UNSW AUSTRALIA
Canberra

Modelling by Building Blocks

A proposed design approach and application in supply chain management

Never Stand Still

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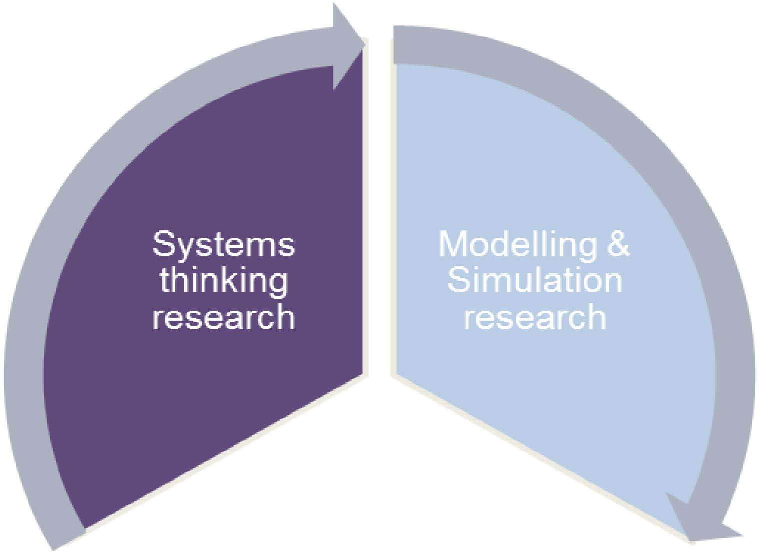
UNSW AUSTRALIA | Capability Systems Centre UNSW Canberra

ADFA AUSTRALIAN DEFENCE FORCE ACADEMY

Systems education and training focus

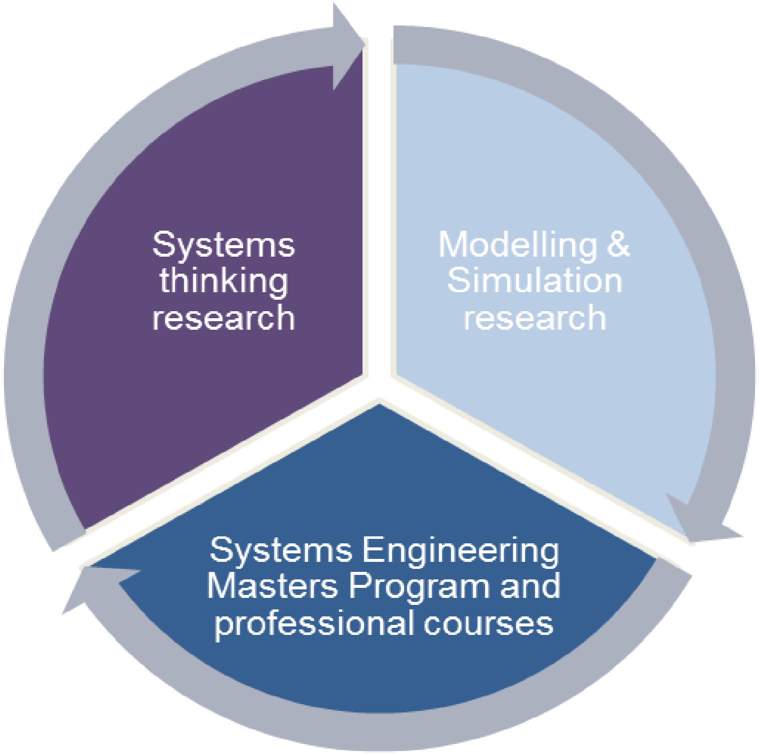
- *Systems thinking research:* Introduces new frameworks, methods and techniques, based in systems theory, for addressing complex systems engineering problems.

Systems education and training focus



- *M&S research:* develops novel systems modelling methodologies and simulation tools to support SE education and training, with focus on the areas of systems design and acquisition.

Systems education and training focus

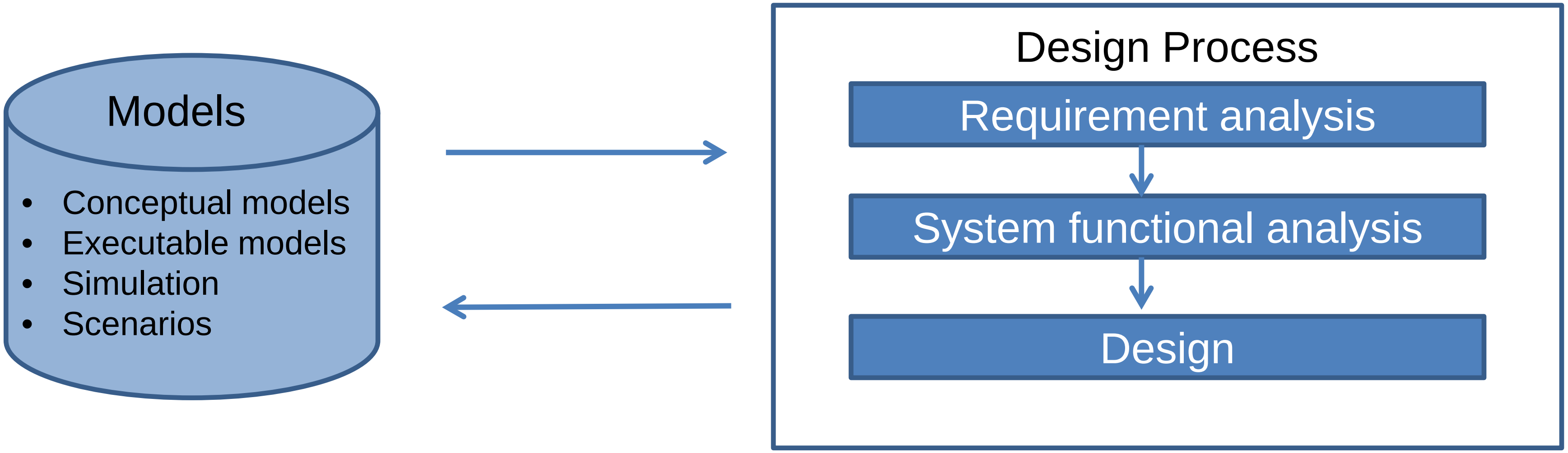


- *SE Masters Program & Professional Education Courses*: design of education curricula (from fundamental to advanced) to support systems thinking and practice in SE.

M&S research theme

- Use case-study driven methodology to:
  - Design a set of M&S capabilities to support the development of composable M&S.
  - Validate the developed capabilities in terms of their fitness-for-purpose in each case study.
- Case studies to support the design, development, and evaluation of the methodology (i.e. process and tools).
- In the initial phase, our aim is to develop and test a prototype toolset to support learning about the design and management of a range of common capability system elements including sustainable supply chains.

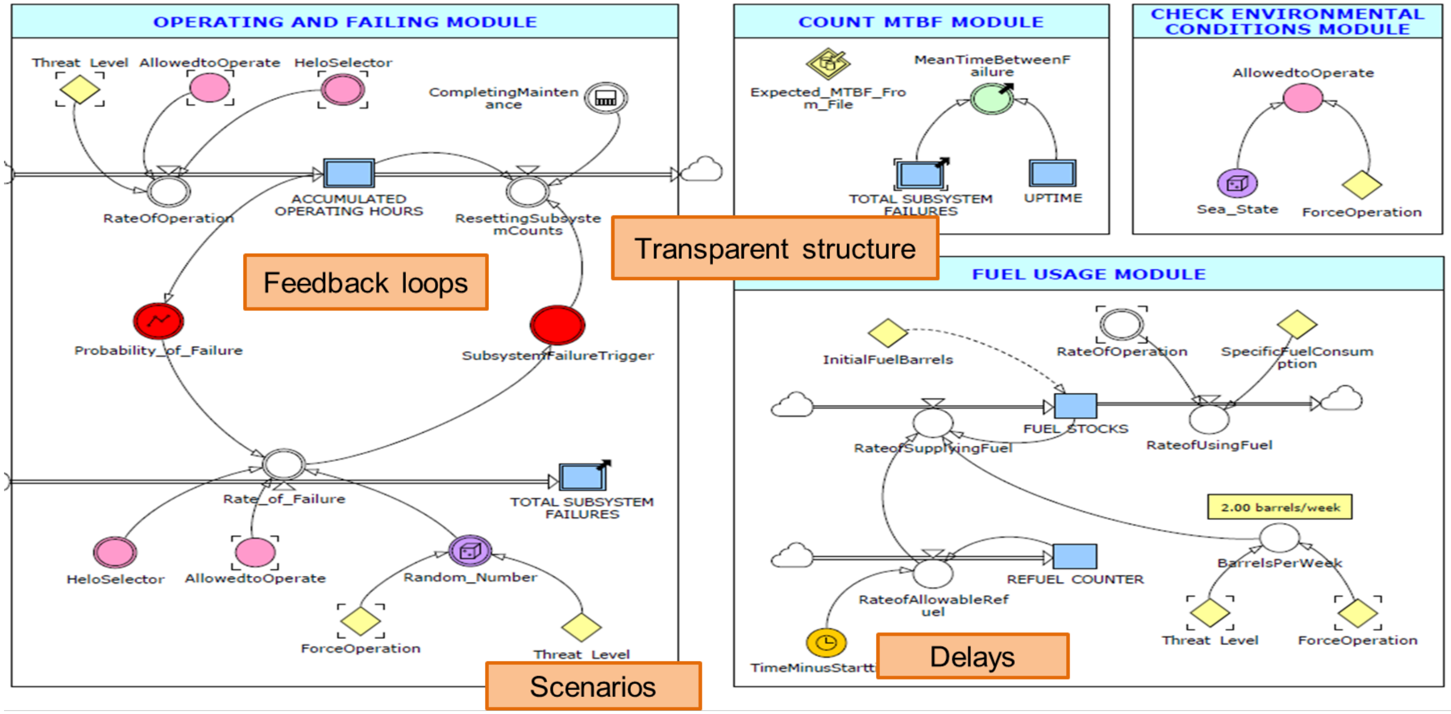
Model-based system design



System dynamics simulation paradigm

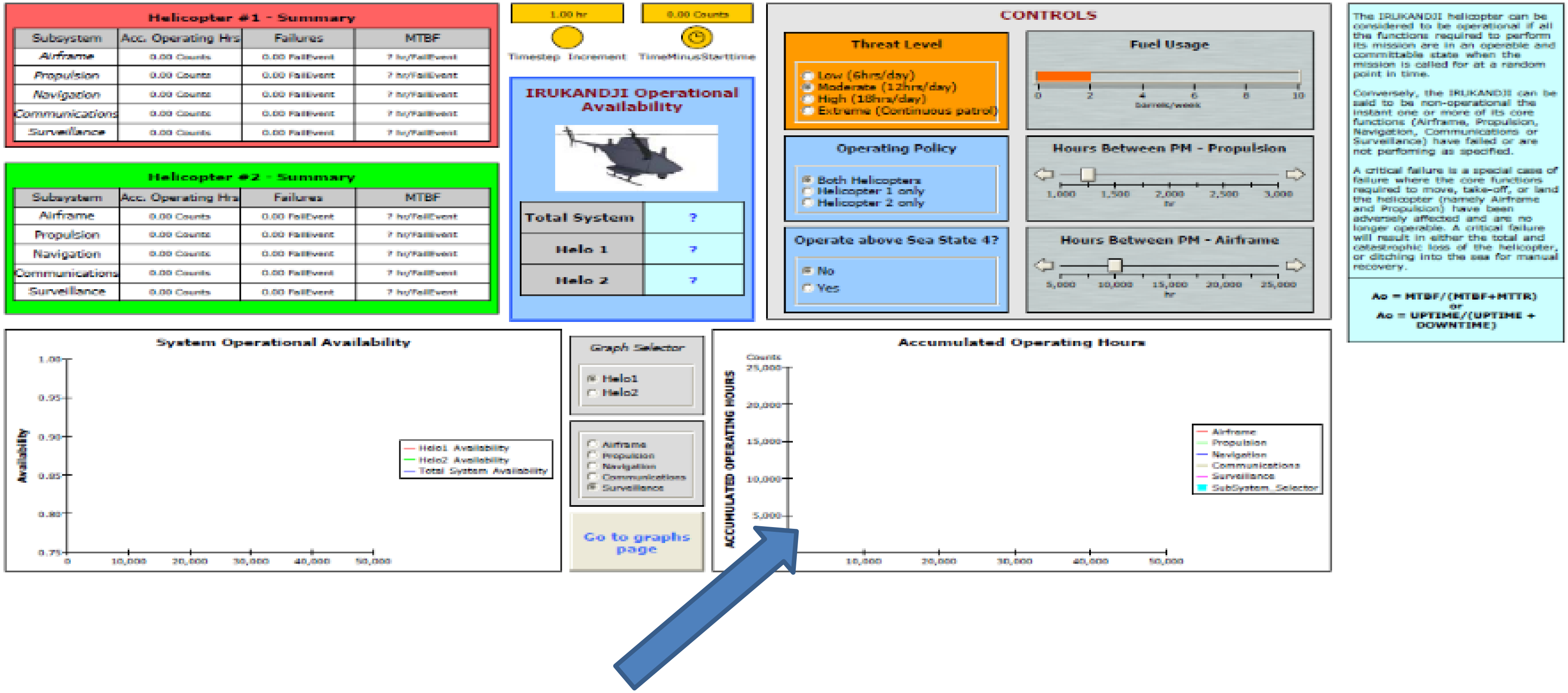
- System dynamics (SD) provides a **powerful set of conceptual and numerical** tools to support systems design and problem solving, including the abilities to:
  - integrate **social and technical** elements;
  - integrate **physical and information** views of the system;
  - model **hierarchical** systems;
  - model **feedback** interactions, **non-linear** relationships, and delays;
  - integrate tools from other modelling paradigms (e.g. discrete event) in a hybrid framework

Example of SD Model Experimentation



- An SD model can model *feedback*, design *scenarios*, model *delays*, observing effects on the system behaviour.
- The *transparent structure* improves learning and validation.

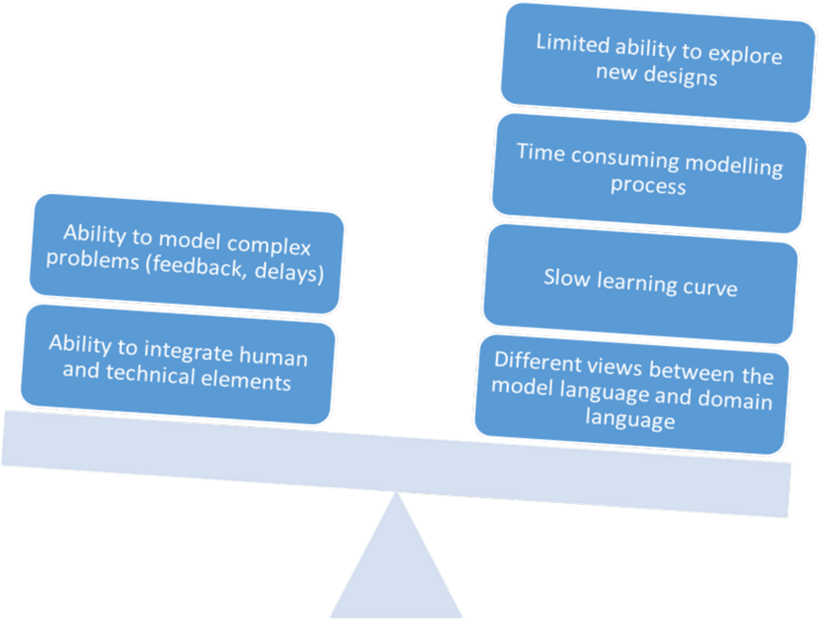
Example of SD Model Experimentation



Behaviour over time

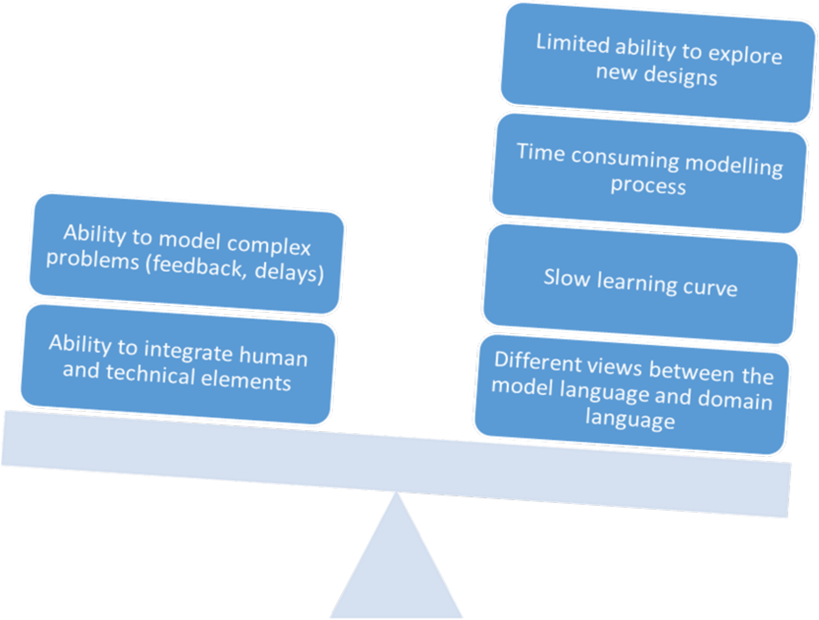
Model-Design Gap

- The modelling process is often criticized for being **resource consuming and skill-intensive**.
  - The major bottleneck in the development phase and during experimenting with simulation models.



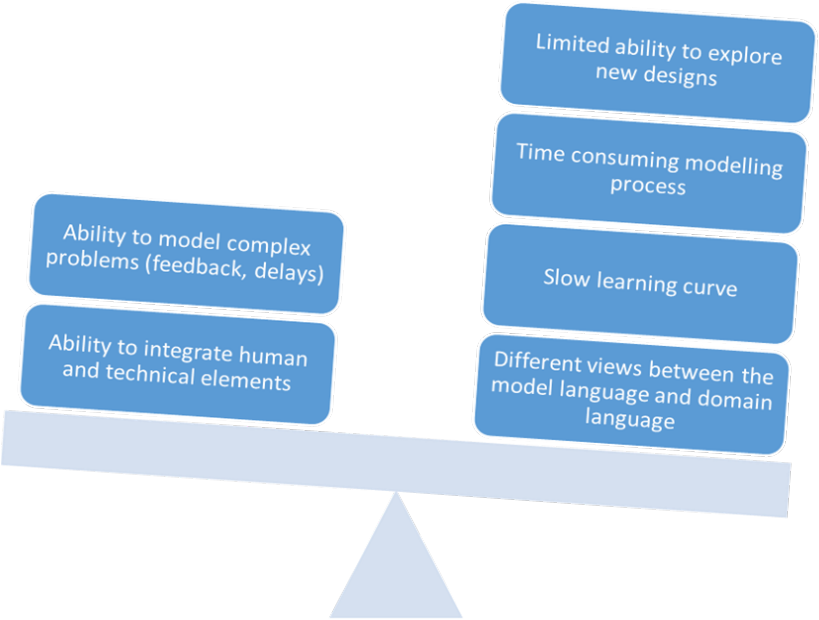
Model-Design Gap

- The learning curve of learning about SD models is often **slow.**
  - Limits ability to engage with stakeholders who not have that much patience.



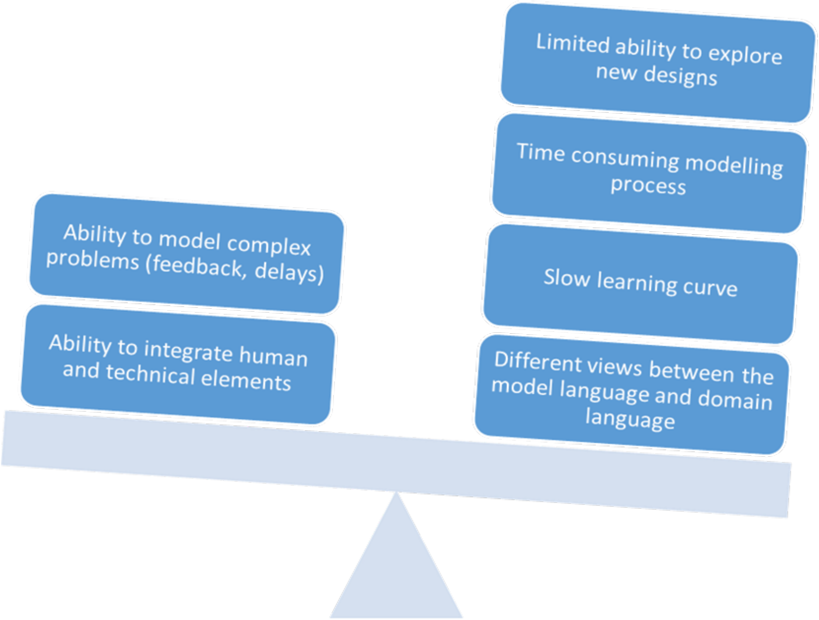
Model-Design Gap

- The model is developed to test a structure defined *a priori*.
  - allows for ability to conduct parametric analysis
  - but limited ability to examine a large number of scenarios and design configurations without having to go through the modelling process all over again



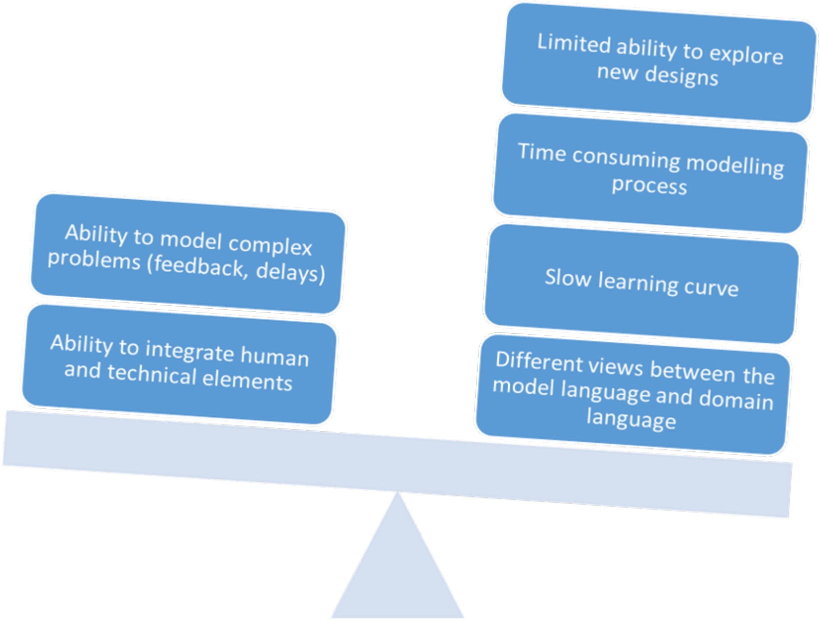
Model-Design Gap

- The model grows in complexity far beyond the **user's cognitive capacity** compromising the model's transparency and discounting the learning insights.
- Arguably the complexity of the model soon grows beyond the intuition of even the most expert modeller.



Model-Design Gap

- model's building blocks (i.e. stocks and flows) may not be **intuitively relevant** to the application domain.
  - A helicopter's operation can be modelled by stocks and flows?

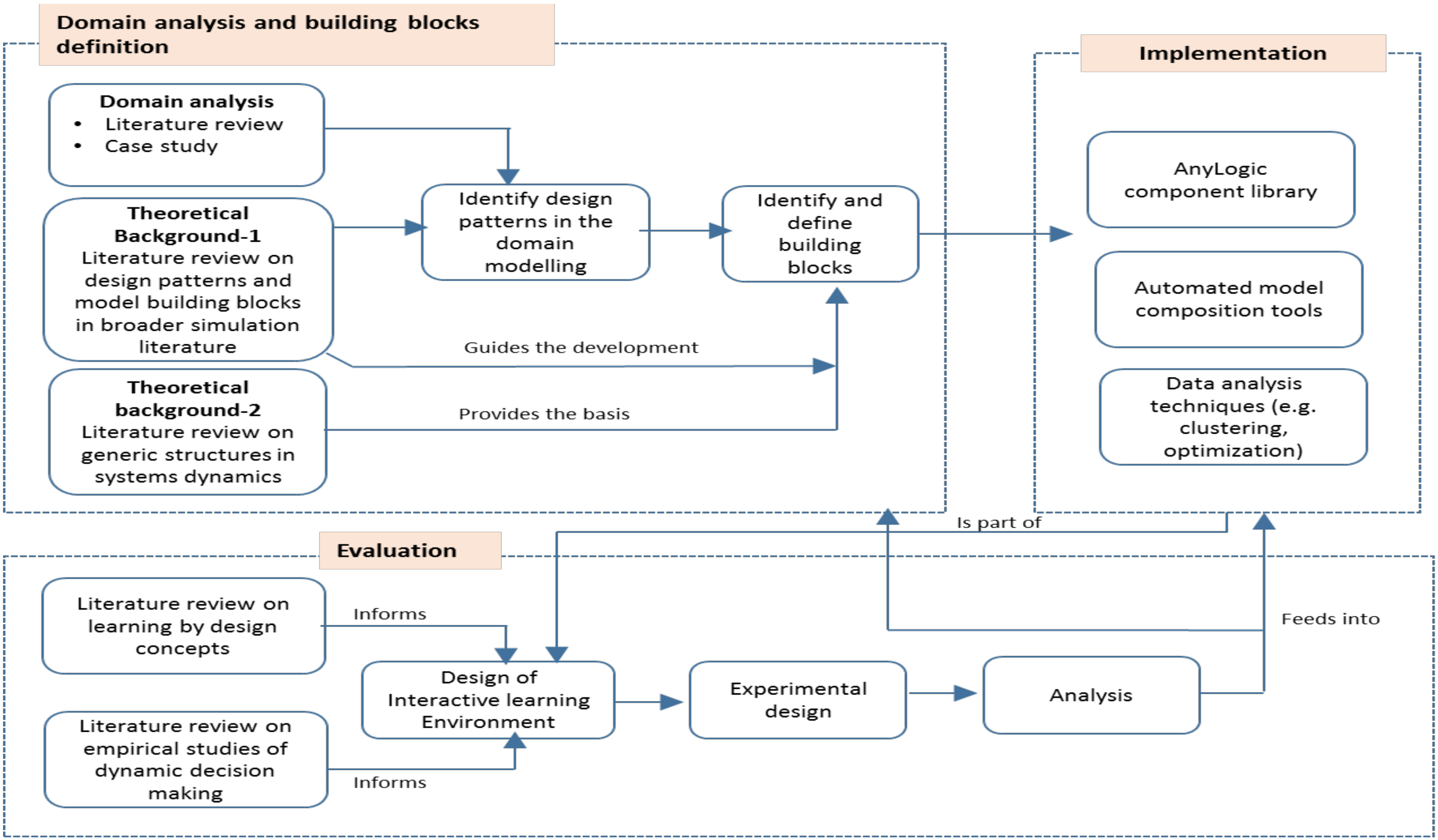


Learning capabilities

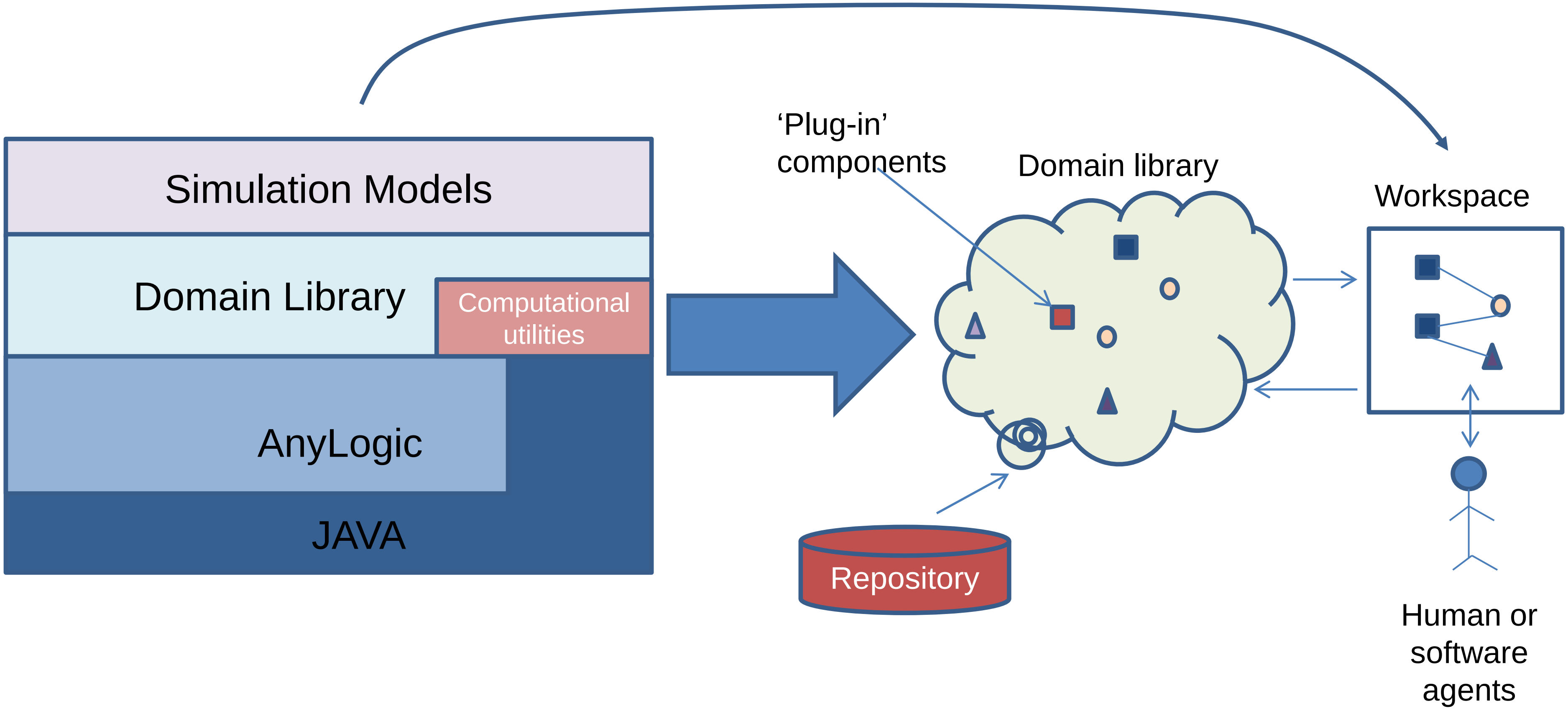
- There is a need for new learning capabilities tools to:
  - Leverage the potential of **SD modelling** in supporting system design
  - Expedite the modelling process by providing **reusable and tested 'plug-in' components**
  - Bridge the chasm between modellers and system engineers by providing **high level domain** objects
  - Improve learning by providing users with the **flexibility to build and experiment** with models, without being overwhelmed with the model's technical details

Research question and objectives

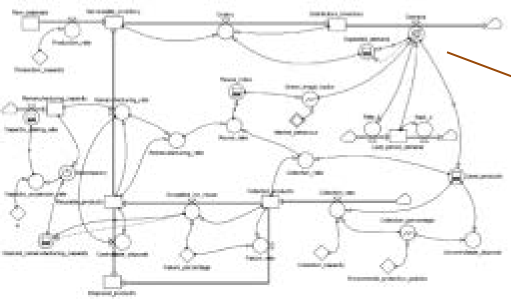
- How to **design**, **use**, and **evaluate** the use of SD model building blocks to support learning about the design of complex systems engineering applications (e.g. supply chain design)?
  - Design a **methodology (i.e. principles, methods, tools)** to develop and validate the building blocks
  - Develop **automated model composition capabilities** to support rapid development of SD models
  - Develop an **experiential learning environment** to support the use of the developed tools
  - Develop **learning assessment techniques** to evaluate the achieved learning outcomes
  - Reflect on the **implementation of the proposed methodology** to inform new case studies


Domain analysis and building blocks definition
Domain analysis
• Literature review
• Case study
Theoretical Background-1
Literature review on design patterns and model building blocks in broader simulation literature
Theoretical background-2
Literature review on generic structures in systems dynamics
Identify design patterns in the domain modelling
Identify and define building blocks
Guides the development
Provides the basis
Implementation
AnyLogic component library
Automated model composition tools
Data analysis techniques (e.g. clustering, optimization)
Is part of
Feeds into
Evaluation
Literature review on learning by design concepts
Informs
Literature review on empirical studies of dynamic decision making
Informs
Design of Interactive learning Environment
Experimental design
Analysis

Technical features



Functional decomposition



No	Article	SCM Issues	Structure patterns
2	Vlachos et al. (2007)	• Reverse logistics • Capacity planning • Demand forecasting • Production planning and scheduling	• Two-stage manufacturing chain • Capacity Expansion • Reverse channel • Information delay
3	Berry and Naim (1996)	• Bullwhip effects • Information sharing • Inventory management • Supply chain integration	• Two stage manufacturing chain • Stock management
4	Croson and Donohue (2005)	• Bullwhip effects • Demand forecasting	• Stock with backlog
5	Fiala 2005	• Information sharing • Supply chain integration	• Two-stage manufacturing chain
6	Fowler (1998)	• Business process redesign (or reengineering)	• Transportation node • Three stage distribution line with in transits • Intelligent forward controller
7	Georgiadis, P., & Vlachos, D. (2004)	• Reverse logistics • Production planning and scheduling • Capacity planning • Demand forecasting	• Two-stage manufacturing chain • Capacity Expansion • Reverse channel • Information delay
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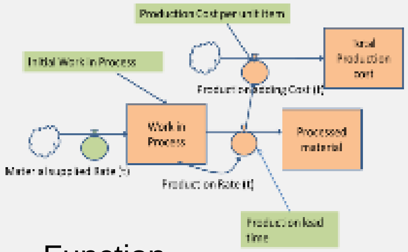
Review of existing SD models in SCM

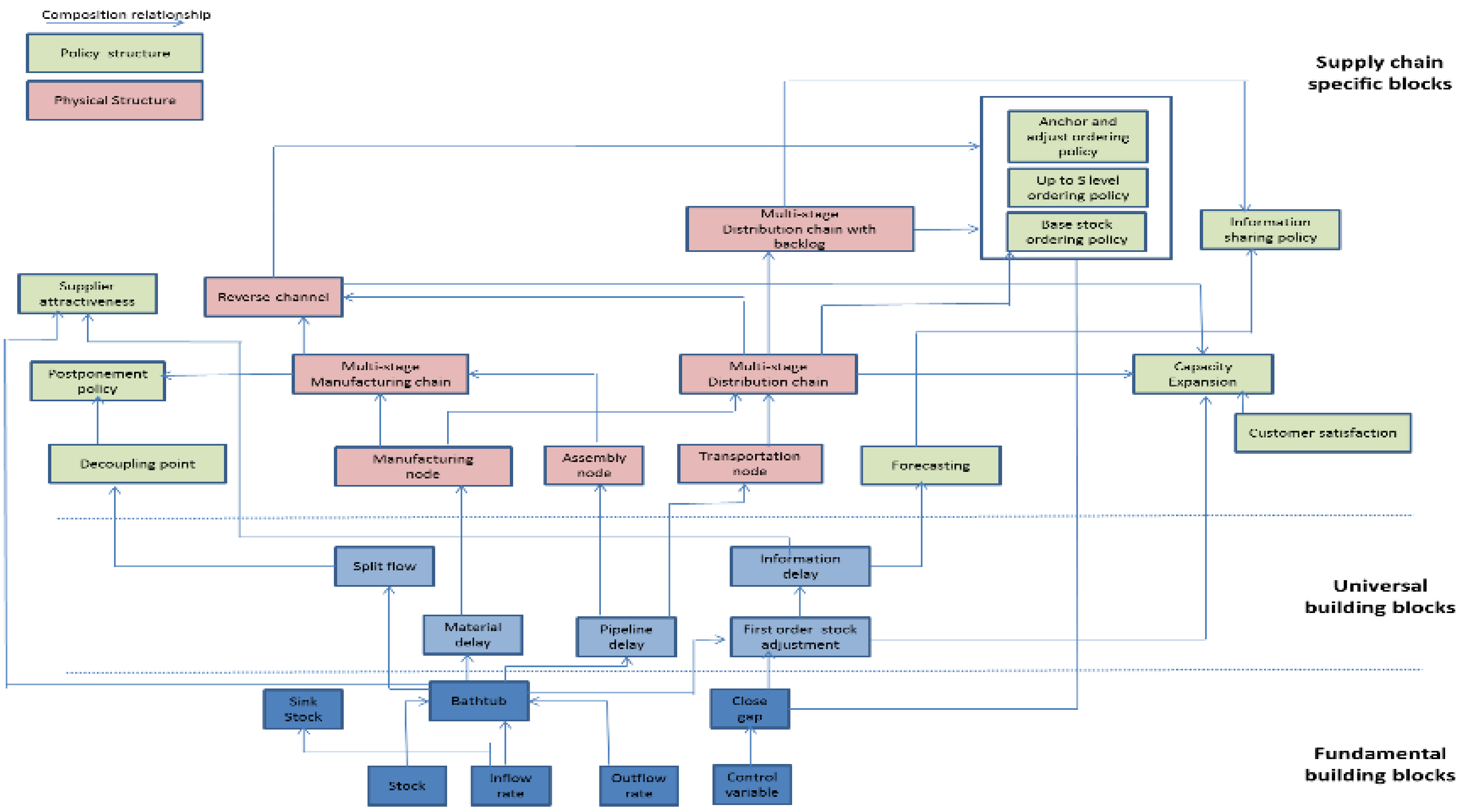


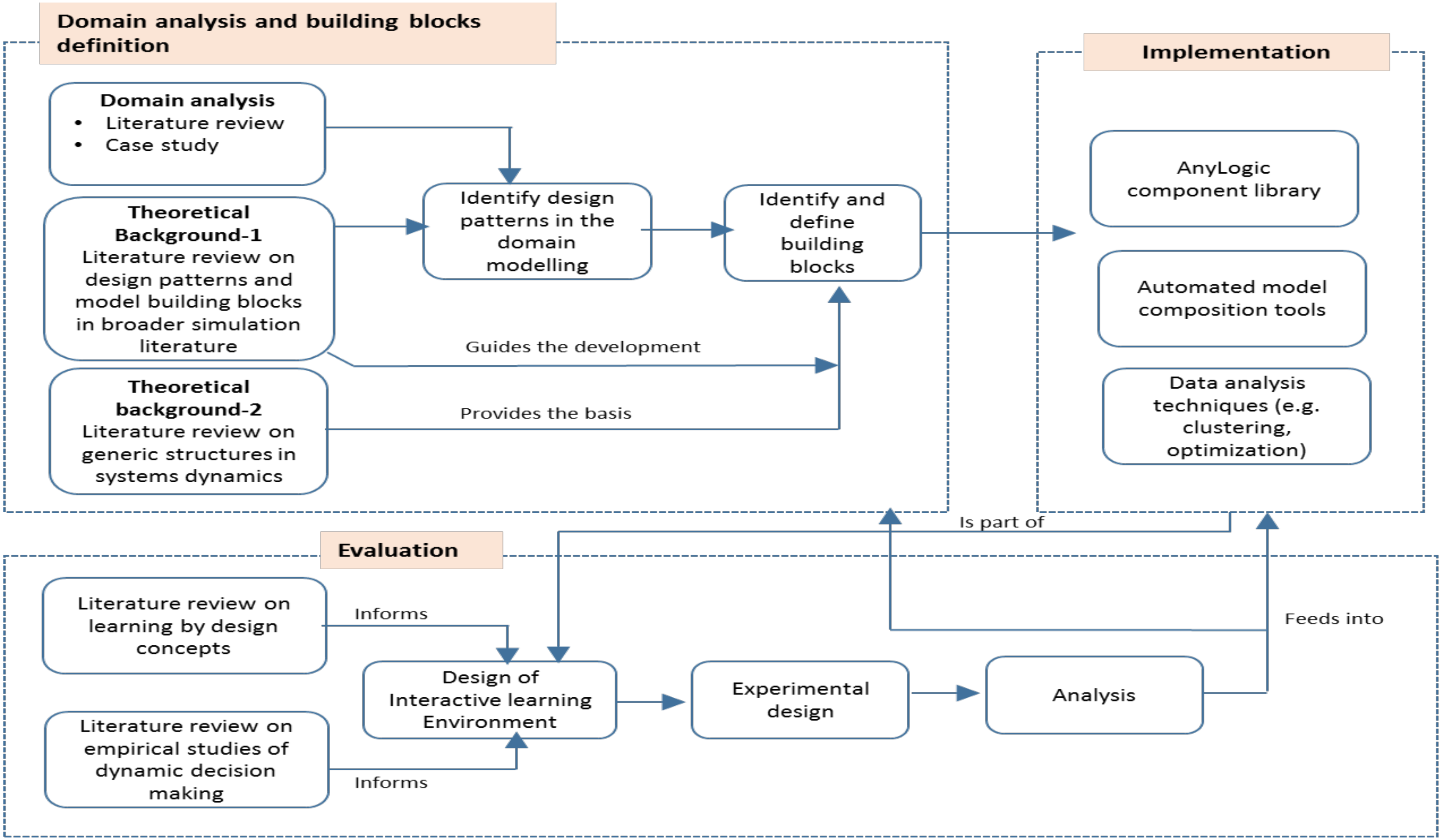
- Function
- Input
- Output
- Structure
- Assumptions
- Companion patterns

Catalogue of structure patterns

- No guarantee that these building blocks can be composed back into a meaningful and valid model, we need an architecture (see next slide for a preliminary attempt)

Systems dynamics models for SCM: structure patterns

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Experimental design
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Feeds into

Preliminary experimental design

- Evaluation Questions
  - To what extent does a ‘learning by design’ approach help in the design and management of complex systems engineering projects?
    - What are the learning effects at individual (e.g. cognitive load) and group levels (e.g. group interaction)?
  - How to promote effective use of learning by design’ approach help in the design and management of complex systems engineering projects?
    - What are the factors that influence user’s acceptance and trust in the reusable artefacts?

Requirements	How achieved?
Access to domain specific building blocks	• Anylogic library
Mechanism to assemble blocks in a meaningful way	• Anylogic Interactive Learning Environment
Mechanism for reflection (linking structure-behaviour-function)	• Design diary what is your design idea (structure), what are you trying to do (rationale), Predict what may happen (predicted behaviour), What is the outcomes (observed behaviour) , how does this satisfy the system requirements (function)
Mechanism for evaluating learning effects	Design of an experiment informed by theory on learning Data collection/analysis (post-pre surveys, and cognitive load)

1. Design Challenge

Problem statement: You are working as a consultant for electronics company PEAR. Your task is to design a supply chain (configuration and operational policy) that enables PEAR to satisfy the following requirements:

1. Production matches demand over x period
2. Inventory cost is less than $Y

Your final report should include:

- A suggestion for supply chain design, and explanation of why do you think this design achieves PEAR requirements
- A suggestion for an ordering policy, and explanation of why do you think this design achieves PEAR requirements

2. Pre-test questionnaire to collect data on their perceptions of the relationship between structure and behaviour.
3. 'Messing about' time to explore the tool
4. Data collection: Experiment+ Design diary + Final report
5. Analyse data to answer the evaluation questions

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