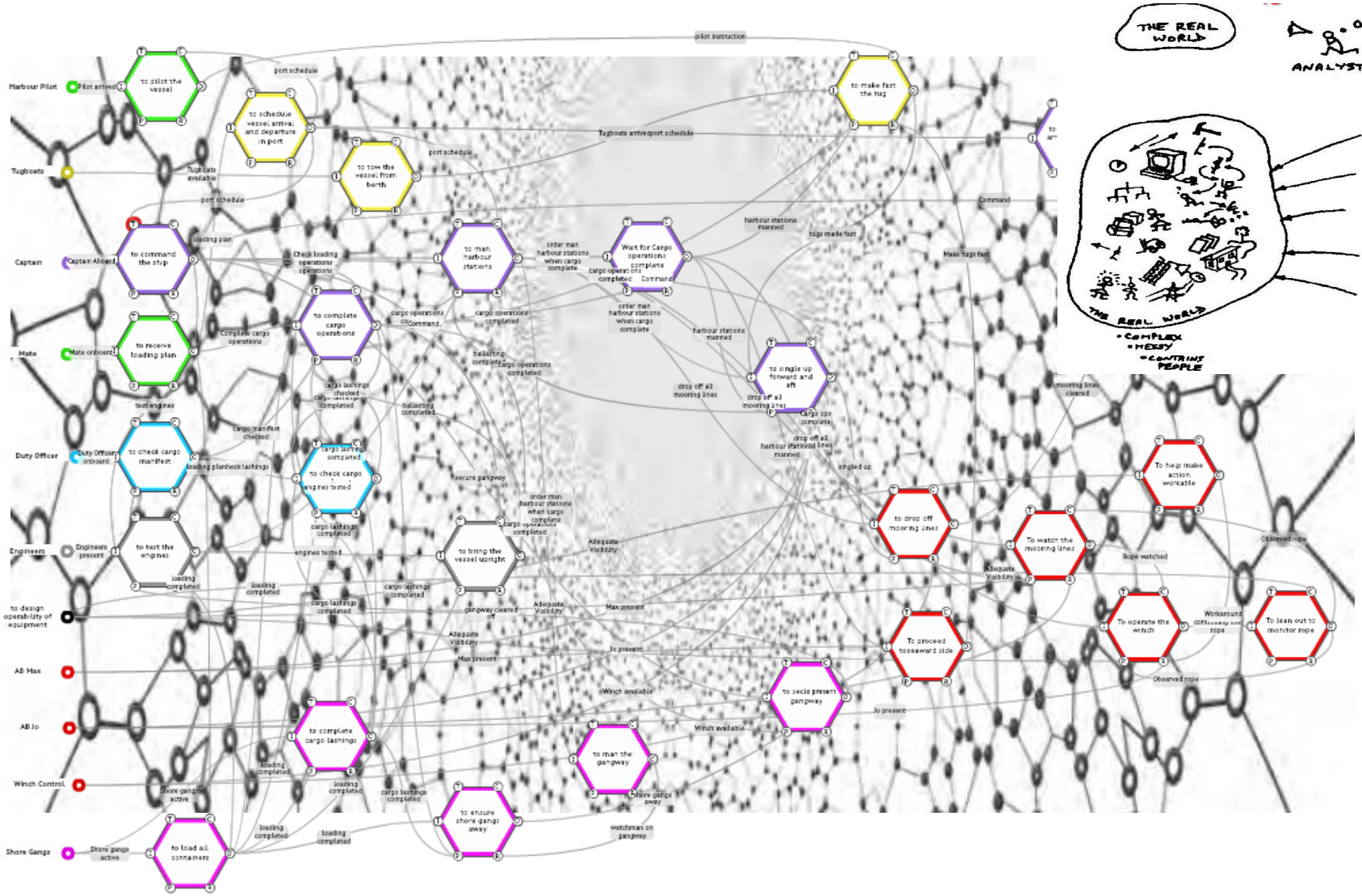


Propagation of Variability in Complex Sociotechnical Systems

M O D E L B A S E D S Y S T E M S (R E S I L I E N C E) E N G I N E E R I N G U S I N G F R A M

David Slater, Rees Hill, Nomoto Hideki and Ralph MacKinnon

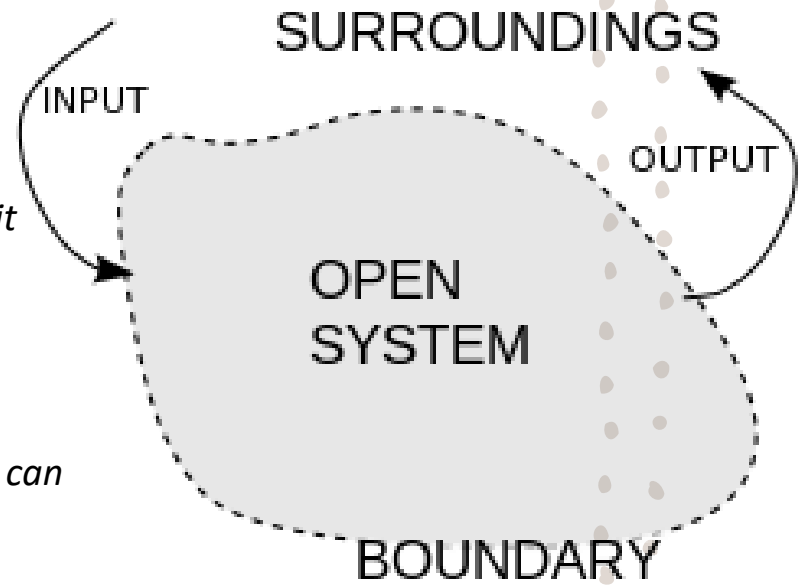
A Systematic Review of Modelling Methodologies

setting criteria for the requirements of an appropriate approach. The criteria chosen:

- ***a solution based on system thinking.***
- ***sufficient resolution or granularity of the representations,***
- ***the nonlinear, non-predetermined nature of the process models***
- ***the ability to predict dynamic behaviour.***
- ***The ability to model unexpected outcomes – (resonance and emergence)***
- ***The ability to follow the propagation of variability through the system.***
- ***and the ability to optimise the performance and resilience of the system.***

System Thinking

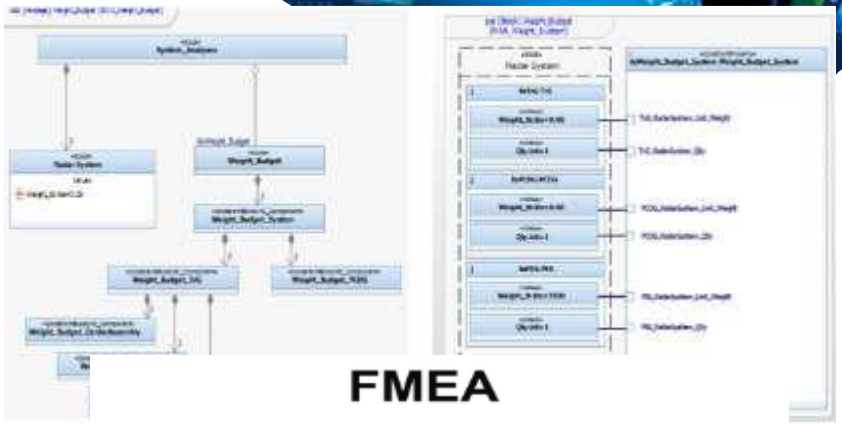
- *"When you analyze a system, you learn something, but you don't get understanding.*
- *The result of analysis of a system is knowledge. And for the first time, in the 1950s, science distinguished between knowledge and understanding, and recognized that all the work of science has produced is knowledge – but not understanding. Understanding requires a different method of thought".*
- *"A system is never the sum of its parts; it's the product of their interaction.*
- *The performance of a system doesn't depend on how the parts perform taken separately, it depends on how they perform together.*
- *– how they interact, not on how they act, taken separately.*
- *Therefore, when you improve the performance of a part of a system taken separately, you can destroy the system".*



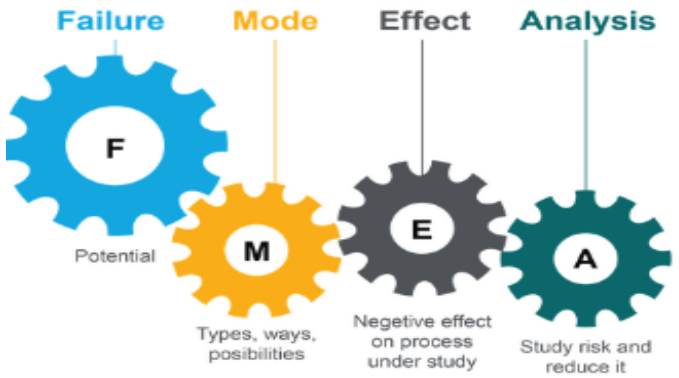
System Thinking Ackoff

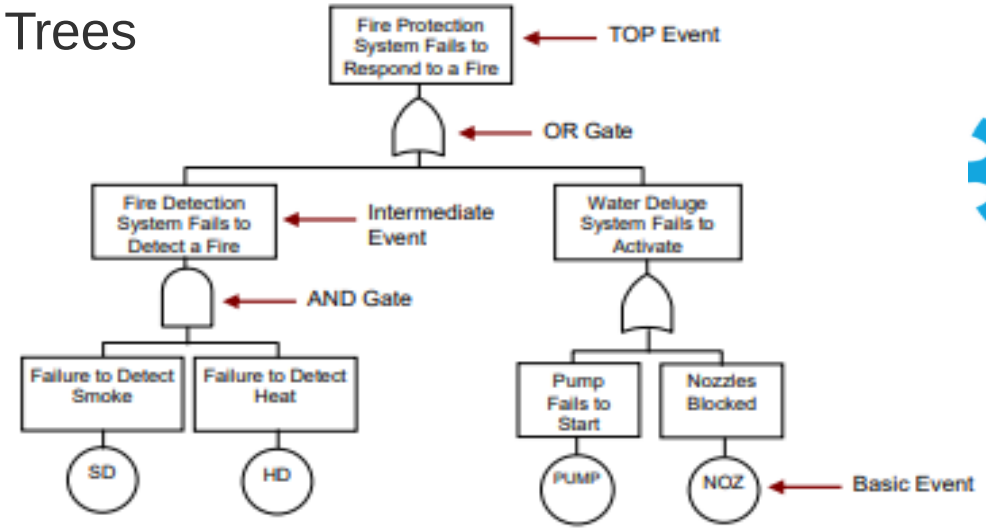
Non -System Models

- MBSE (Model Based System Engineering)
- FMEA (Failure Modes and Effects)
- Cause consequence “Roots”
- Logic Trees



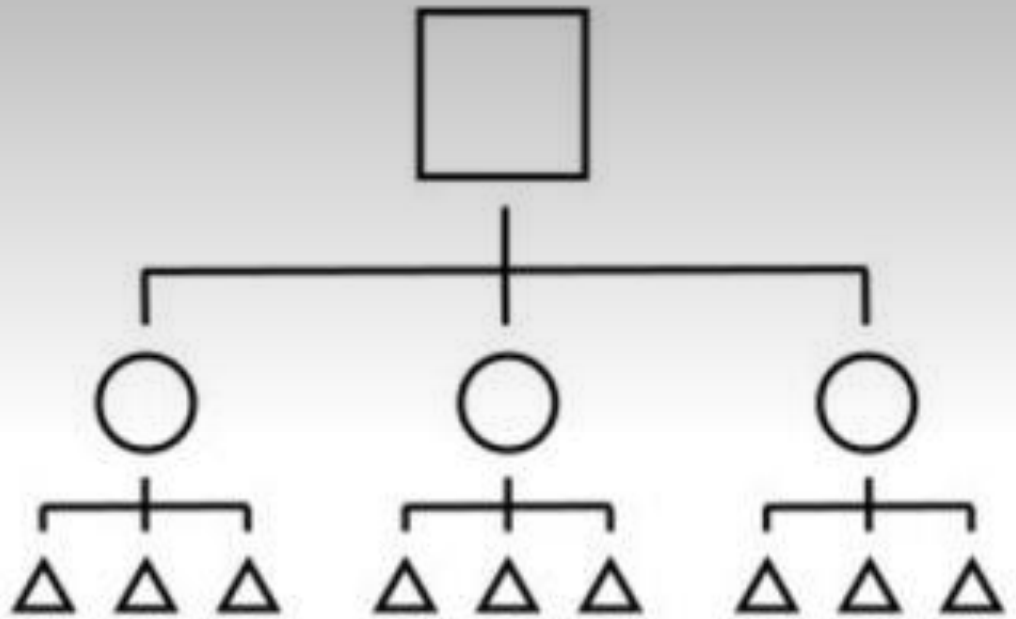
FMEA



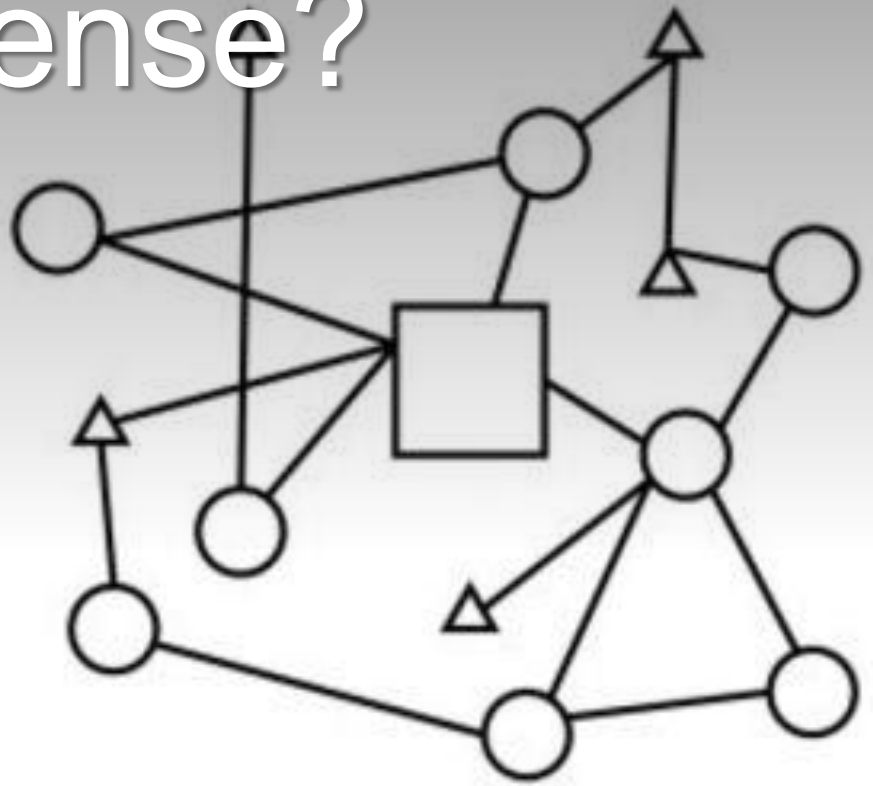


Understanding Routine vs Complex Process

Doesn’t make sense?



What we were designed for



What we are facing

Understanding Routine Process

Classical Recipes

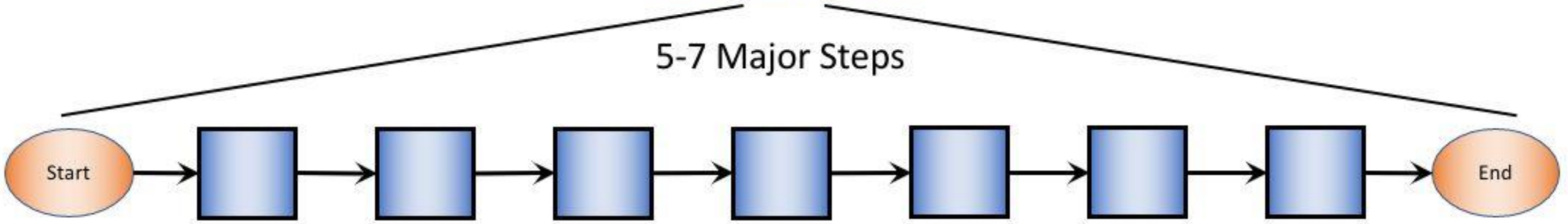
Suppliers
The provider of inputs to your process

Inputs
Materials, resources or **data** required to execute your process

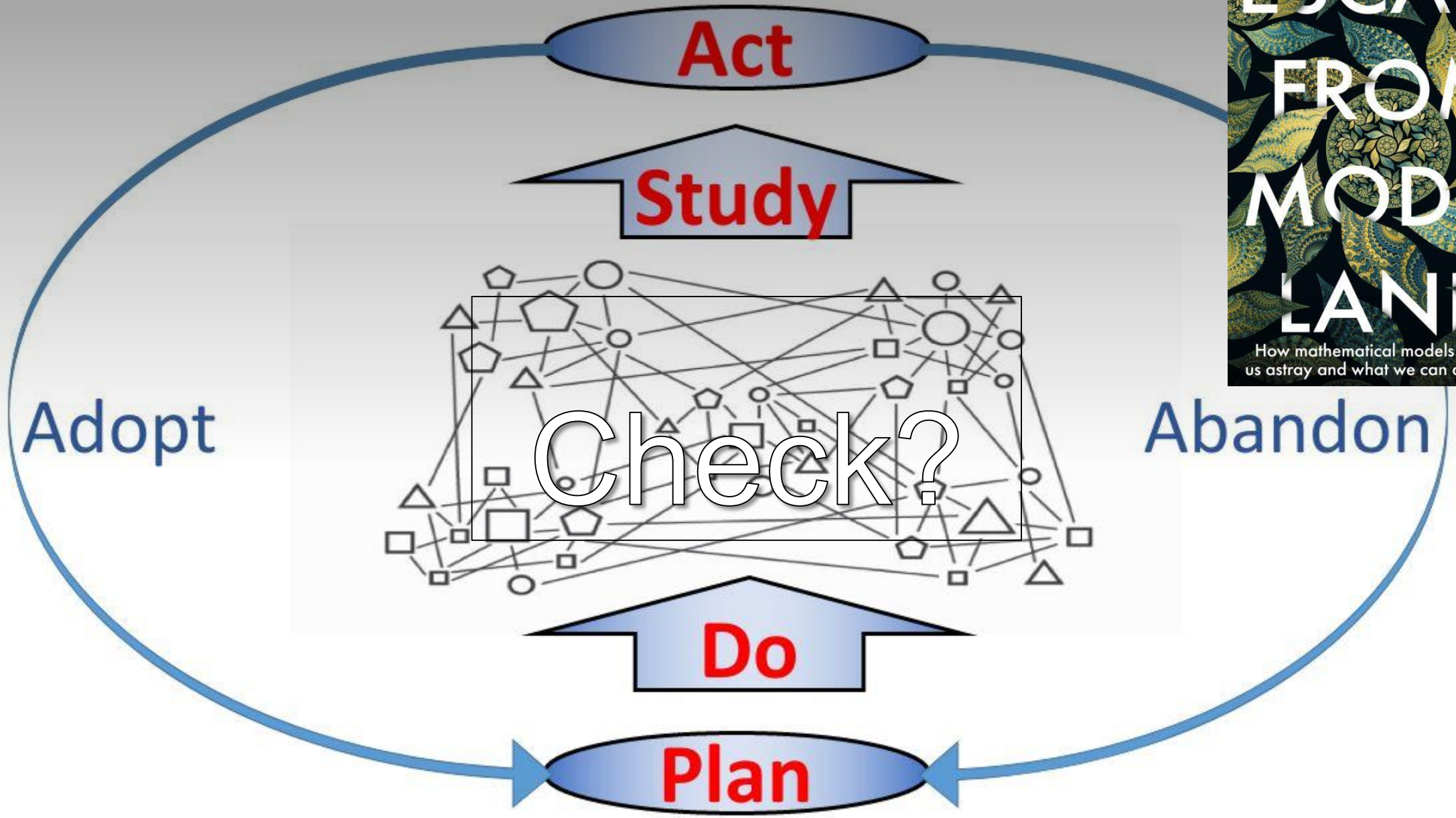
Process
A structured set of activities that transform a set of inputs into specified outputs, providing value to customers and stakeholders

Outputs
The products or services that result from the process

Customers
The recipient of the process output

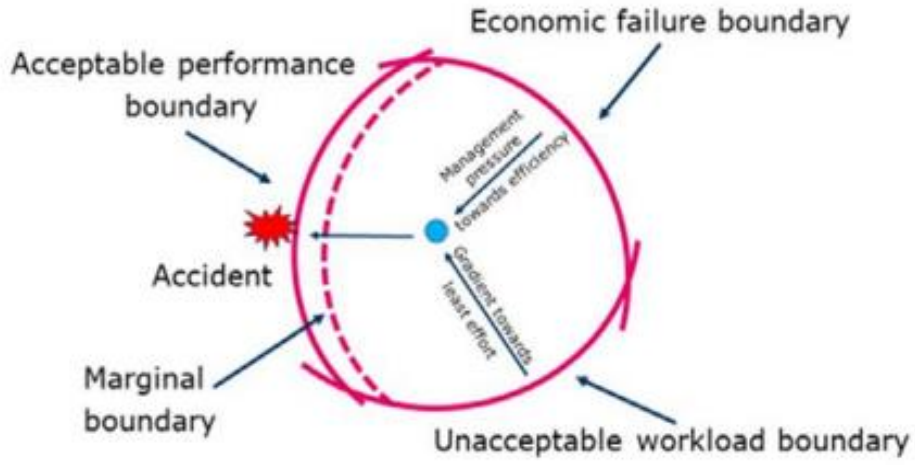


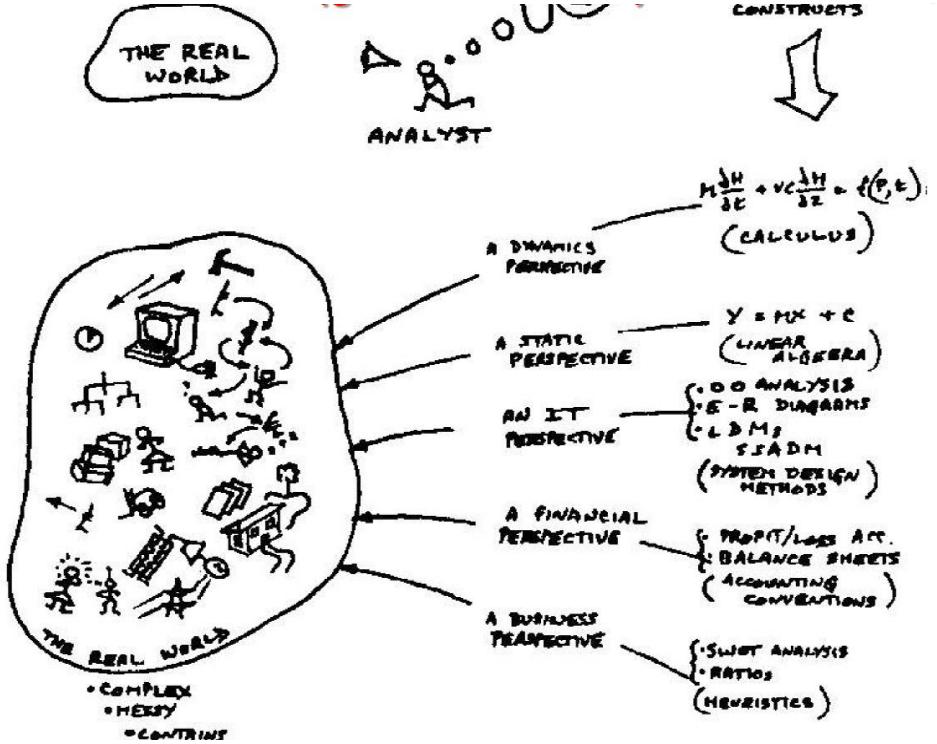
Understanding Complex Process

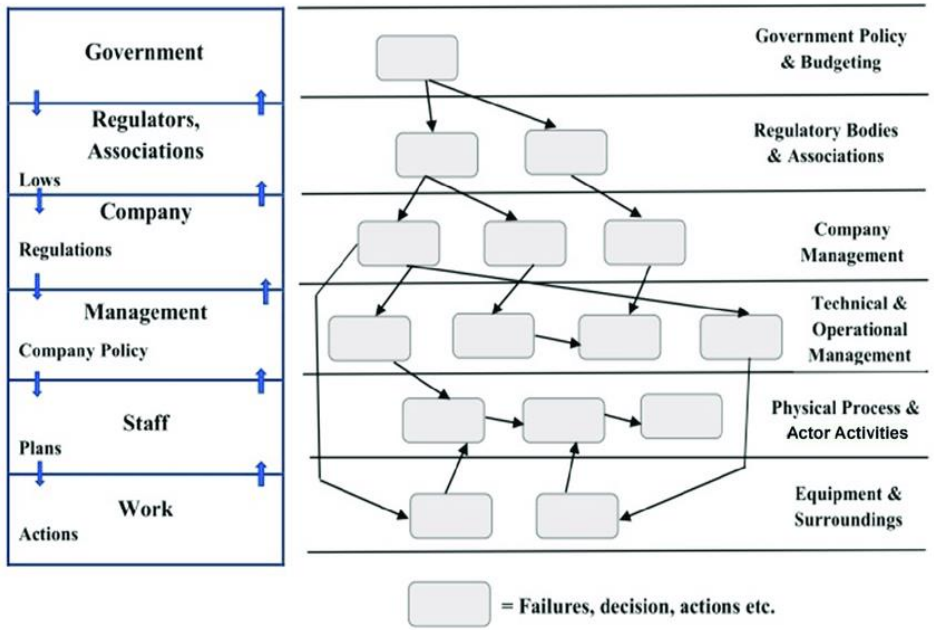


“Soft” Systems

- Checkland
- Rasmussen – Drift and Hierarchies
- Accimaps - Hopkins

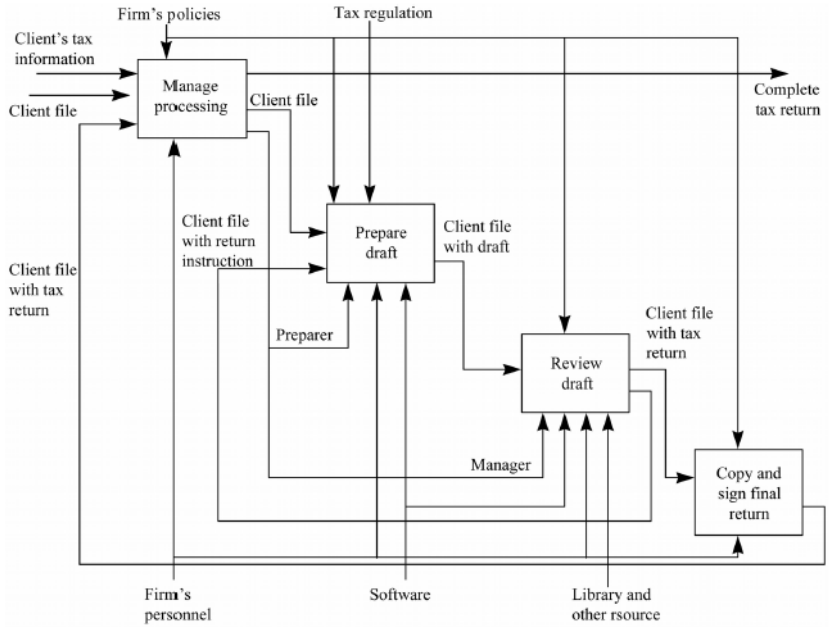






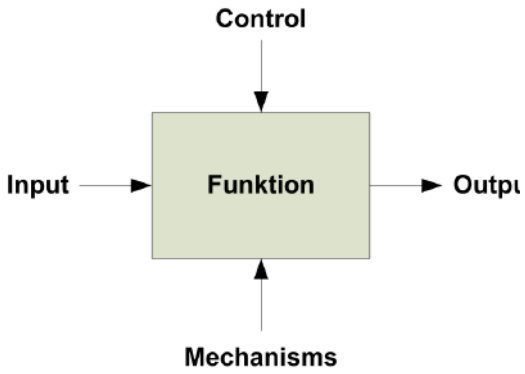
“Harder” Systems

- STAMP (System Theoretic Accident Method (Proba
- SADT (Structured Analysis and Design Technique)

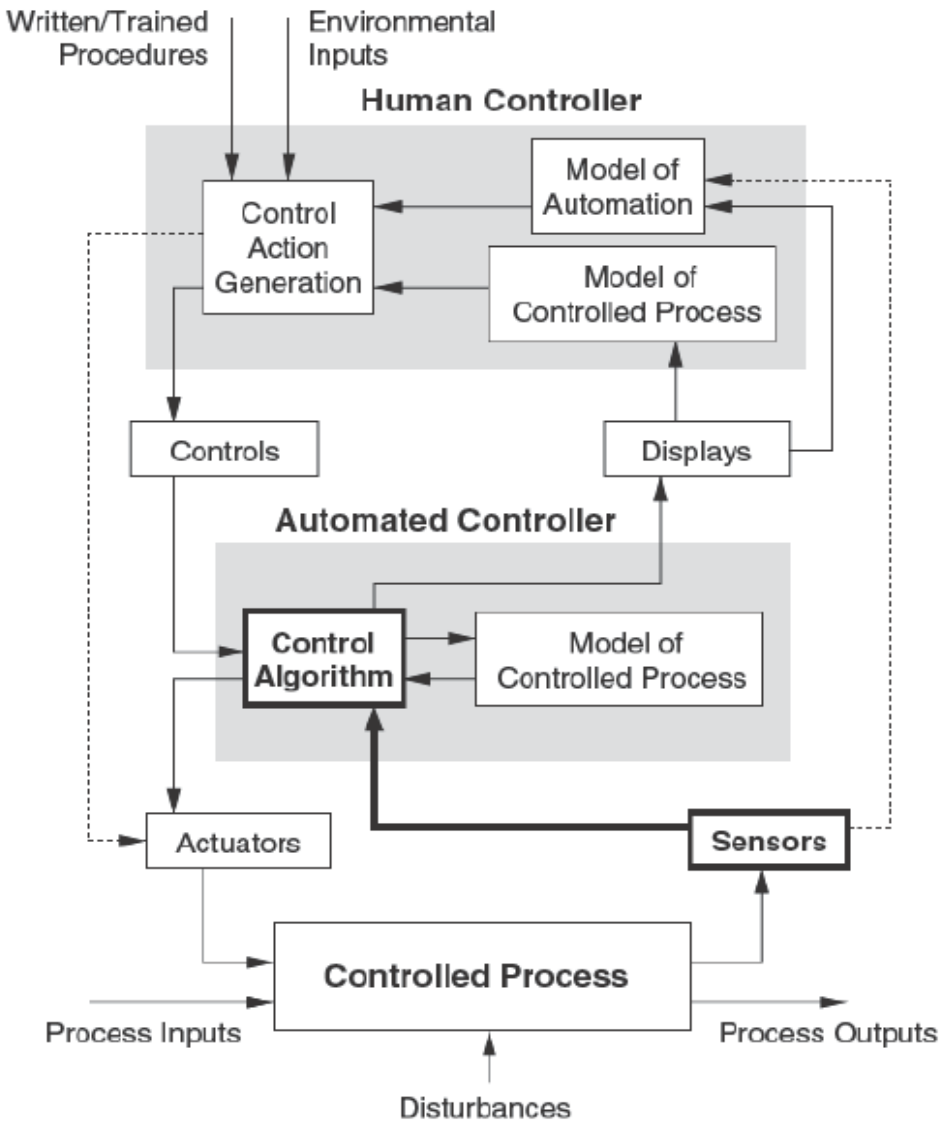


Source: Congram and Epelman (1995)

Structured analysis and design technique



The connectors represent defined relations



FRAM

- A method to create a model, A FRAM model is neither a process model, nor a graph or a network model.
- It is a system of interacting, interdependent functions (agent agnostic)
- Each function has an associated METHOD, which describes the “inner workings” of the function. (more than a blob, a node, or a rectangular box)
- The ‘production rule’ part of the method specifies how the Output(s) are generated.
- The state of the Outputs from the upstream functions determines when a function will become active, and the method specifies what the outcomes will be.
- In an interpretation, (instantiation) of a FRAM model all functions should be examined simultaneously, rather than sequentially (chaining).

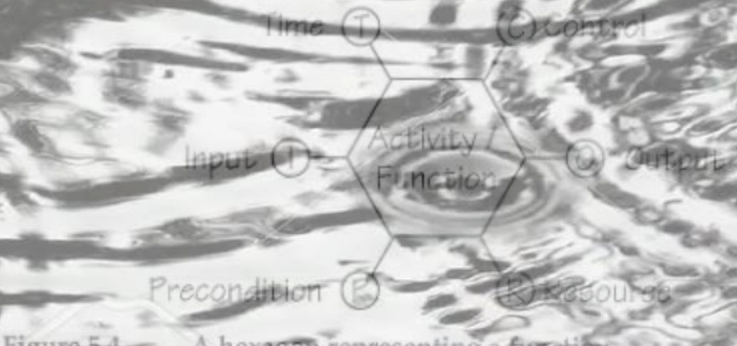


Figure 5.4 A hexagon representing a function

```
{- The function itself -}
f t = if t then true else zero
```

“The FRAM is a method-sine-model rather than a model-cum-method.

This means that the FRAM is used to develop a model of the activity (process or performance) that is the focus of the analysis.

The FRAM merely describes (rather than interprets) systems, allowing a prospective or retrospective analysis.

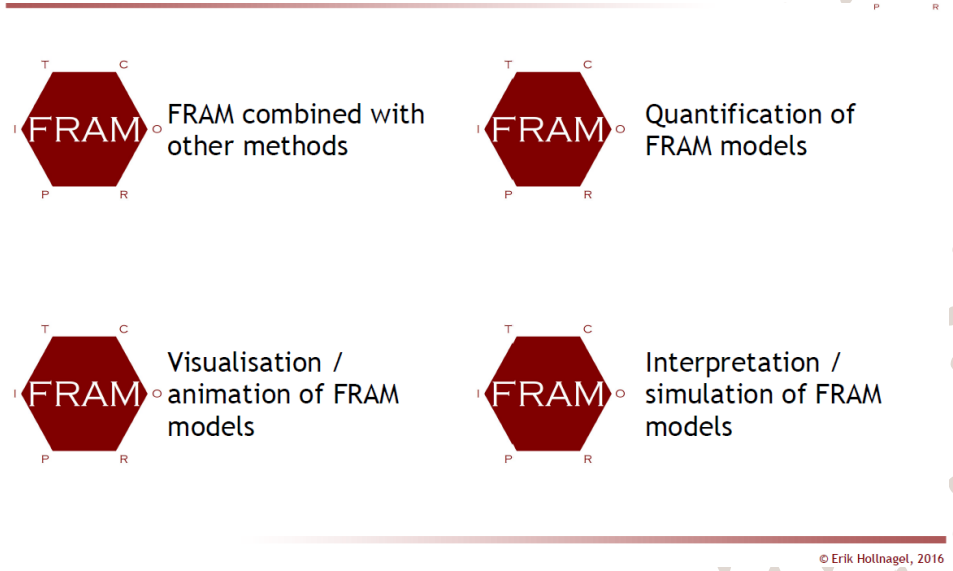
The FRAM guides the analysts and provides them with clues where to look, but not with answers!”

ChtGPT **1**

A complex Adaptive system

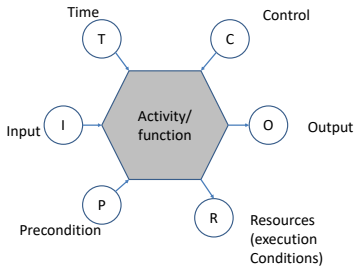
The Way Ahead – Hollnagel 2016

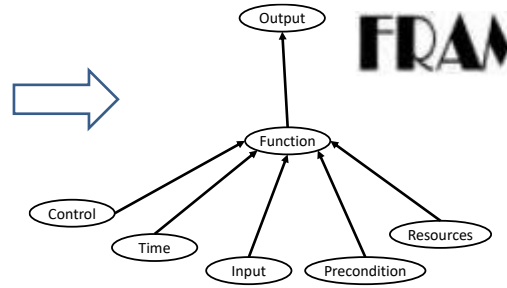
CONTINUOUS IMPROVEMENT – ALMOST CAUGHT UP?

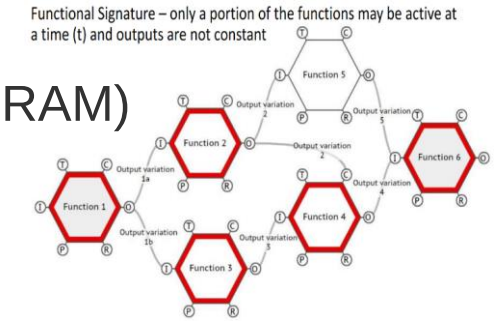


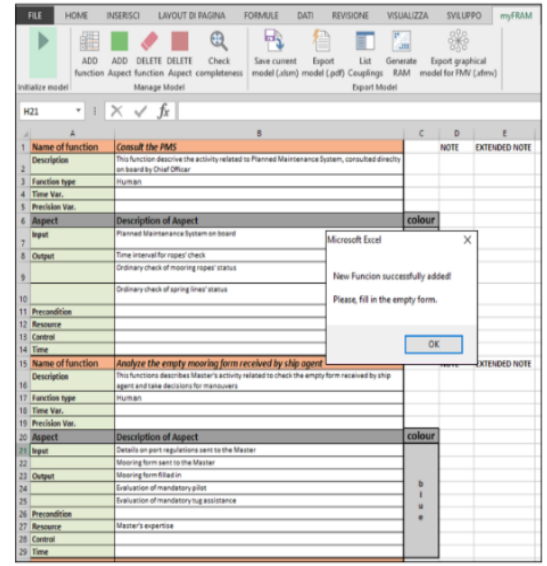
Extensions and add-ons

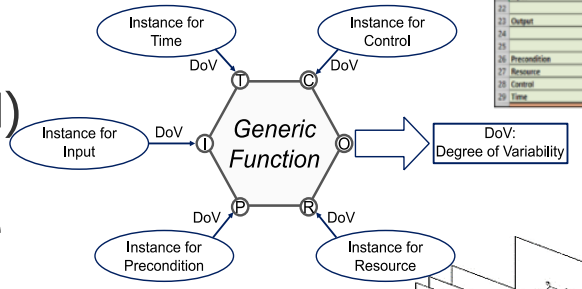
- Outcome Probabilities – Hill and Slater 2017 (BBN's)
- Pre-processing and Montecarlo – Patriarca 2017 (myFRAM)
- Simulation – Smith 2018 (DynaFRAM)
- Probability of variability – Hirose (Fuzzy FRAM)
- Time series and hierarchies (2019) – Patriarca (myFRAM)
- Control and security systems (2019) – Nomoto (Byzantine algorithms)
- Etc., etc.

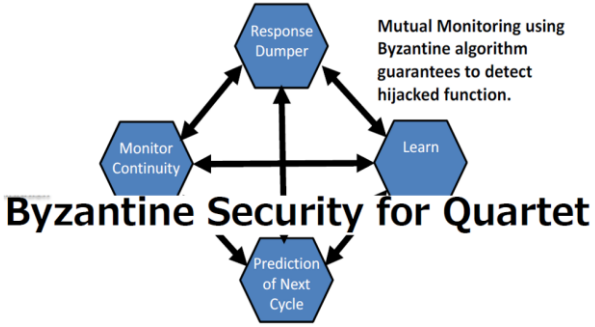


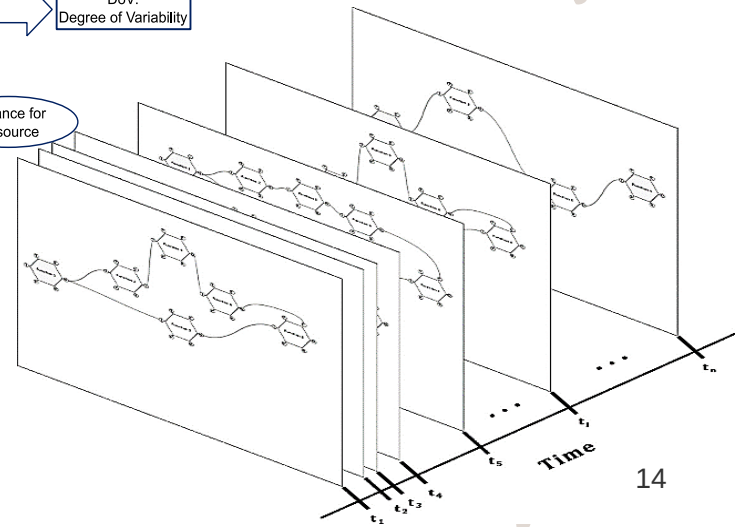






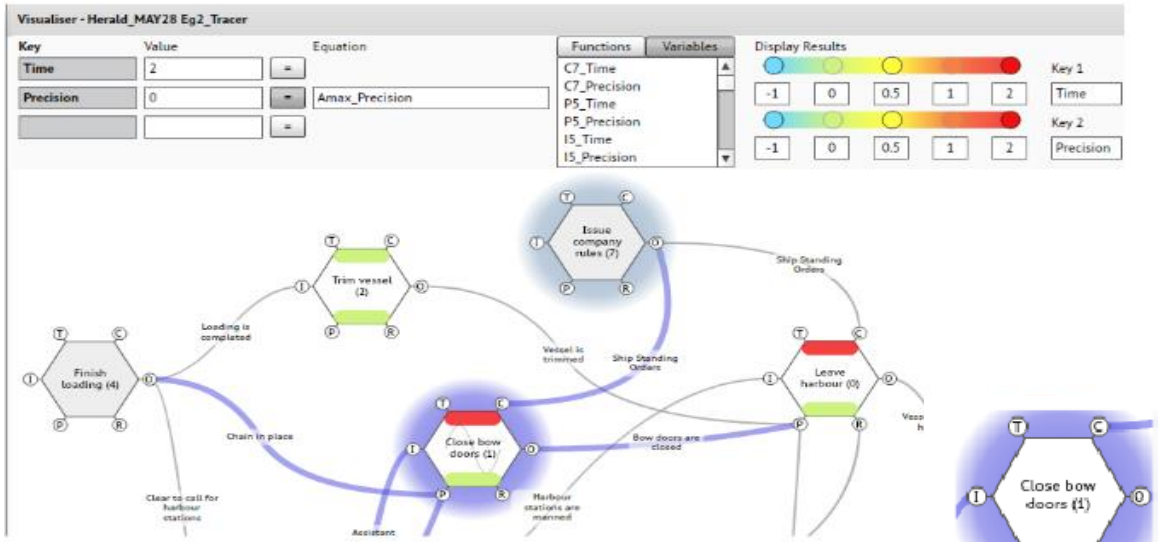


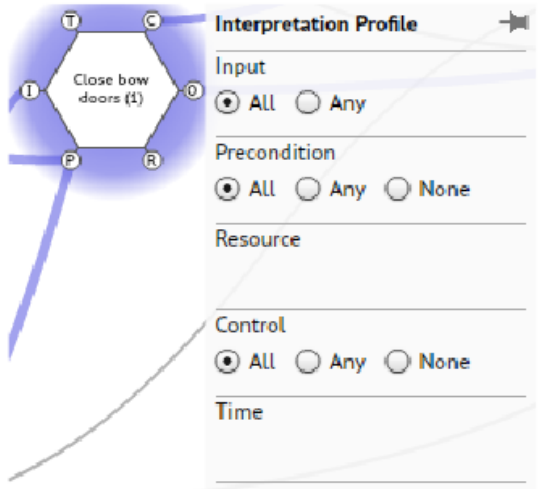




Implementation, interpretation and validation of the “production rules”

- Metadata – Hill

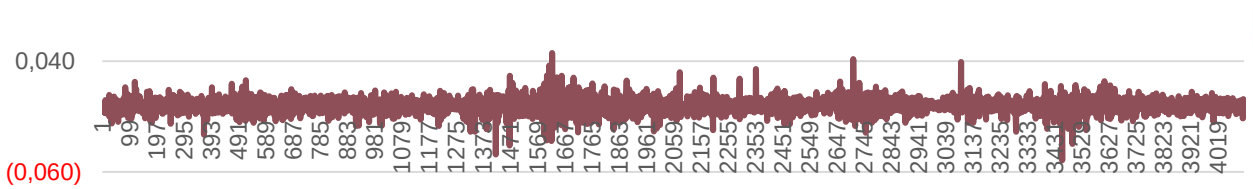




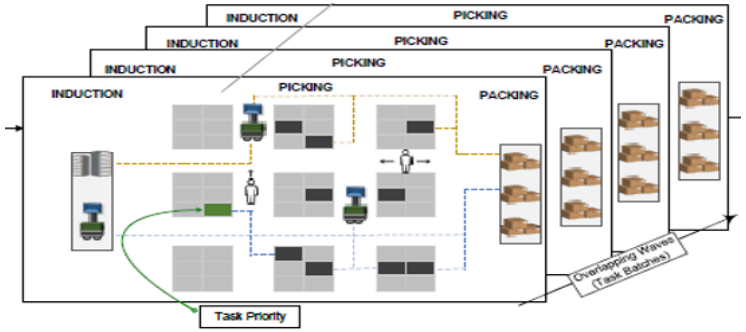
- The FRAM Model Interpreter - Hollnagel

Open-source exploitation

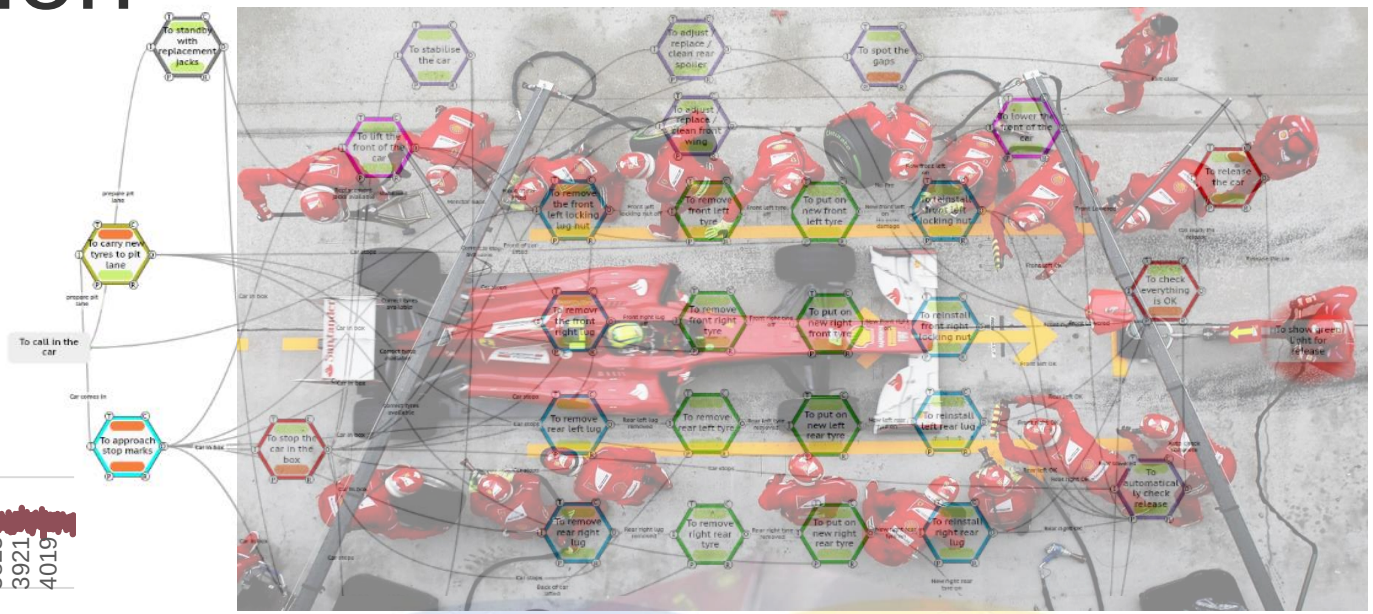
- Dynamics – Formula 1 pit stop
- Dynamic BBN's
- Machine Learning – Nomoto (Tokyo)

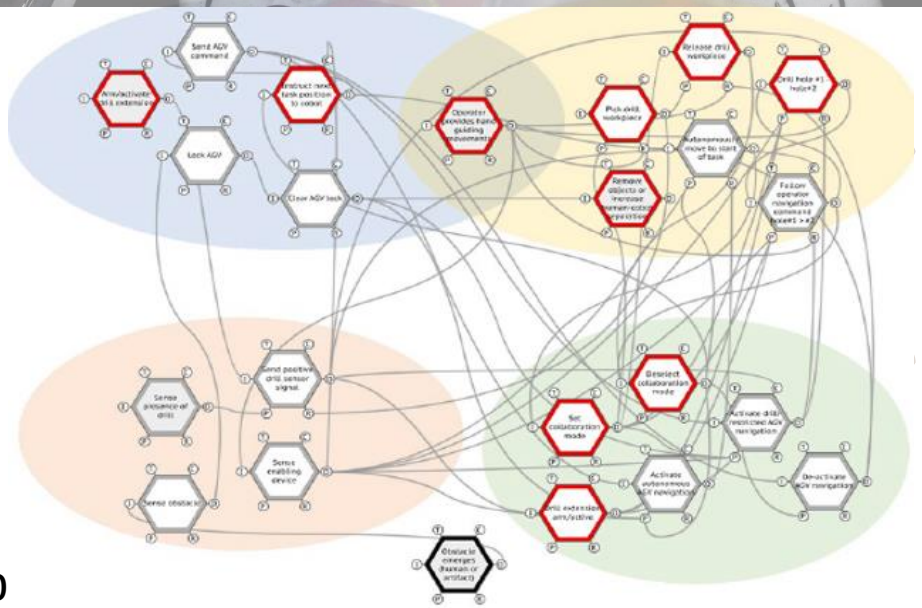


- AI and Robots – Andriaensen (Copenhagen)



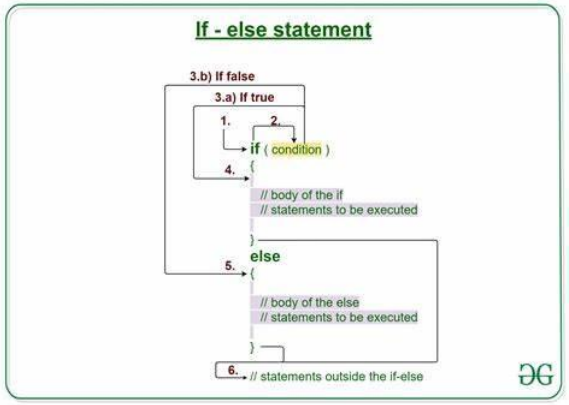
- Resilience – Nomoto (Copenhagen)





Methodology	System Thinking	Granularity	Process Scheme	Variability	Emergence	Dynamic	Resilience
MBSE	Yes	Process	Fixed, linear				
FMEA	No	Components	NA				
FTA	No	Components	NA				
Soft Systems	Yes	Activity	Nonlinear				
Rasmussen Drift	Yes	Activity	Fixed				
Accimaps	Yes	Activity	Fixed				
STAMP	Yes	Process	Fixed				
SADT	Yes	Functions	Fixed				
FRAM	Yes	Functions	Interactive	Yes	Yes		
Monte Carlo + FRAM	Yes	Functions	Interactive	Yes	Yes		
Byzantine Algorithm + FRAM	Yes	Functions	Interactive	Yes	Yes		
Fuzzy Logic + FRAM	Yes	Functions	Interactive	Yes	Yes		
Markov Chains	Yes	Nodes	Fixed	Yes	Yes	Yes	
BBN's + FRAM	Yes	Functions	Interactive	Yes	Yes		
DBBNs + FRAM	Yes	Functions	Interactive	Yes	Yes	Yes	
FMI	Yes	Functions	Interactive	Yes	Yes	Yes	
Metadata	Yes	Functions	Interactive	Yes	Yes	Yes	
Systemic potentials in FRAM +++	Yes	Functions	Interactive	Yes	Yes	Yes	Yes

I rest my case!




```
$skyColor = "blue";

if ($skyColor == "blue") {
    print "the sky is normal";
} else {
    print "Something isn't normal";
```