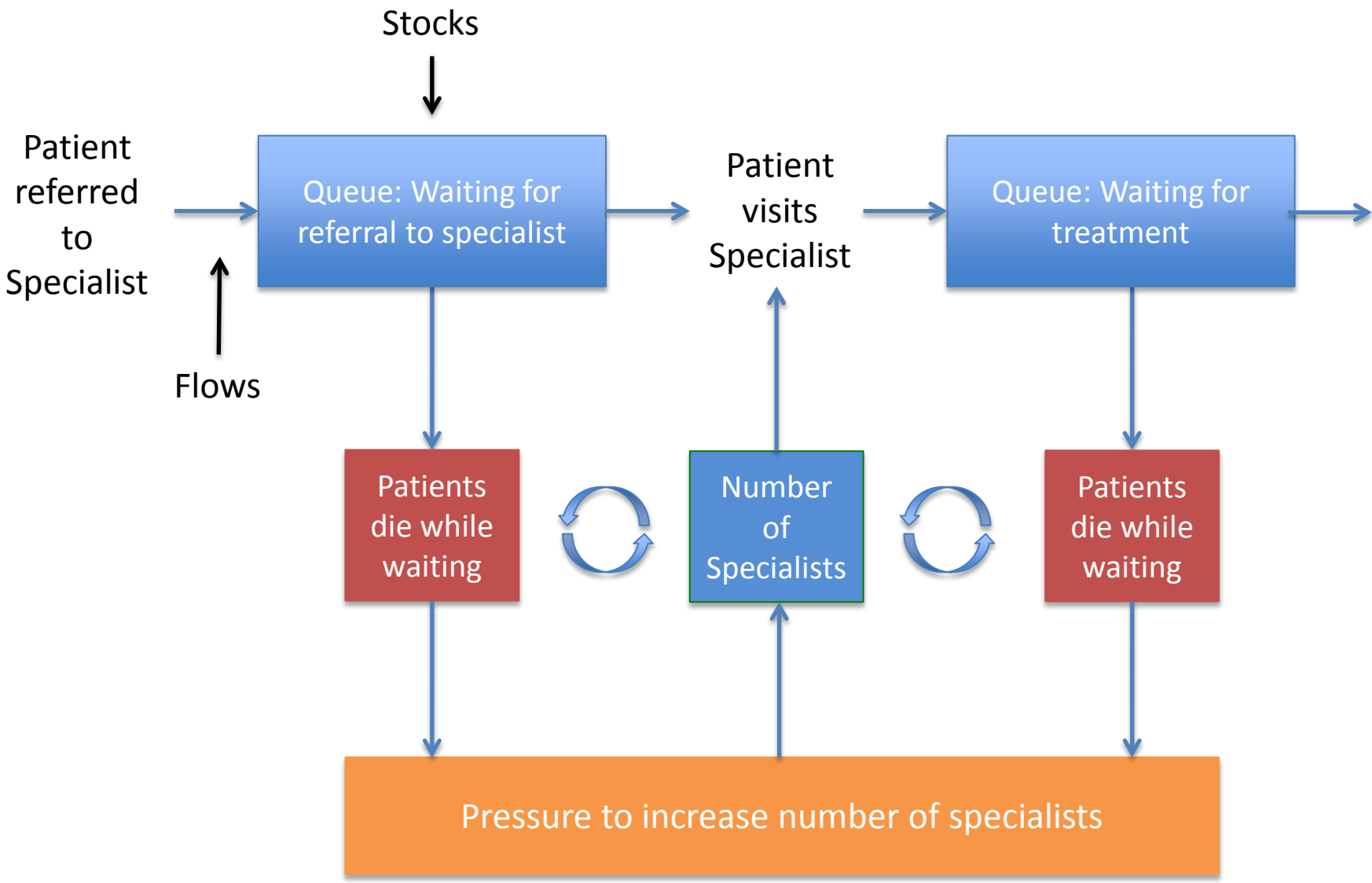
SCS for the Cancer Referral Process



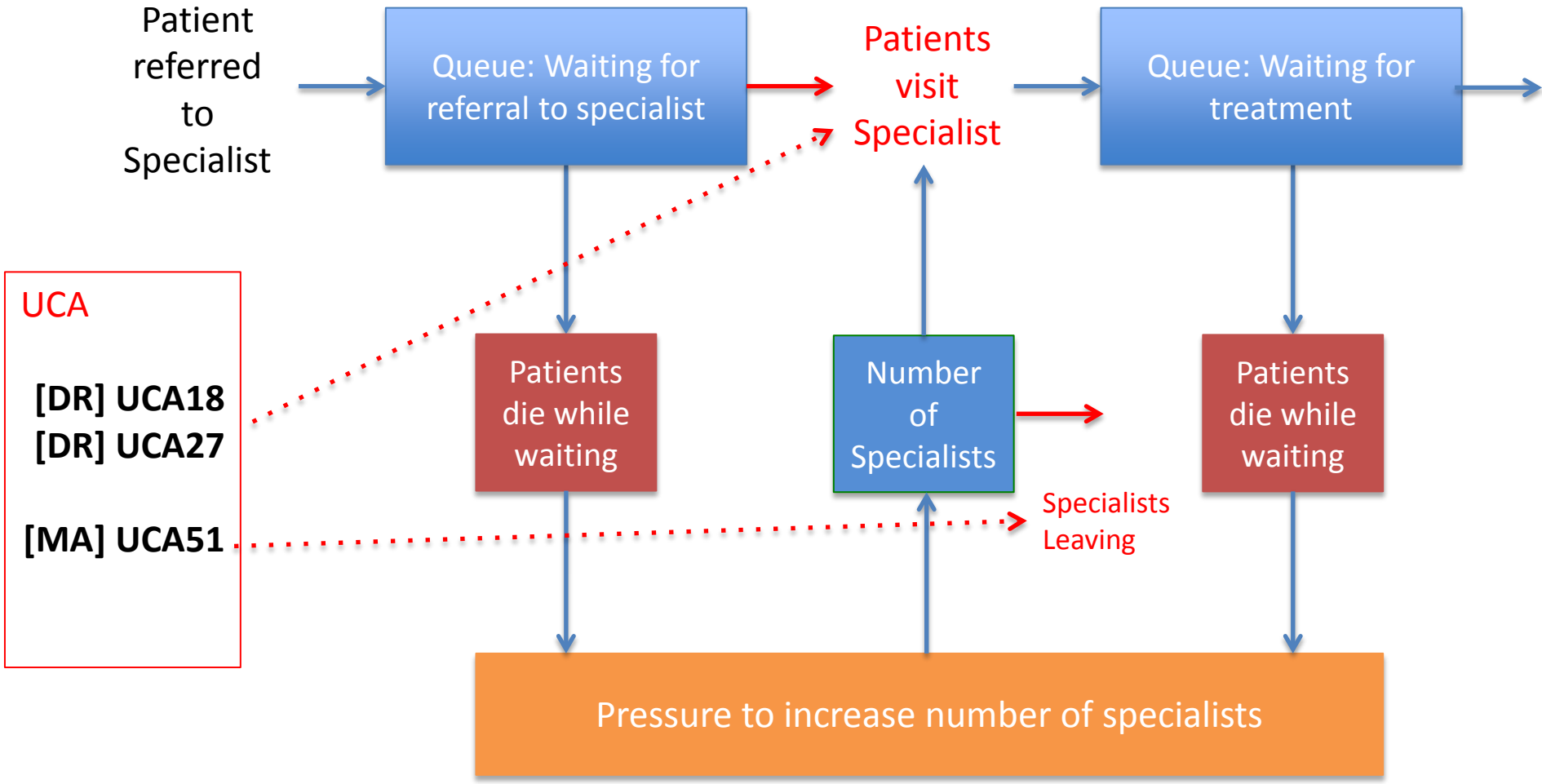
Input to the SD model

- UCAs considered in the SD model
  - [DR] [CA4] [UCA18] *Does not send/give discharge letter*
  - [DR] [CA6] [UCA27] *Does not send referral proforma*
  - [MA] [CA1] [UCA51] *Cuts number of specialists*

Waiting for Specialist & Treatment Model



Adding UCAs to the Model



Factorial Experimental Design
2^3= 8 runs

Run Number	[MA] UCA51	[DR] UCA18	[DR] UCA27	Notes
BASELINE				Baseline
MDUS-2	X			Single Factor
MDUS-3		X		Single Factor
MDUS-4			X	Single Factor
MDUS-5	X	X		Two Factor
MDUS-6	X		X	Two Factor
MDUS-7		X	X	Two Factor
MDUS-8	X	X	X	Three Factor

X → CHANGE FROM BASELINE VALUE

Model Data

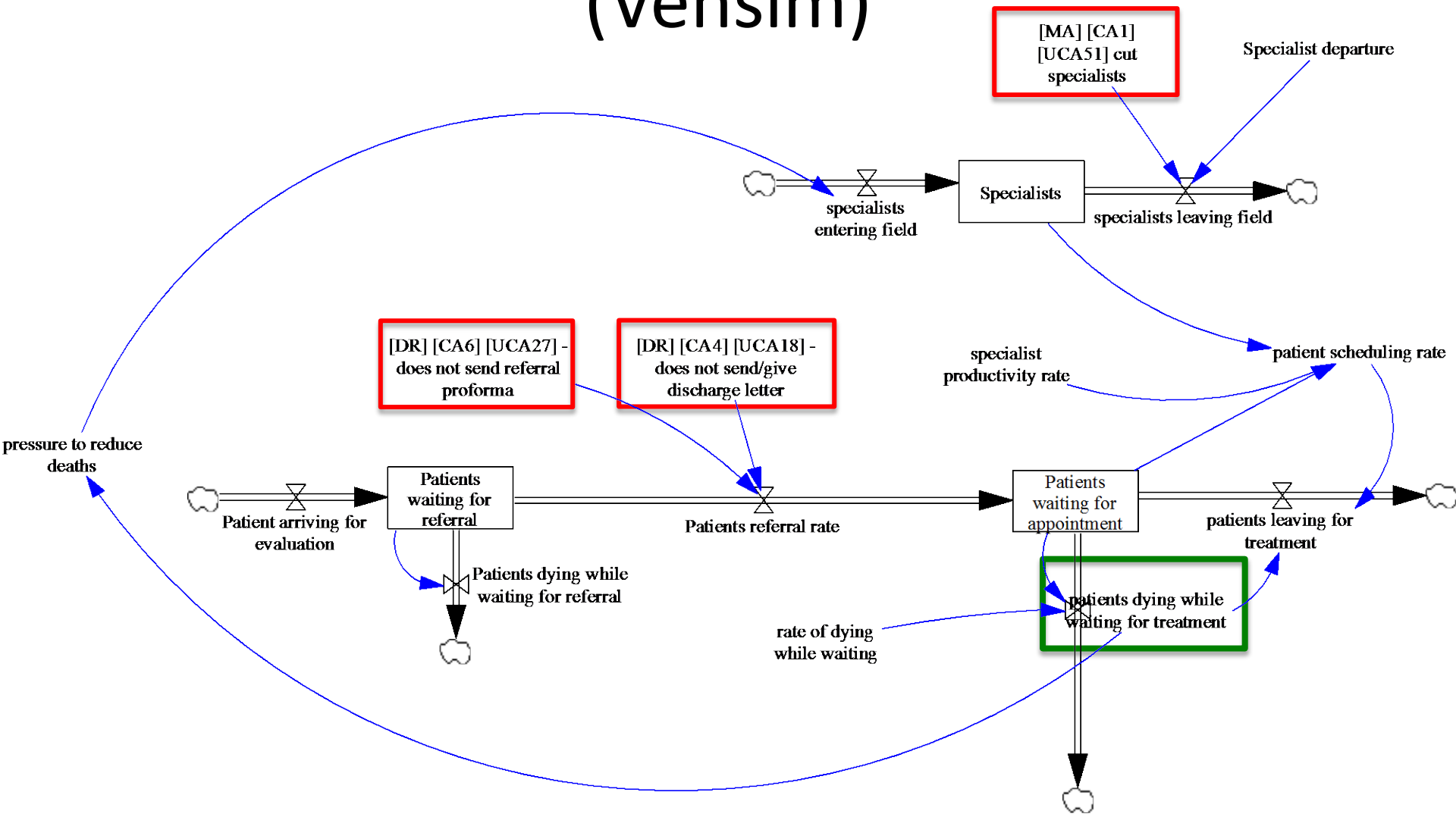
Parameter	Value	Units	Source	Notes
Patients referred to specialist	1000	Patients/week	Assumption	Chosen to balance demand and capacity*
Specialist Productivity Rate	20	Patients seen/week	Assumption	
Number of Specialists	50	Specialists	Assumptions	
Rate of dying while waiting	3/100000	Deaths/100k patients/week	Fraser Institute Canada 2014	All cause mortality

*Nominal Capacity (20 x 50) = Nominal Demand (1000)

UCA SD Model Values

UCA	Variable	Parameters		VALUE
[MA] UCA51	Managers cut number of specialists	Number of specialists cut	Duration of cut	10% cut, pulse at 50 weeks for 50 weeks
[DR] UCA18	Doctor send/give discharge letter	Percentage of patient flow receiving discharge letter		95%
[DR] UCA27	Doctor send referral proforma	Percentage of patient flow receiving referral pro forma		98%

System Dynamics Model (Vensim)



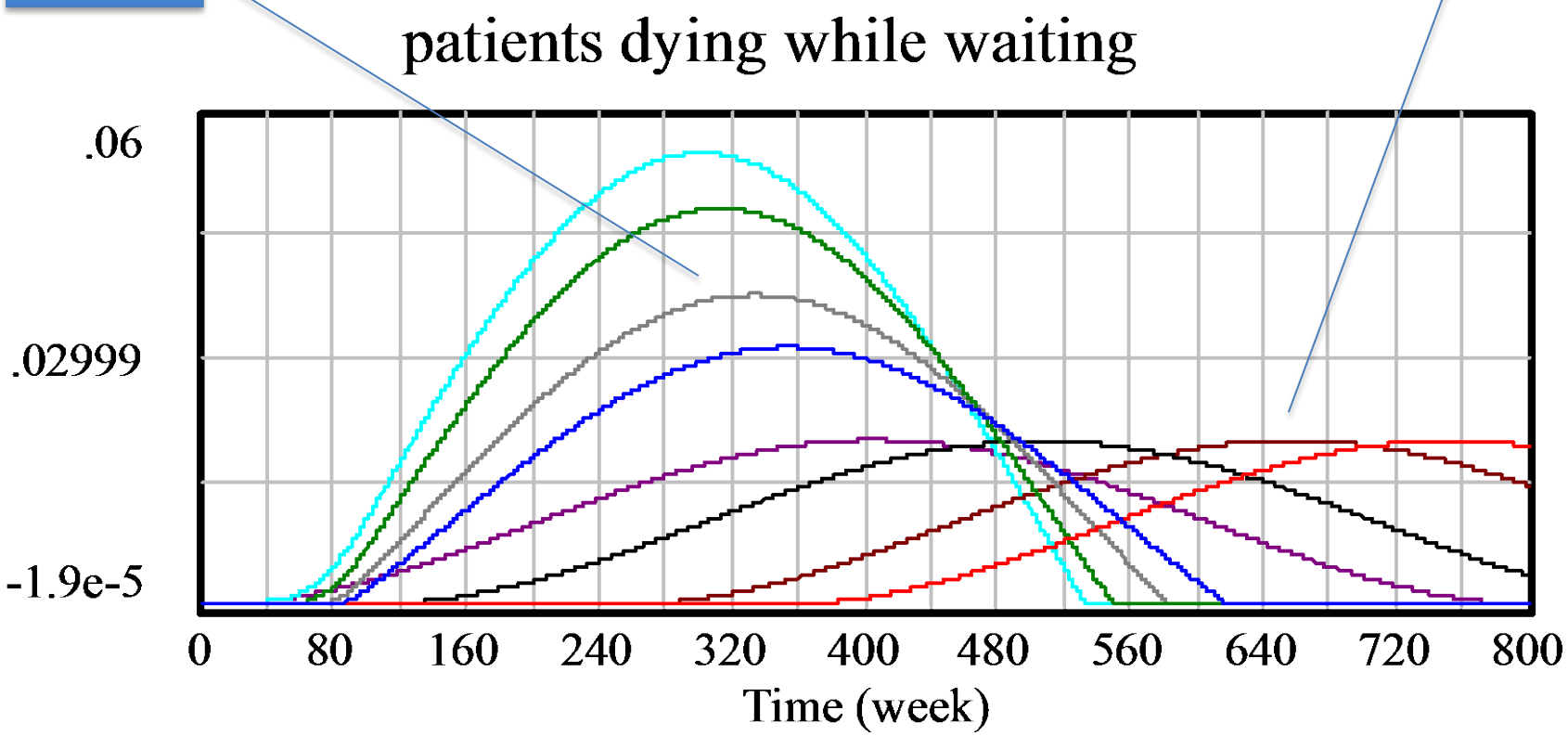
UCA

Model Output

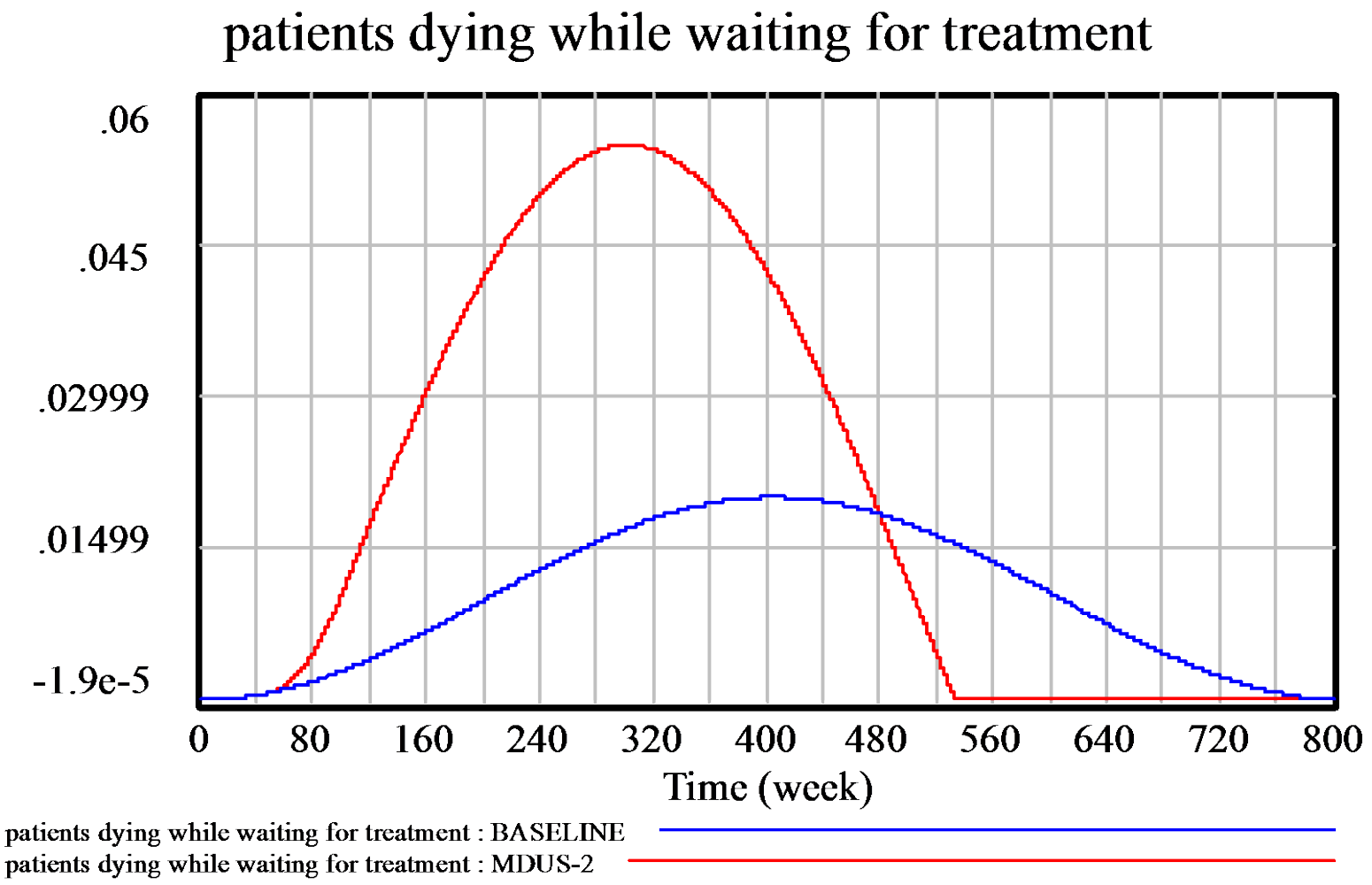
SD Modeling Results
Rates of dying while waiting

Specialists Cut

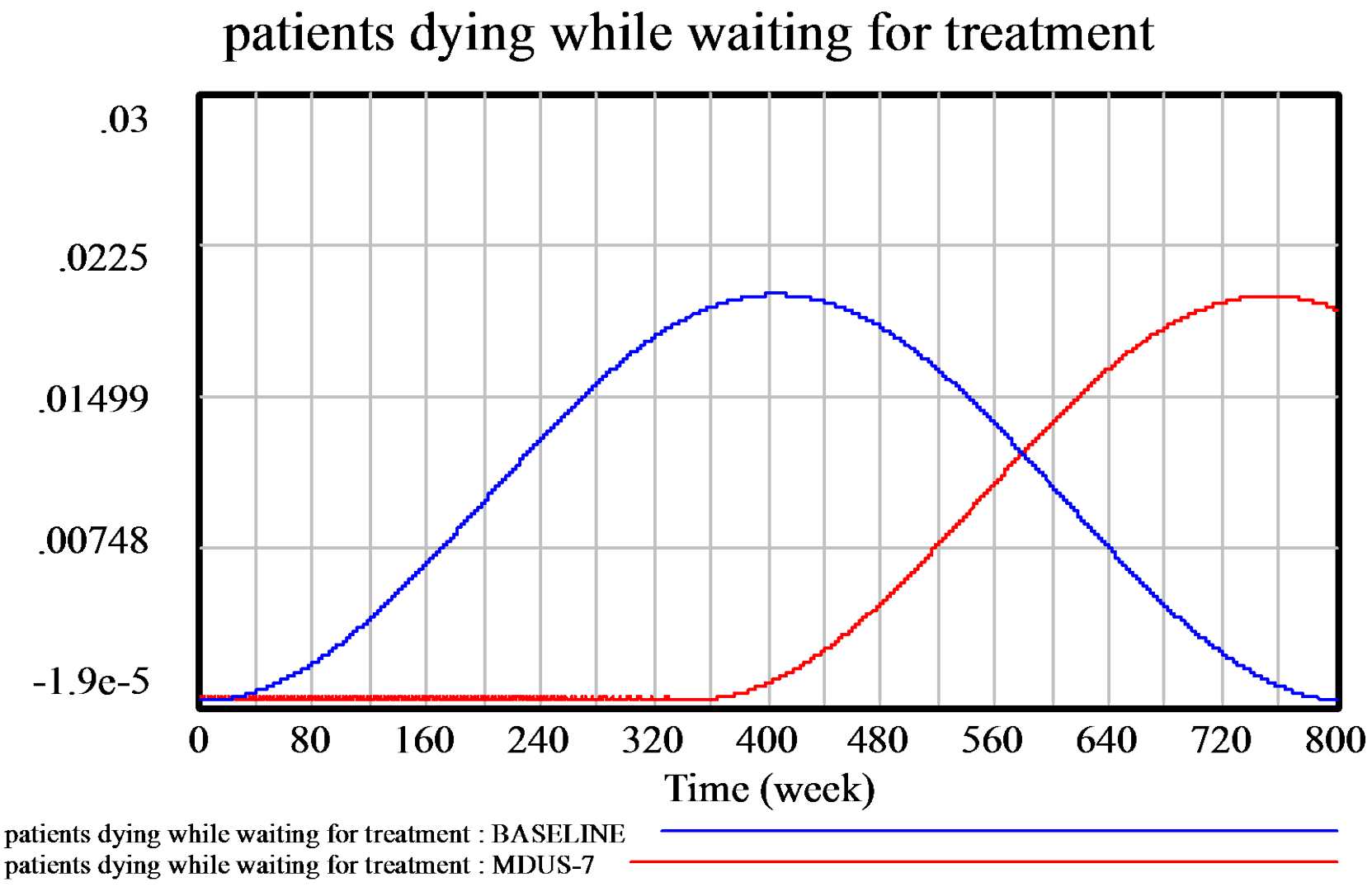
Referrals Cut



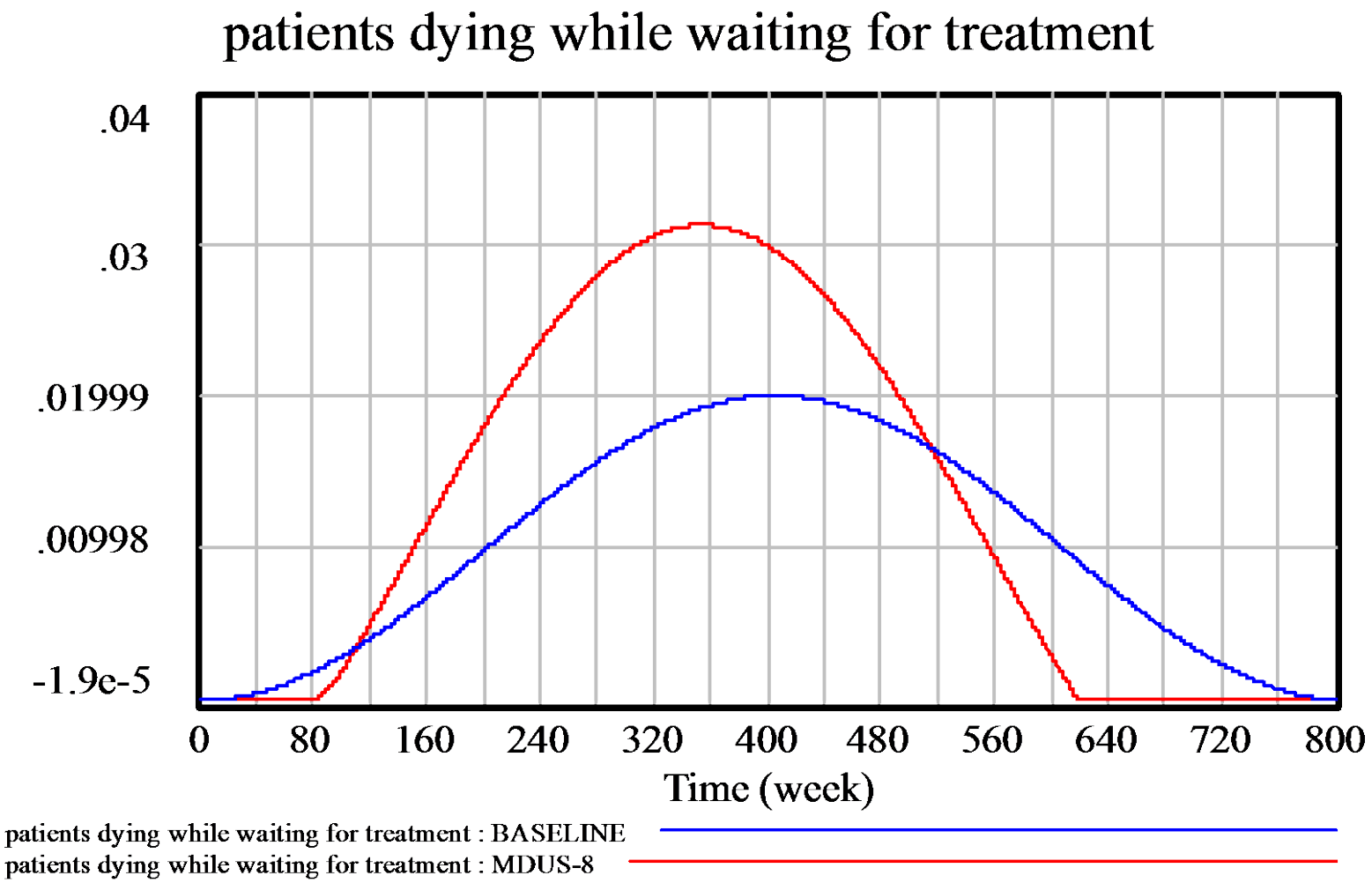
Rates of dying while waiting
Specialist Cuts vs Baseline
(No Referral Reduction)



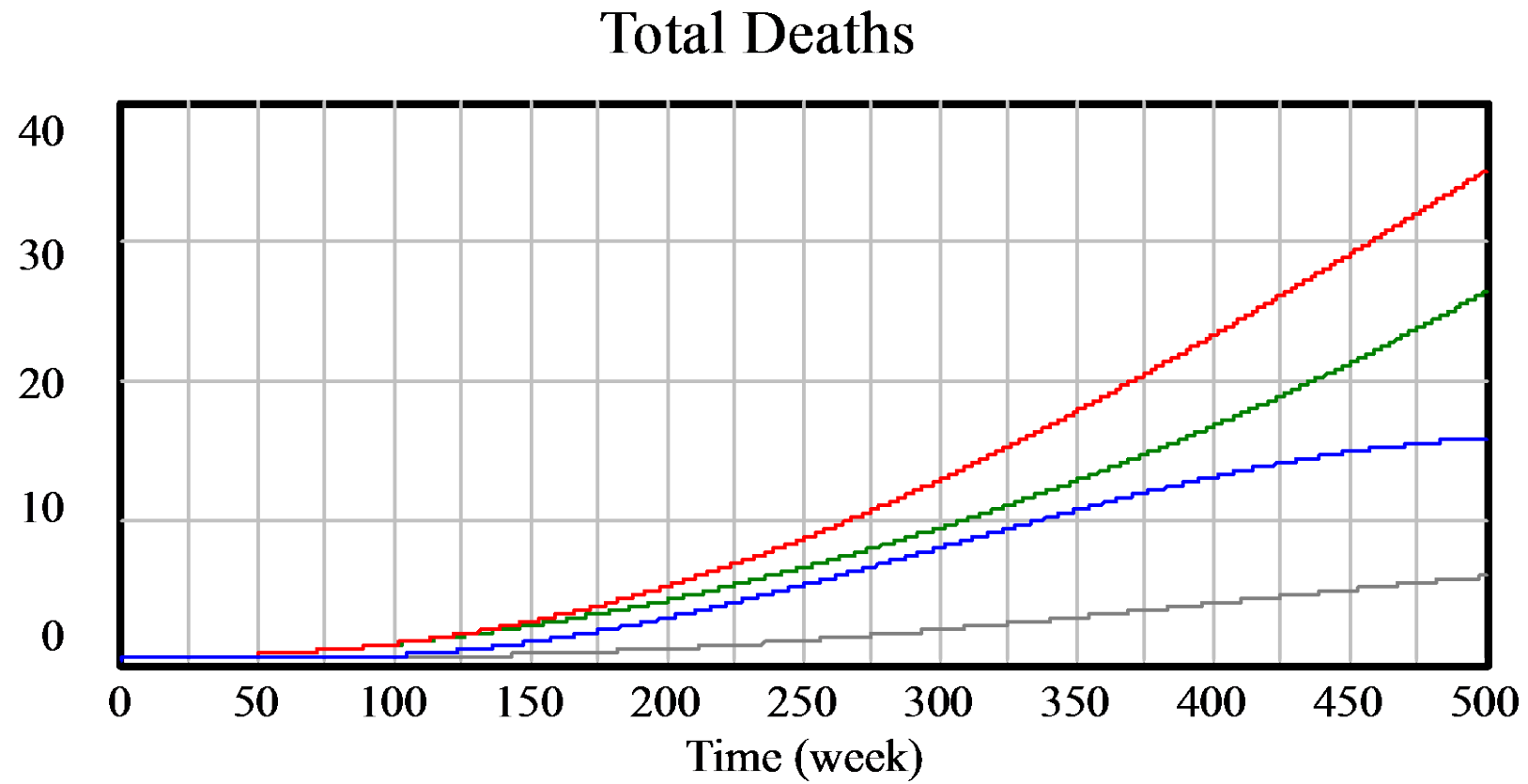
Rates of dying while waiting
Referrals reductions vs Baseline
(No Specialist Cuts)



Rates of dying while waiting
Specialist Cuts and Referral Reductions vs Baseline



Total Deaths



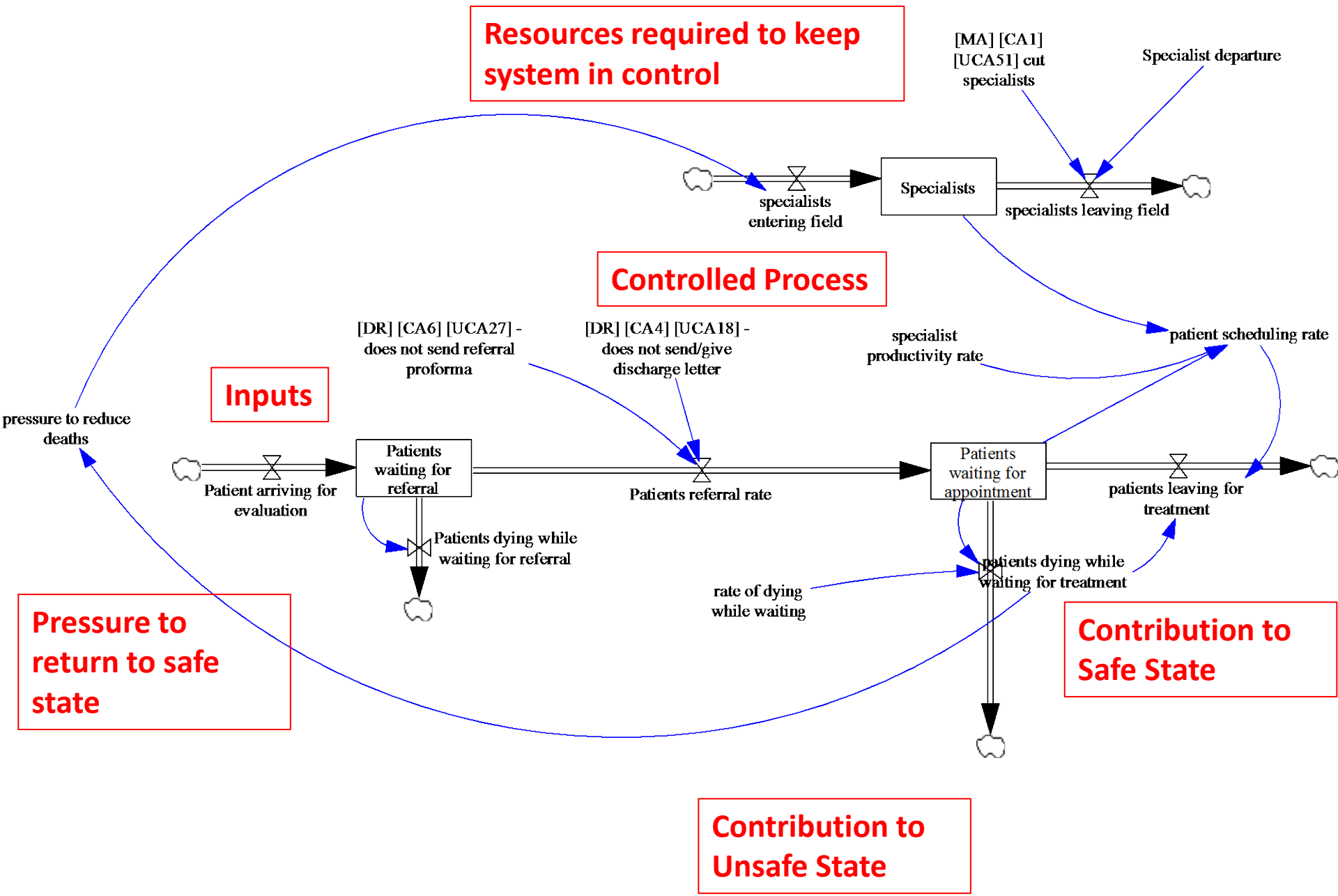
Modeling Observations

- Specialist Cuts more impactful than Referral Reductions
- UCAs modify flows
- Model structure is not changed by including UCAs
- Some UCAs take longer to recover from than others
  - Should be noted in designing mitigations
- Need to make sure you look at total system losses
  - Deaths while waiting for treatment and Deaths waiting for referral

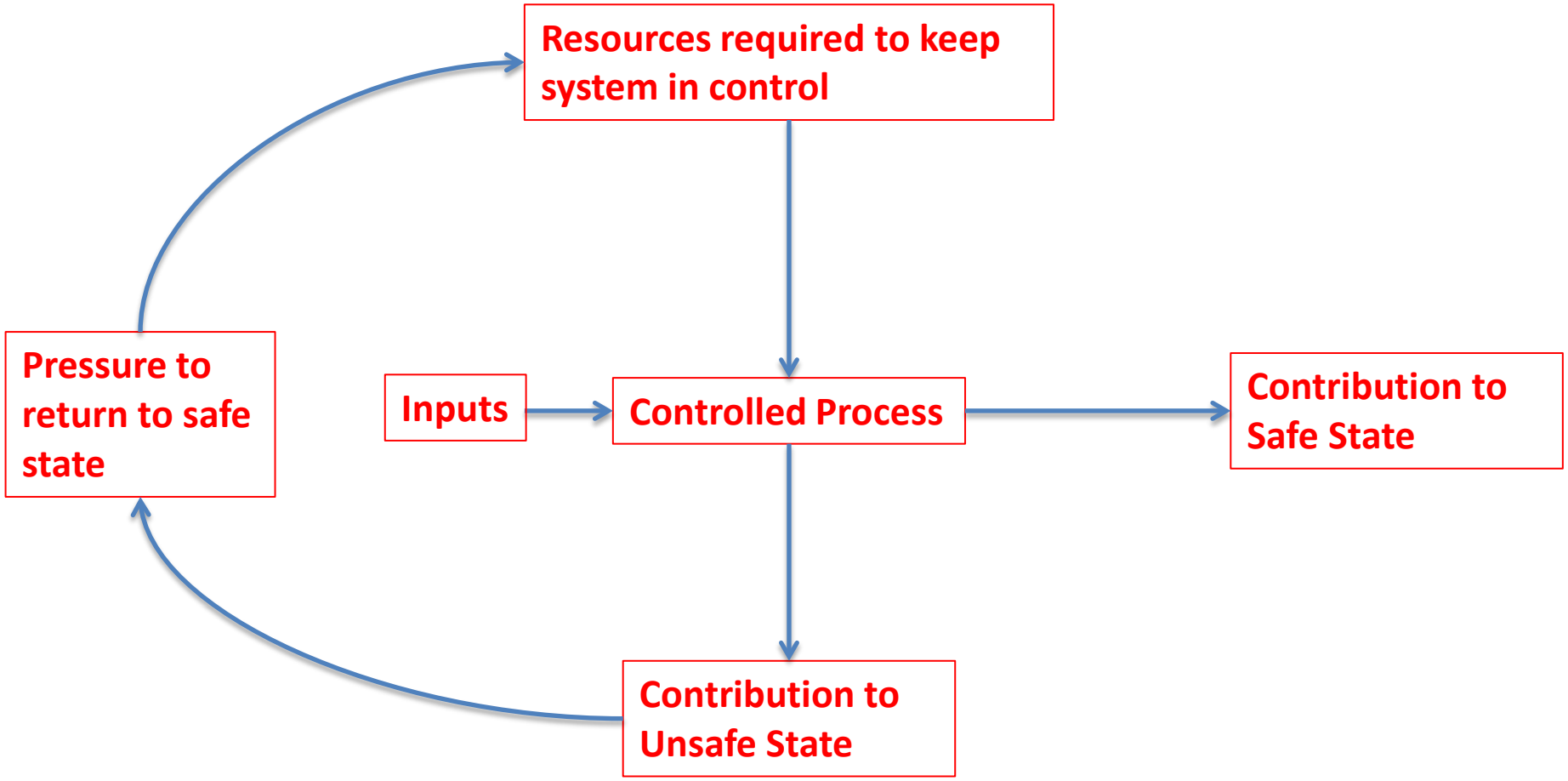
Drift Rate vs Recovery Rate (Possible Prioritization Method)

		Recovery Time	
		Short	Long
Drift Time	Short	2	1
	Long	4	3

Can this model be generalized?



Generalized Model



Final Remarks

1. Bring dynamic analysis to STAMP
2. STPA Step 1 & SD to model the dynamics of the drift from safe to unsafe states
3. Linkage by using the UCAs as variables in the SD model
4. Each UCA can trigger other UCAs
5. Manipulation of each UCA in combination with other UCAs at the same to assess the speed of drift into failure
6. STAMP and SD combination gives insight on rate of drift and recovery time for systems
7. UCAs impact flows between stocks but not structure of the model

Future Work

- Validate the model
  - SD models are illustrative, not predictive.
  - Interview experts to get better estimates of values of flow and fixed constants
  - Review SD literature for “pressure” models
- Assess the drift into failure and the recovery of the system based on more than one hazard
- Consider all UCAs and group them
- Generalize to other domains
  - Food Safety
  - Perhaps other problematic fields, i.e. Mining, Railways

Thank you!

Contact

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Model Variable Relationships

Model Variable	Value	Units	Init
Specialists	Specialists entering – specialists leaving	Specialists	50
Patients waiting for appointment	Patients arriving – patients scheduled – patients dying while waiting	Patients	0
Patients dying while waiting	Patients waiting x Rate of dying while waiting	Patients/week	
Patient scheduling rate	Specialists x specialist productivity	Patients/week	
Patients leaving for treatment	Max (patient scheduling rate,0)	Patients/week	
Pressure to reduce deaths while waiting	Patients dying while waiting	Dimensionless	
Specialists entering	Pressure to reduce deaths	Specialists/week	

Run Values

Run Number	[MA] UCA51	[DR] UCA18	[DR] UCA27	Result
1	0	0	0	BASELINE
2	50,50	0	0	MDUS-2
3	0	.95	0	MDUS-3
4	0	0	.98	MDUS-4
5	50,50	.95	0	MDUS-5
6	50,50	0	.98	MDUS-6
7	0	.95	.98	MDUS-7
8	50,50	.95	.98	MDUS-8