What Can Formal Modeling Add to Qualitative Systems Thinking?

A Case of the Shifting the Burden Archetype

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Research Questions

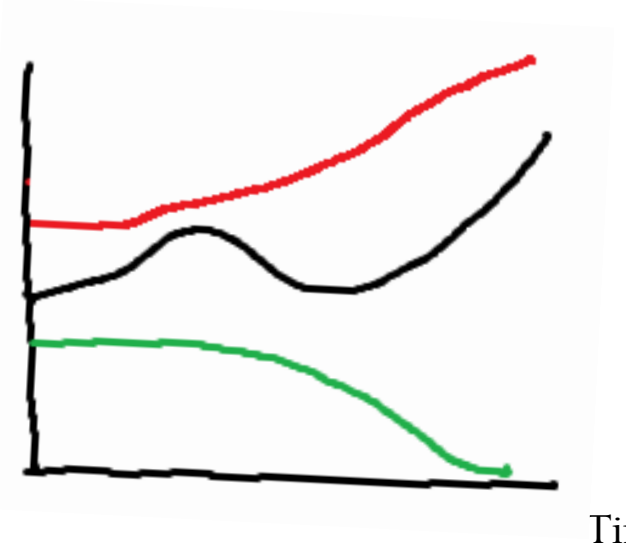
- Can a formal simulation model reproduce the dynamic behavior as described in the shifting the burden archetype?
  - Dowling, MacDonald and Richardson (1995)

- What can formal modeling add to qualitative systems archetype? In particular, should one always strive to eliminate shifting the burden as prescribed?

Acknowledgement: Nelson Repenning, Peter Senge, John Sterman

Shifting the Burden Behavior

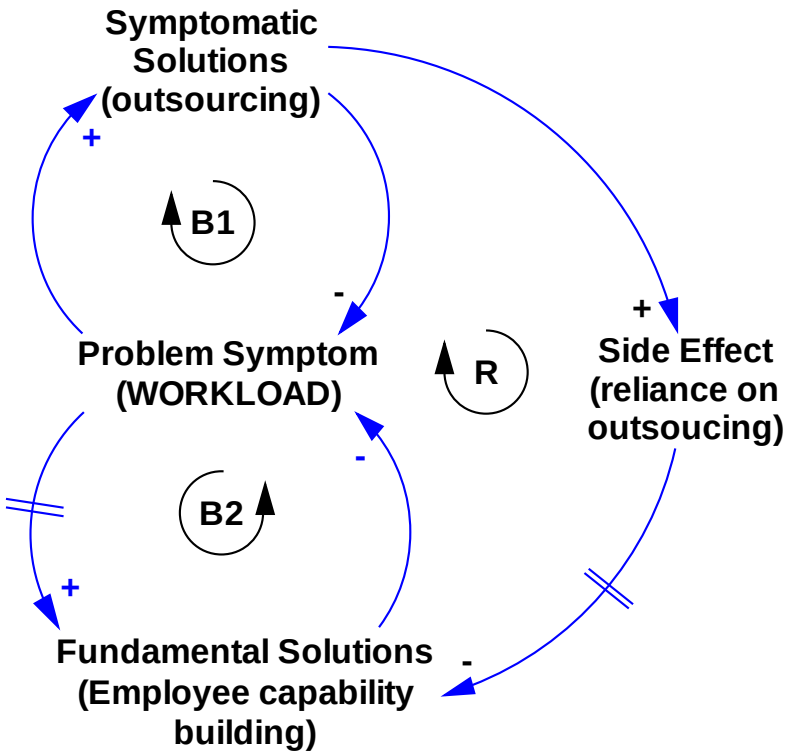
- "An underlying problem generates symptoms that demand attention. But the underlying problem is difficult for people to address, either because it is obscure or costly to confront. So people "shift the burden" of their problem to other solutions – well-intended, easy fixes which seem extremely efficient. Unfortunately, the easier "solutions" only ameliorate the symptoms; they leave the underlying problem unaltered. The underlying problem grows worse, unnoticed because the symptoms apparently clear up, and the system loses whatever abilities it had to solve the underlying problem." (Senge 1990 , The Fifth Discipline, p.104)

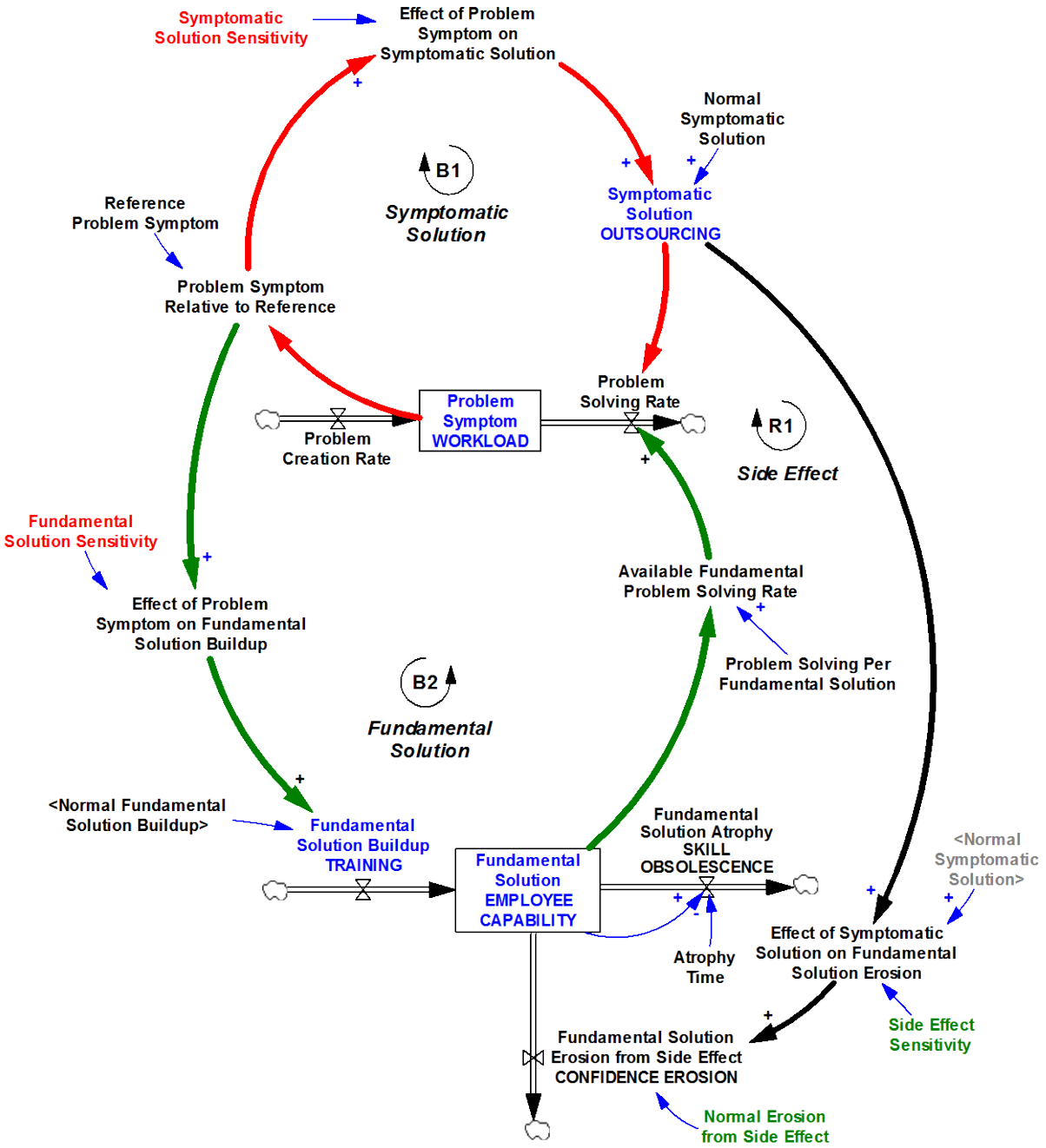


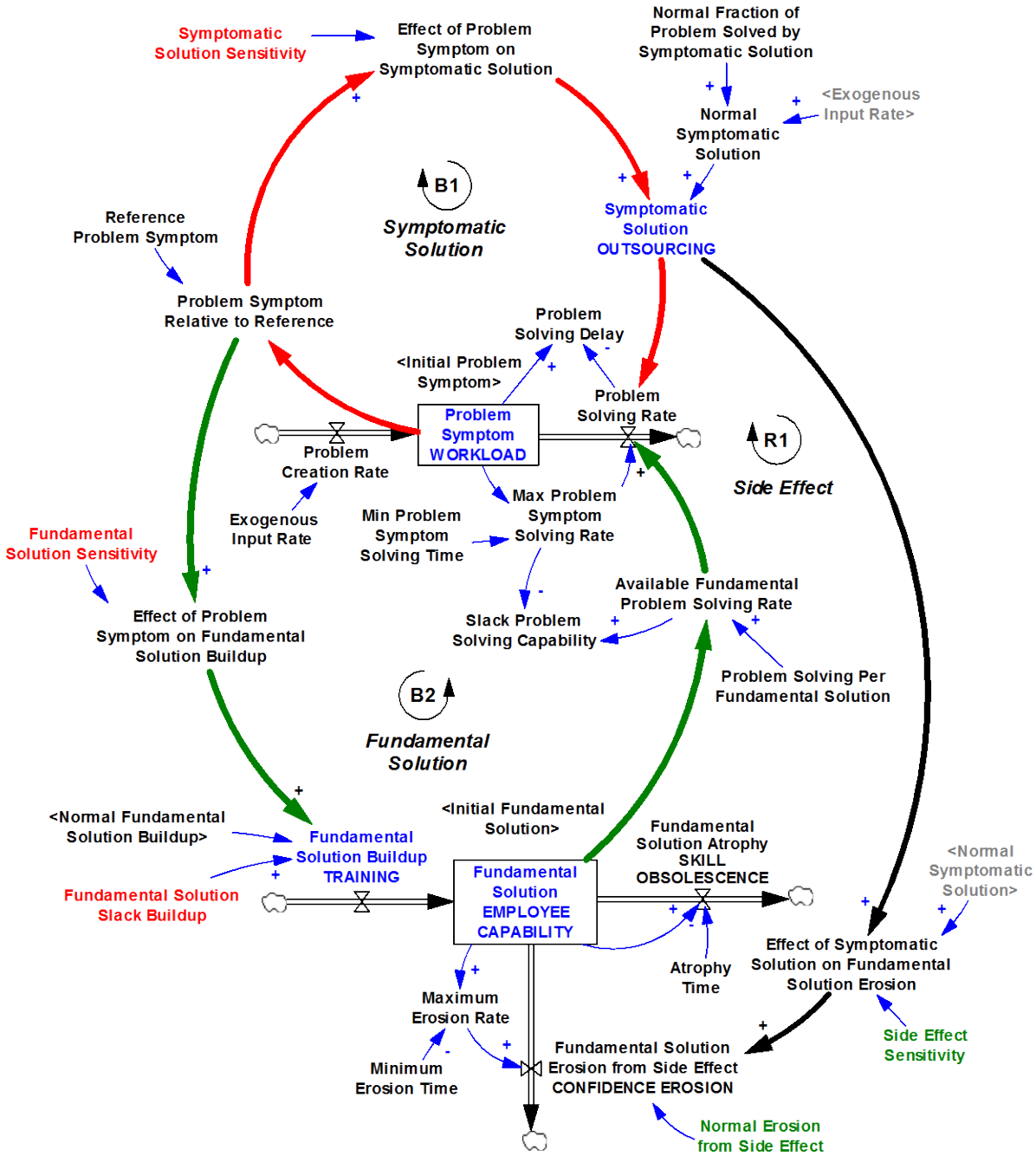
Shifting the Burden Structure

- "The shift the burden is composed of two balancing (stabilizing) processes. Both are trying to adjust or correct the same problem symptom. The top circle represents the symptomatic intervention; the "quick fix." It solves the problem symptom quickly, but only temporarily. The bottom circle has a delay. It represents a more fundamental response to the problem, one whose effects take longer to become evident. However, the fundamental solution works far more effectively – it may the only enduring way to deal with the problem." (Senge 1990, p.106)

- " Often (but not always), in shifting the burden structures there is also an additional reinforcing (amplifying) process created by "side effects" of the symptomatic solution. When this happens, the side effects often make it more difficult to invoke the fundamental solution." (Senge 1990, p.106)




Symptomatic Solution Sensitivity
Effect of Problem Symptom on Symptomatic Solution
Normal Symptomatic Solution
B1
Symptomatic Solution
Symptomatic Solution OUTSOURCING
Reference Problem Symptom
Problem Symptom Relative to Reference
Problem Solving Rate
Problem Symptom WORKLOAD
Problem Creation Rate
R1
Side Effect
Fundamental Solution Sensitivity
Effect of Problem Symptom on Fundamental Solution Buildup
Available Fundamental Problem Solving Rate
Problem Solving Per Fundamental Solution
B2
Fundamental Solution
<Normal Fundamental Solution Buildup>
Fundamental Solution Buildup TRAINING
Fundamental Solution EMPLOYEE CAPABILITY
Fundamental Solution Atrophy SKILL OBSOLESCENCE
<Normal Symptomatic Solution>
Atrophy Time
Effect of Symptomatic Solution on Fundamental Solution Erosion
Side Effect Sensitivity
Fundamental Solution Erosion from Side Effect CONFIDENCE EROSION
Normal Erosion from Side Effect

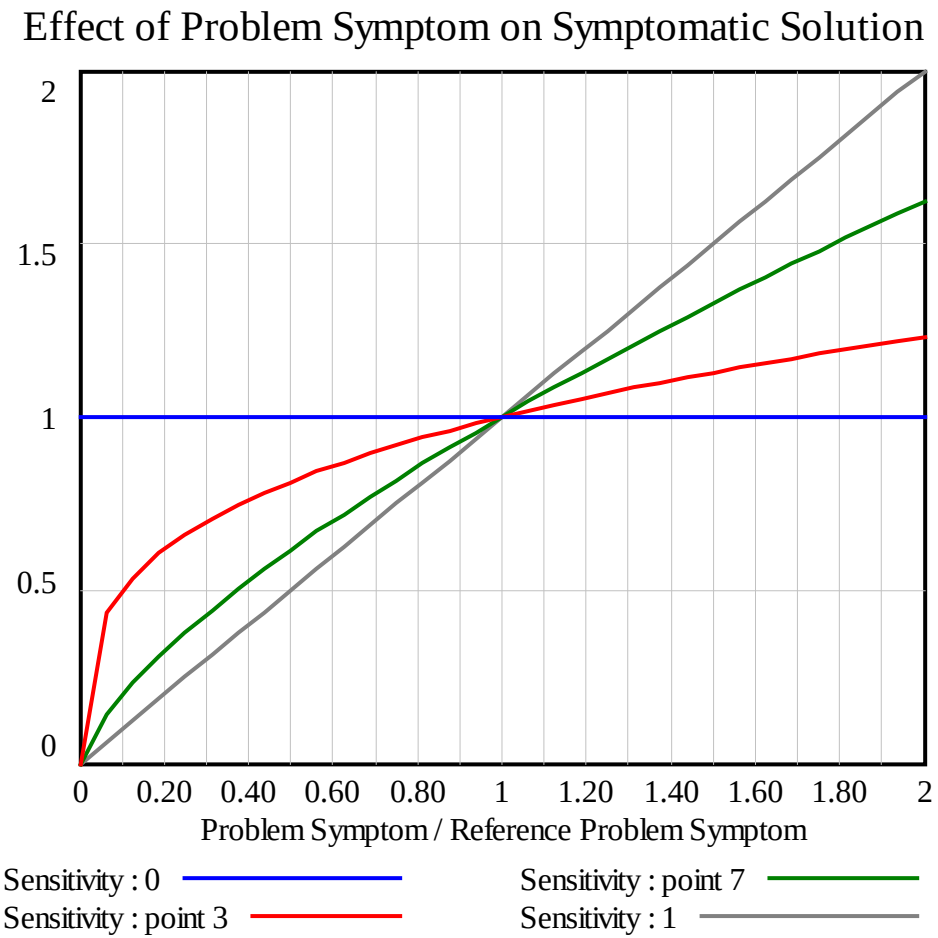

Symptomatic Solution Sensitivity
Effect of Problem Symptom on Symptomatic Solution
Normal Fraction of Problem Solved by Symptomatic Solution
<Exogenous Input Rate>
Normal Symptomatic Solution
B1
Symptomatic Solution
Reference Problem Symptom
Symptomatic Solution OUTSOURCING
Problem Symptom Relative to Reference
Problem Solving Delay
<Initial Problem Symptom>
Problem Solving Rate
Problem Symptom WORKLOAD
Problem Creation Rate
R1
Side Effect
Exogenous Input Rate
Min Problem Symptom Solving Time
Max Problem Symptom Solving Rate
Fundamental Solution Sensitivity
Available Fundamental Problem Solving Rate
Effect of Problem Symptom on Fundamental Solution Buildup
Slack Problem Solving Capability
Problem Solving Per Fundamental Solution
B2
Fundamental Solution
<Normal Fundamental Solution Buildup>
<Initial Fundamental Solution>
Fundamental Solution Buildup TRAINING
Fundamental Solution Atrophy SKILL OBSOLESCENCE
<Normal Symptomatic Solution>
Fundamental Solution Slack Buildup
Fundamental Solution EMPLOYEE CAPABILITY
Effect of Symptomatic Solution on Fundamental Solution Erosion
Atrophy Time
Maximum Erosion Rate
Side Effect Sensitivity
Minimum Erosion Time
Fundamental Solution Erosion from Side Effect CONFIDENCE EROSION
Normal Erosion from Side Effect

Symptomatic Solution

= Normal Symptomatic Solution * Effect of Problem Symptom on Symptomatic Solution

Effect of Problem Symptom on Symptomatic Solution

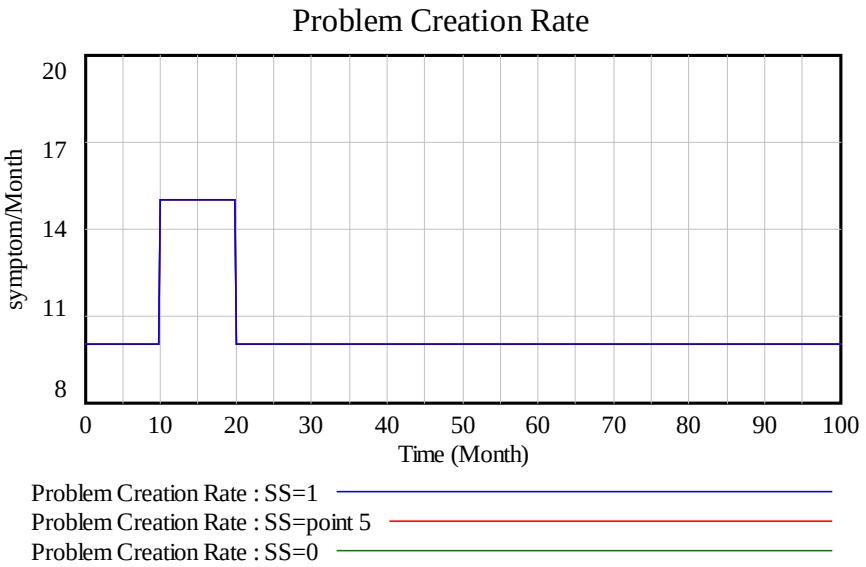
= (Problem Symptom/Reference Problem Symptom) ^ Symptomatic Solution Sensitivity

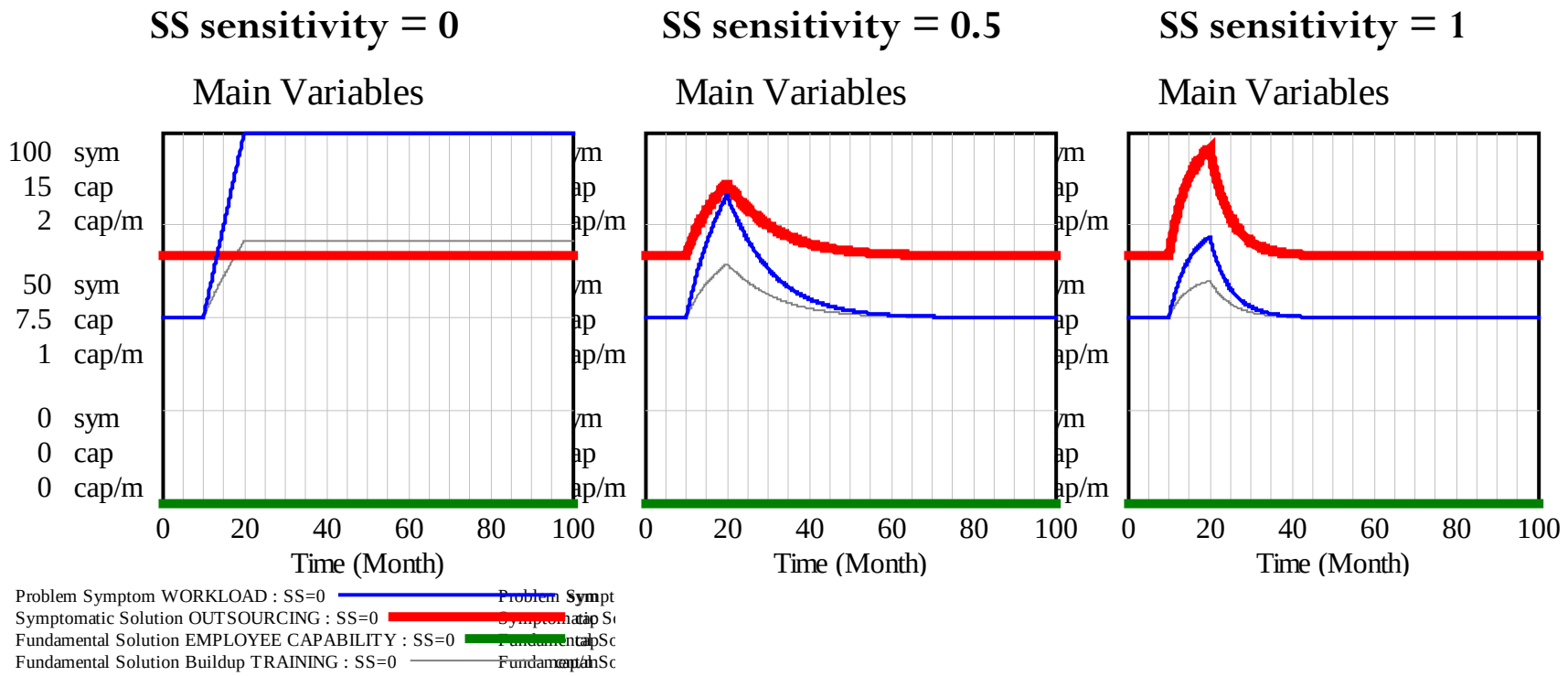


Partial Model Test 1:
B1 Symptomatic Solution only

- Cut B2 Fundamental Solutions and R1 Side Effect loops → Only B1 loop
- Test: Pulse problem creation rate from 10 to 15 at time 10 for 10 months
- Adjusting Symptomatic Solution (SS) Sensitivity from 0 to 0.5 to 1

- Question 1: Is shifting the burden intended rational?





Decision Rule: higher problem symptoms (PS), enact higher symptomatic solutions (SS) to reduce the problems.

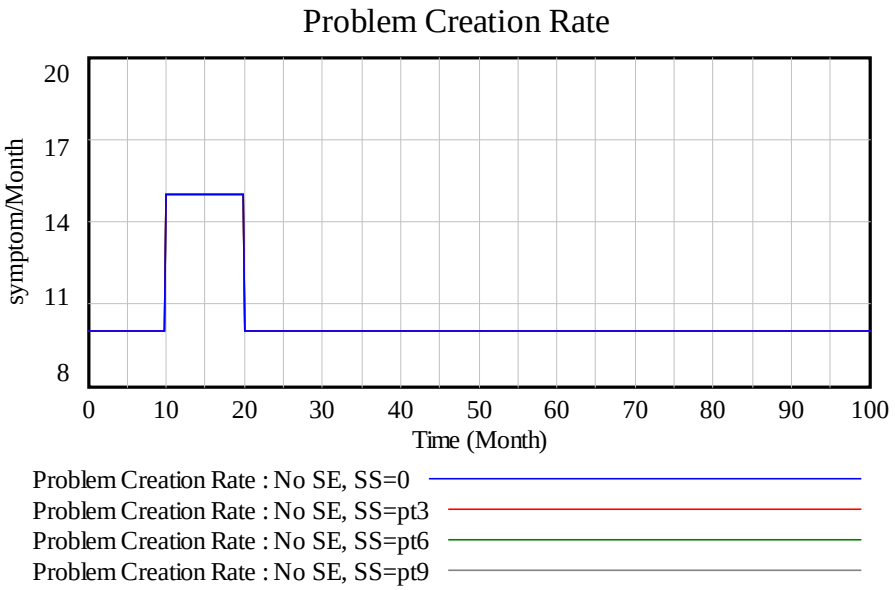
Intended Rationality: Higher SS sensitivity from 0 to 0.5 to 1, higher SS (red) which reduces PS (blue) and restores to equilibrium faster.

Insight 1: Without fundamental solution and side effect, shifting the burden is intended rational as it reduces problem symptoms as expected.

Partial Model Test 2: B1 + B2, No Side Effect

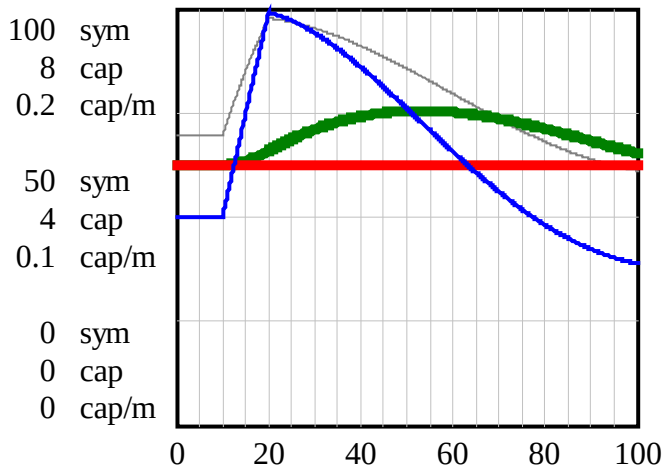
- Cut R1 Side Effect loop → B1 + B2
- Test: Pulse problem creation rate from 10 to 15 at time 10 for 10 months
- Adjusting Symptomatic Solution (SS) Sensitivity from 0 to 0.3 to 0.6 to 0.9

- Question 2: Without side effect, is shifting the burden always bad?

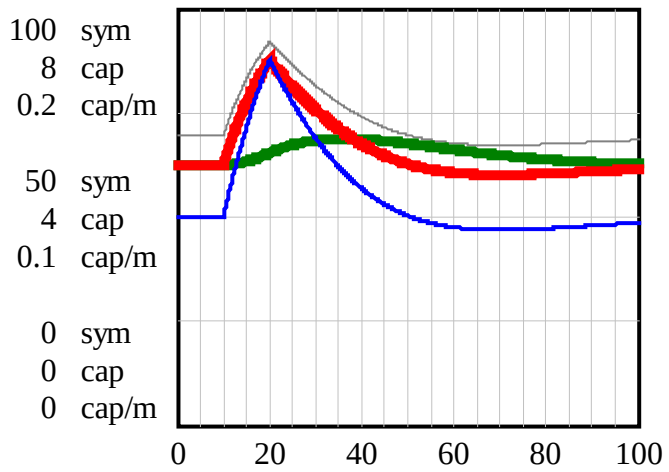


Higher Symptomatic Solution Sensitivity, higher symptomatic solution (red) and lower fundamental solution (green) → Problem symptom (blue) restores faster to equilibrium.

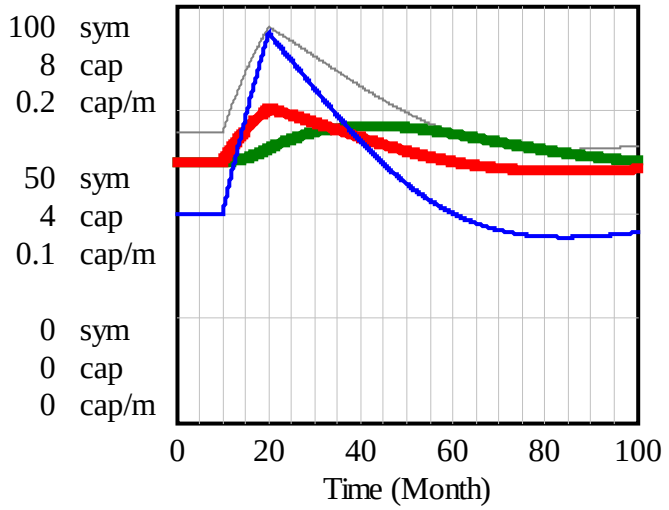
SS sensitivity = 0



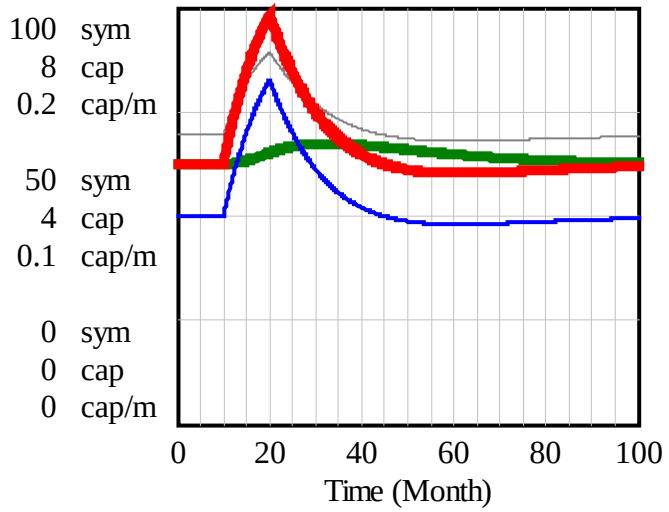
SS sensitivity = 0.6



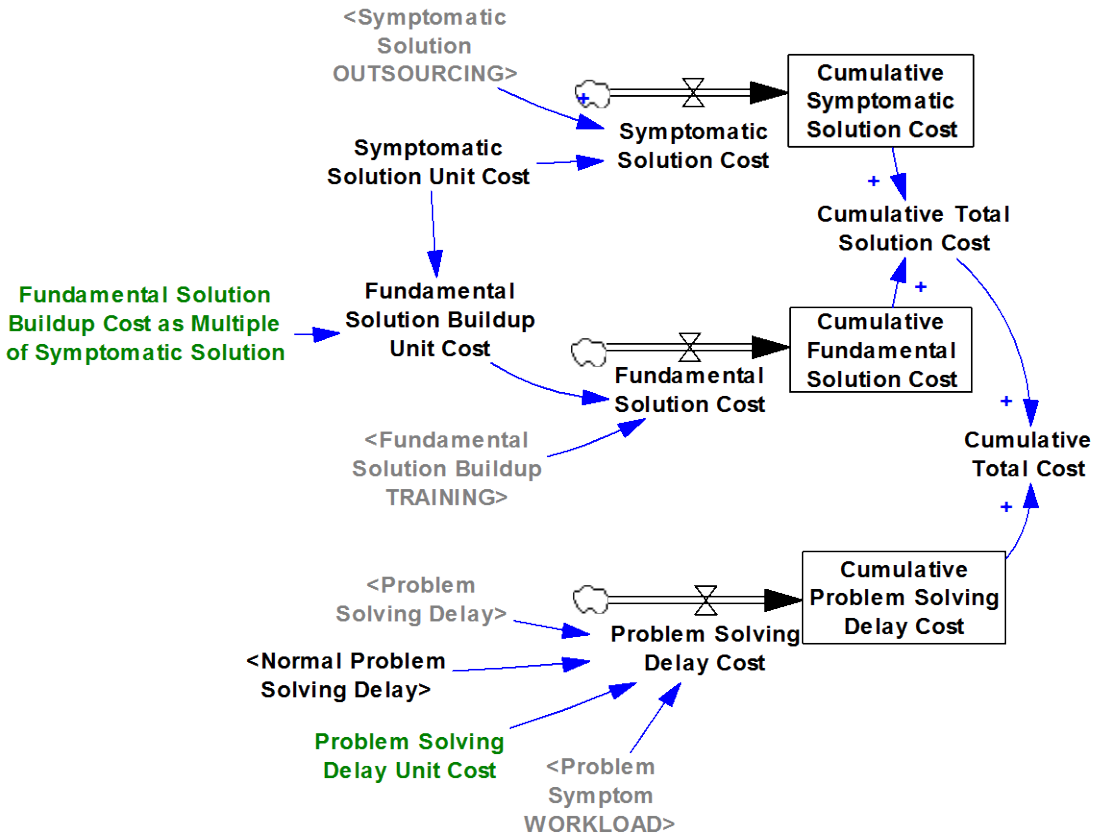
SS sensitivity = 0.3



SS sensitivity = 1



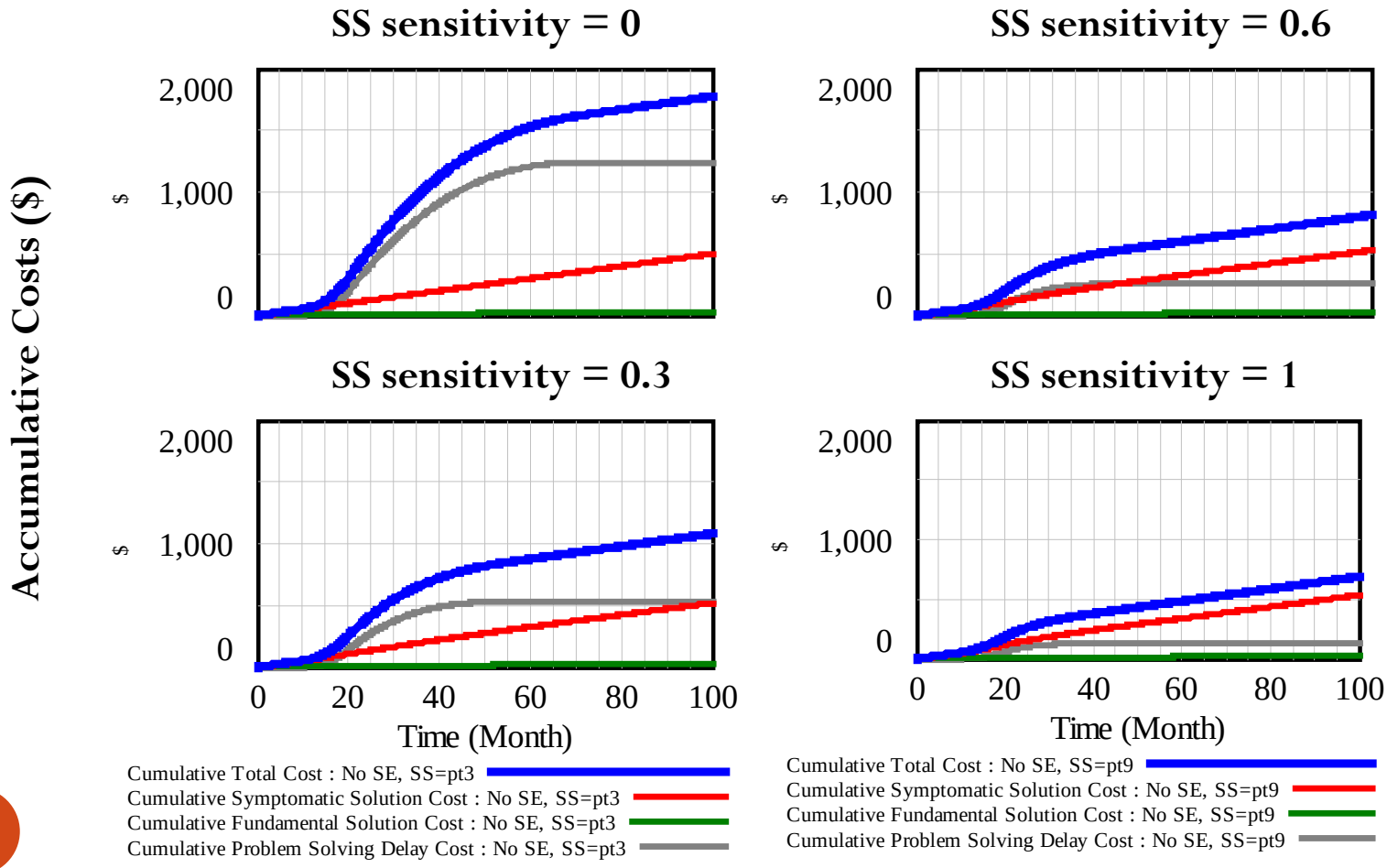
Cost Accounting



Is shifting the burden necessary bad? It depends.

If there is a cost for solving problems slower than expected (Problem Solving Delay Cost), then higher symptomatic solution helps restore equilibrium faster, thus reduces the cumulative costs.

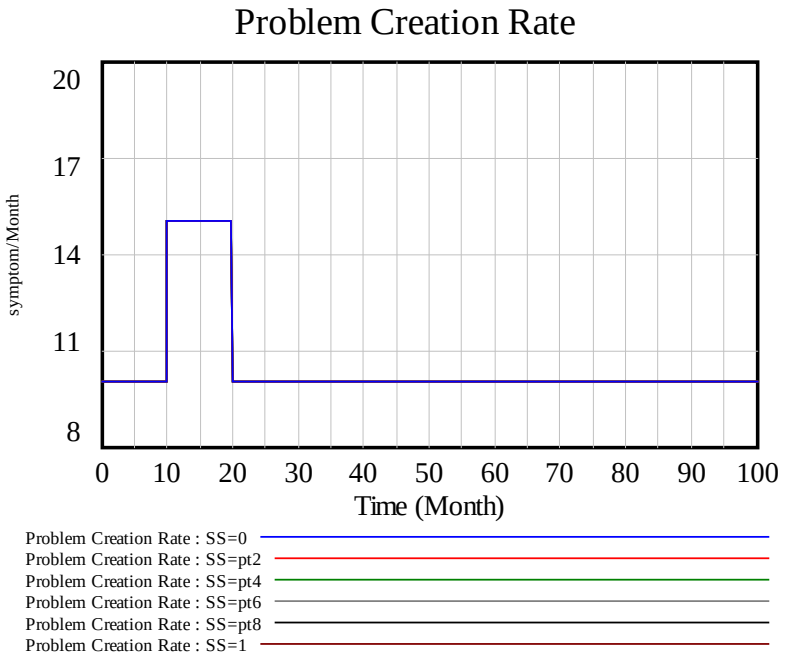
Insight 2: Shifting the burden is beneficial when there is (1) no or low enough side effect from symptomatic solution and (2) high enough problem solving delay cost.



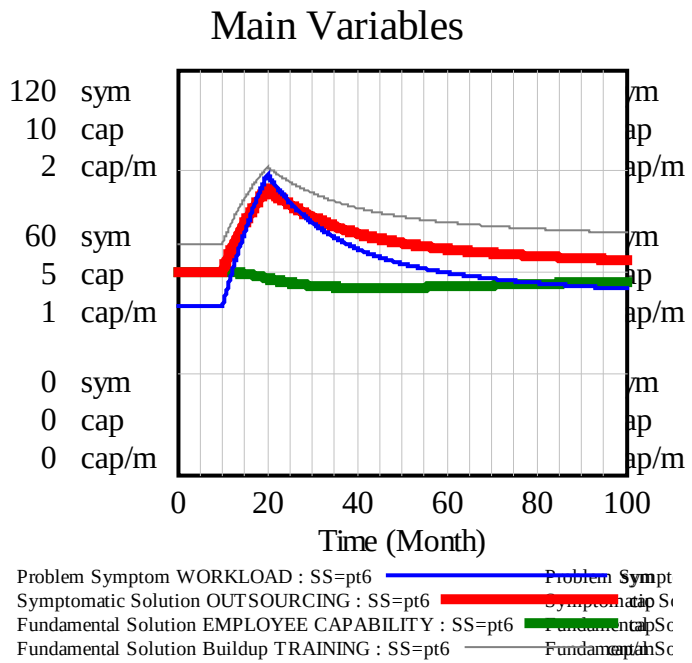
Full Model: B1+B2+R1

- Test: Pulse problem creation rate from 10 to 15 at time 10 for 10 months
- Adjusting Symptomatic Solution (SS) Sensitivity from 0 to 0.2 to 0.4 to 0.6 to 0.8 to 1

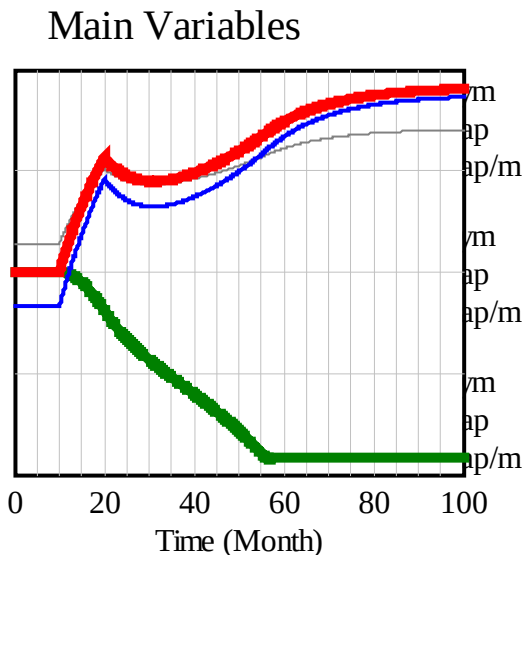
- Question 3: With side effect, do we see shifting the burden dynamics as described?
- Question 4: With side effect, is shifting the burden always bad?



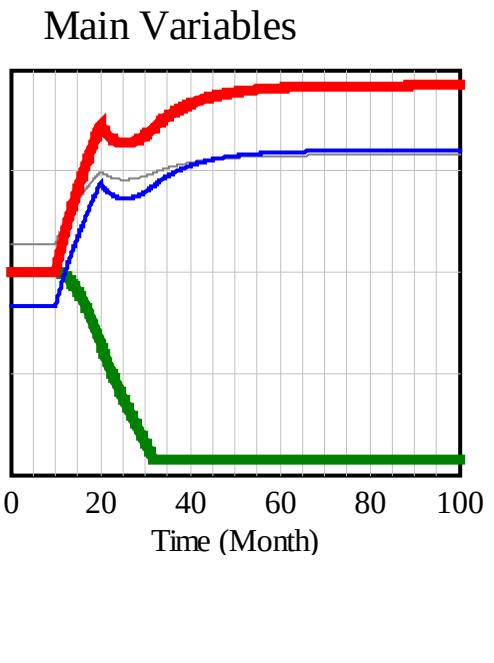
SS sensitivity = 0.6



SS sensitivity = 0.8



SS sensitivity = 1

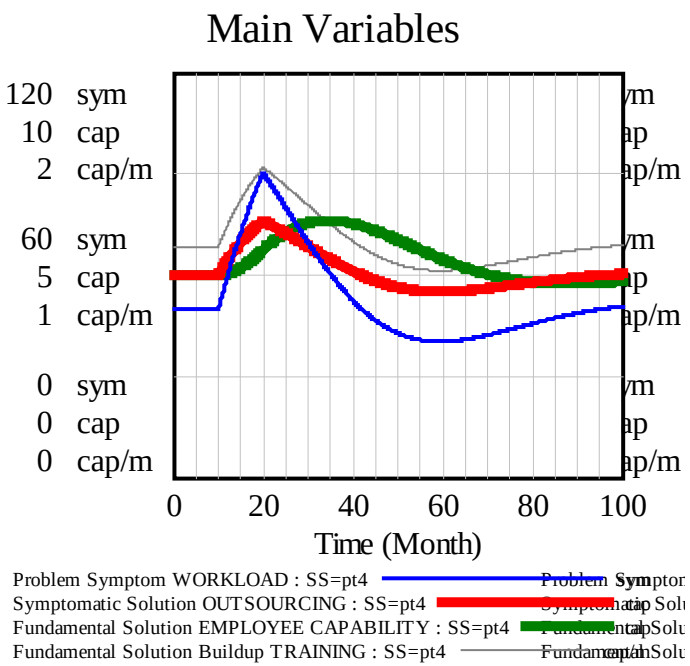


Higher SS sensitivity, higher SS (red) and lower FS (green) → Shifting the burden does occur.

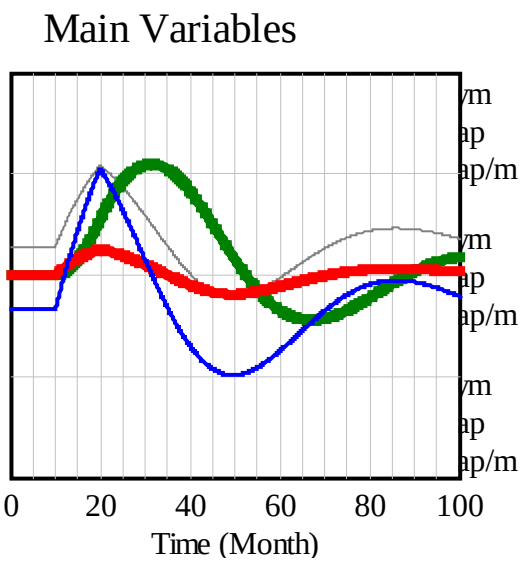
When SS sensitivity = 0.8 → SS increases (red) which lowers PS temporarily (blue) → however, side effect induced by too many SS causes FS to erode → PS increases rapidly → need more SS → even faster FS erosion …

Insight 3: With side effect, shifting the burden too much can tip the system into vicious circle.

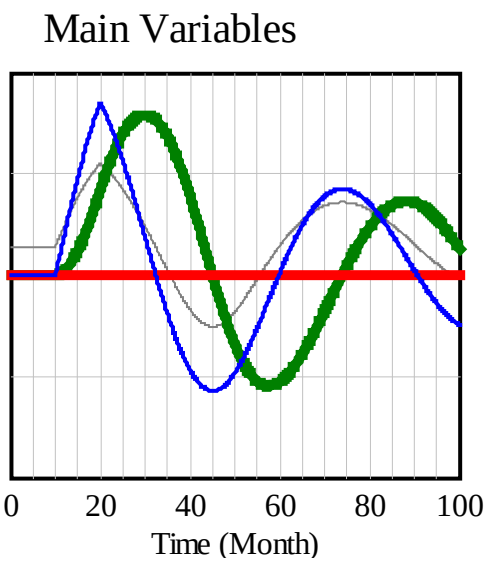
SS sensitivity = 0.4



SS sensitivity = 0.2



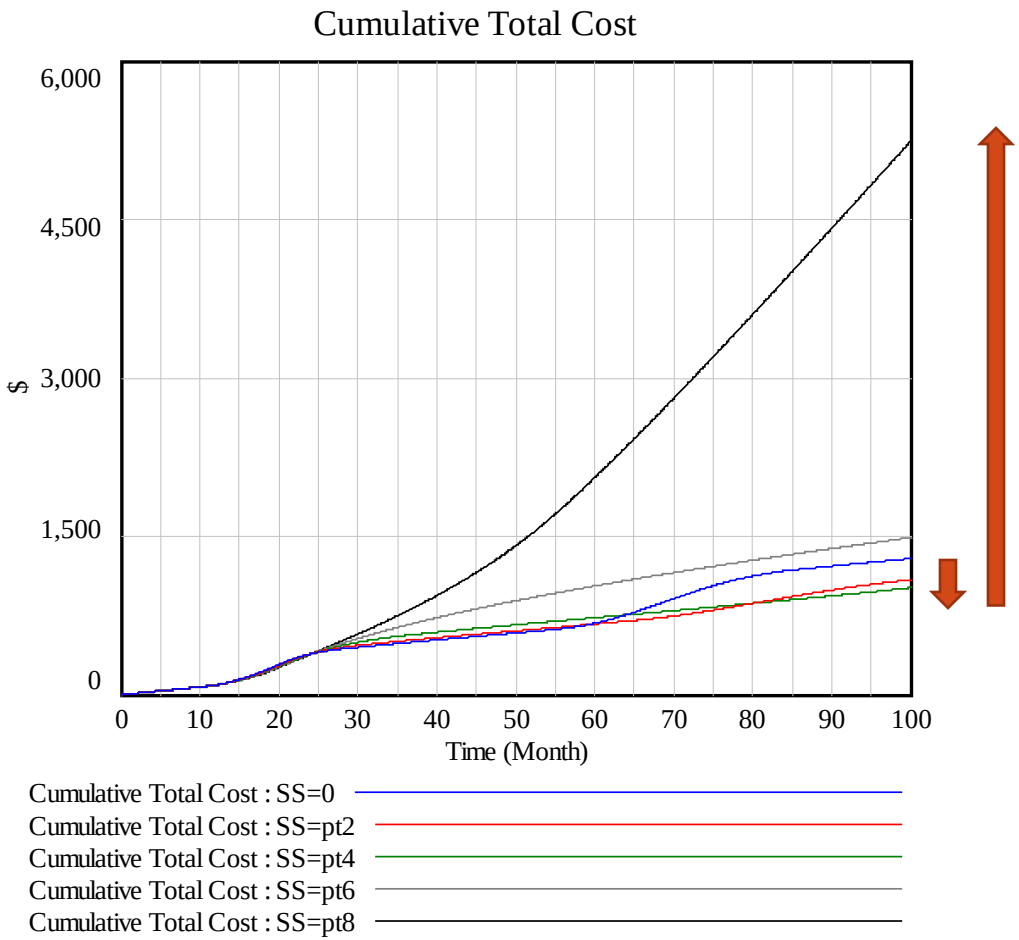
SS sensitivity = 0



As SS sensitivity reduces from 0.4 to 0.2 to 0, there is less SS (red), however FS (green) and PS (blue) oscillate!

When SS sensitivity = 0 → a pulse shock of PS increases FS buildup (grey) → FS increases with time delay → FS overshoots → PS drops significantly → cut back FS buildup → FS erodes with time delay → FS undershoots → PS increases significantly ….

Insight 4: Appropriate level of shifting the burden can dampen FS oscillation, stabilize PS and reduce problem solving delay costs.



As SS sensitivity goes from 0 (blue) to 0.2 (red) and 0.4 (green), the cumulative total cost actually decreases due to SS helps dampen FS and PS oscillations, and reduces problem solving delay costs.

As SS sensitivity increases to 0.6 (grey) and 0.8 (black), the cumulative total cost increases dramatically due to too high the shifting the burden tips the system into a vicious circle.

Takeaway

- A formal simulation model can reproduce the dynamic behavior as described in the shifting the burden archetype.

- Qualitative systems thinking archetype indicates shifting the burden is costly and should be eliminated whenever possible. However, formal simulation analysis reveals under certain conditions shifting the burden can actually be beneficial.

- Formal modeling and simulation analysis can reveal insights not captured by qualitative systems thinking. We call on similar formal modeling work for other system archetypes.