The Basics of 4-Dimensionalism and the Role it Can Take in Supporting Large Scale Data Integration

4-Dimensionalism in Large Scale Data Sharing and Integration
Newton Gateway to Mathematics

GCHQ UCL Brunel University London University of Southampton The University of Warwick

University of Cambridge

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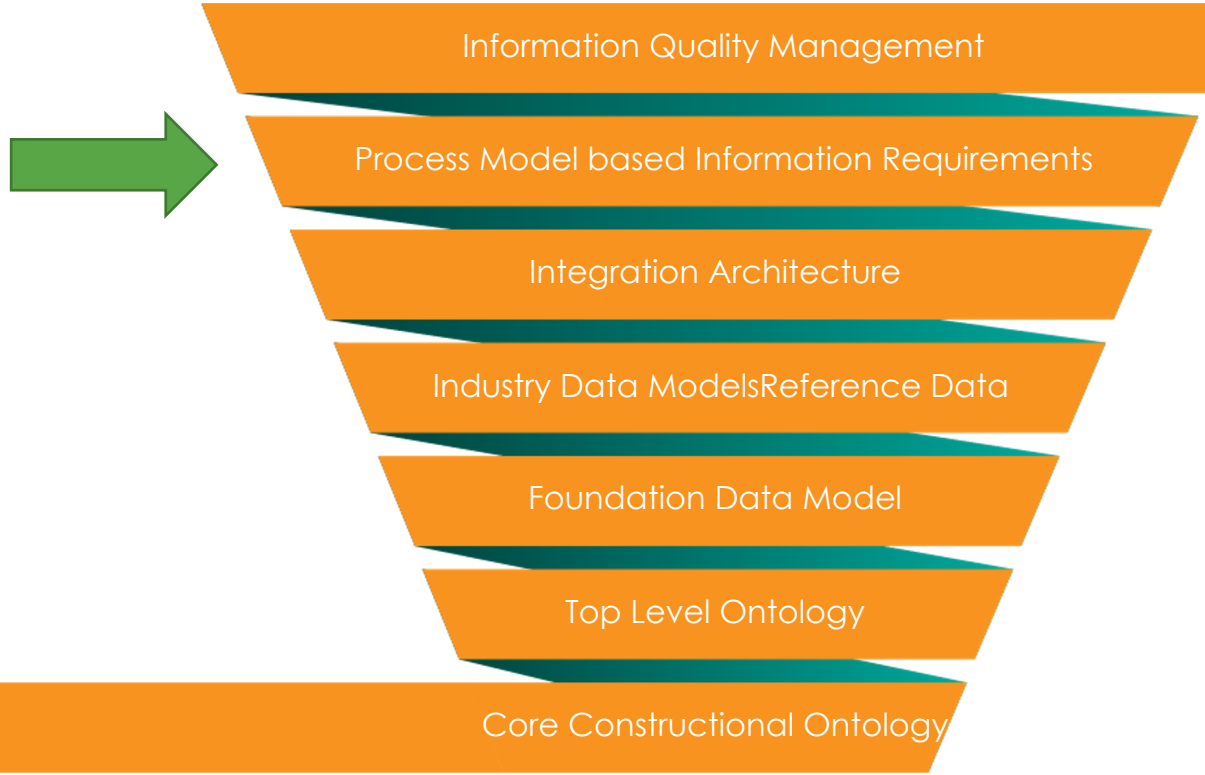
The Seven Circles of Information Management



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Decisions and the role of information

- Public Accounts Committee Challenges in using data across government, Sept 2019
- National Audit Office Challenges in using data across government, June 2019
- COVID-19: Royal Society DELVE Initiative, Nov 2020 Data Readiness: Lessons from an emergency

"The lack of a common language for understanding data quality […]."

- Joint Biosecurity Centre DSAB Minutes, Oct 2020, "The complexities involved in working with data from multiple sources."
- Grenfell tower Hackitt Report, Building A Safer Future The need for a Golden thread of building information
- Net Zero

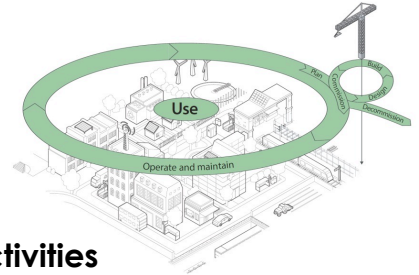
Prime Minister's Council for Science and Technology, A systems approach to delivering NetZero, Jan 2020, "Develop the analytical capability, flow of information, and reporting needed to inform decisions."

IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1

Extensive section on data quality and the challenges in achieving it

- NASA and INCOSE Data-centric Systems Engineering. Revisiting the roots of Systems Engineering and data
- ISO 19650 for BIM states the need for information requirements to be captured but doesn't explain how it could be done
- Massive time and cost over-runs on megaprojects like High Speed 2, Crossrail 1, Berlin Tegel Airport, etc

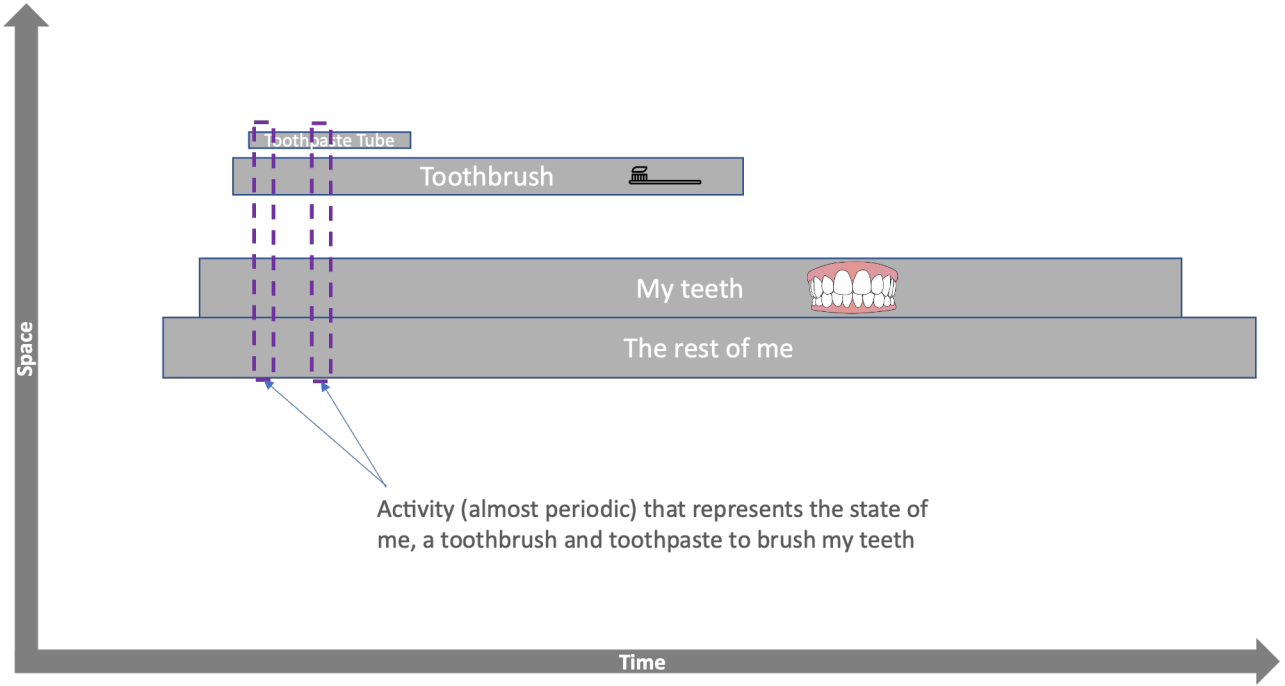
Decisions – Examples that are NDT relevant



- Systems Engineering activities
- Procurement activities
- Regulations and Compliance activities
- Detailed engineering activity
- Construction
- Operations and Maintenance
- Disposal activity
- In-use energy optimisation
- Service optimisation
- Service **integration**
- Risk management
- Situational awareness and decision support
- The work of government…

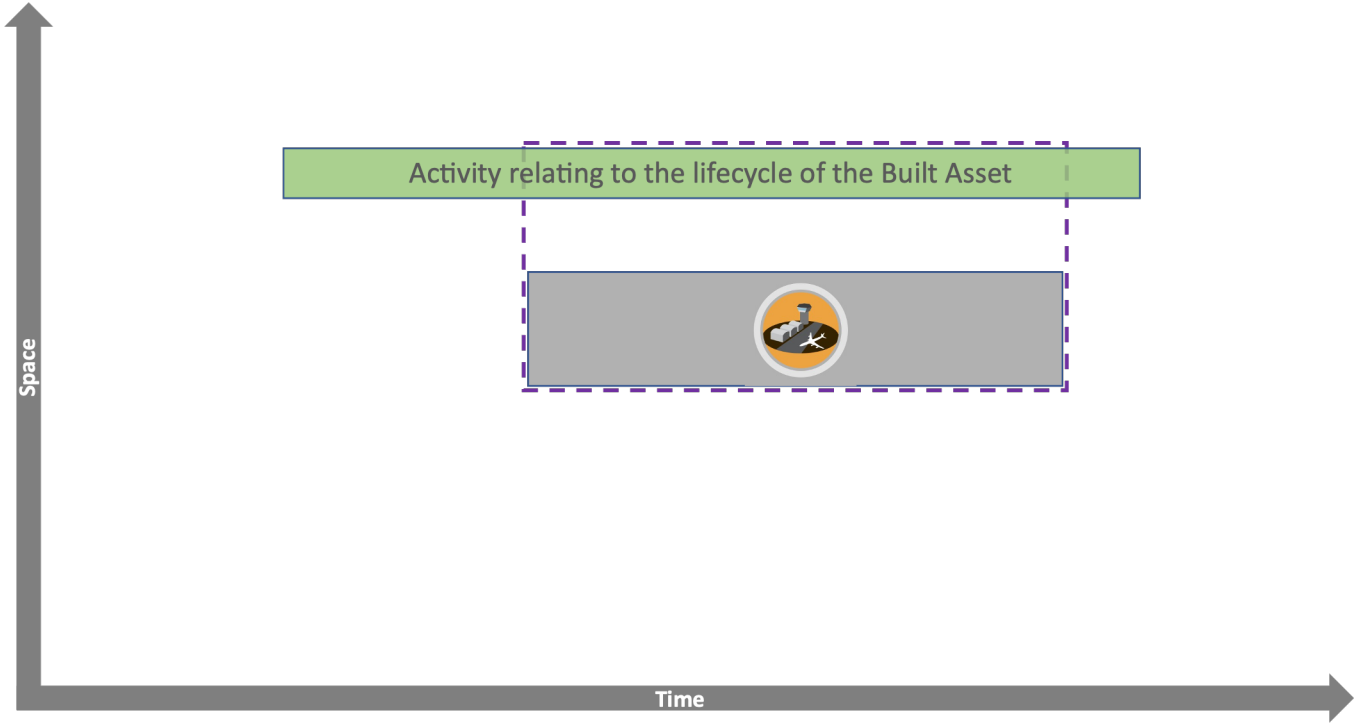
- They are all to do with **activities**
- What's common to all of these? Many of the **same** people, materials, locations, environmental factors, organisations, etc are involved throughout.
- Most of these are **common activities** and can, collectively, cover a vast range of applications and involve many people, organisations and 'stuff'.
- **Good decisions are key to all of them**, yet the topic receives little attention and reference to the same things happens independently and inconsistently.
- **Information is used throughout but there is a lot of room for improvement**. Large-scale integration of data at the required quality is intended to address this.

Activity analysis



Space-time diagrams can offer a clear, diagrammatic way of representing what is going on

Analysis – in support of identifying information requirements



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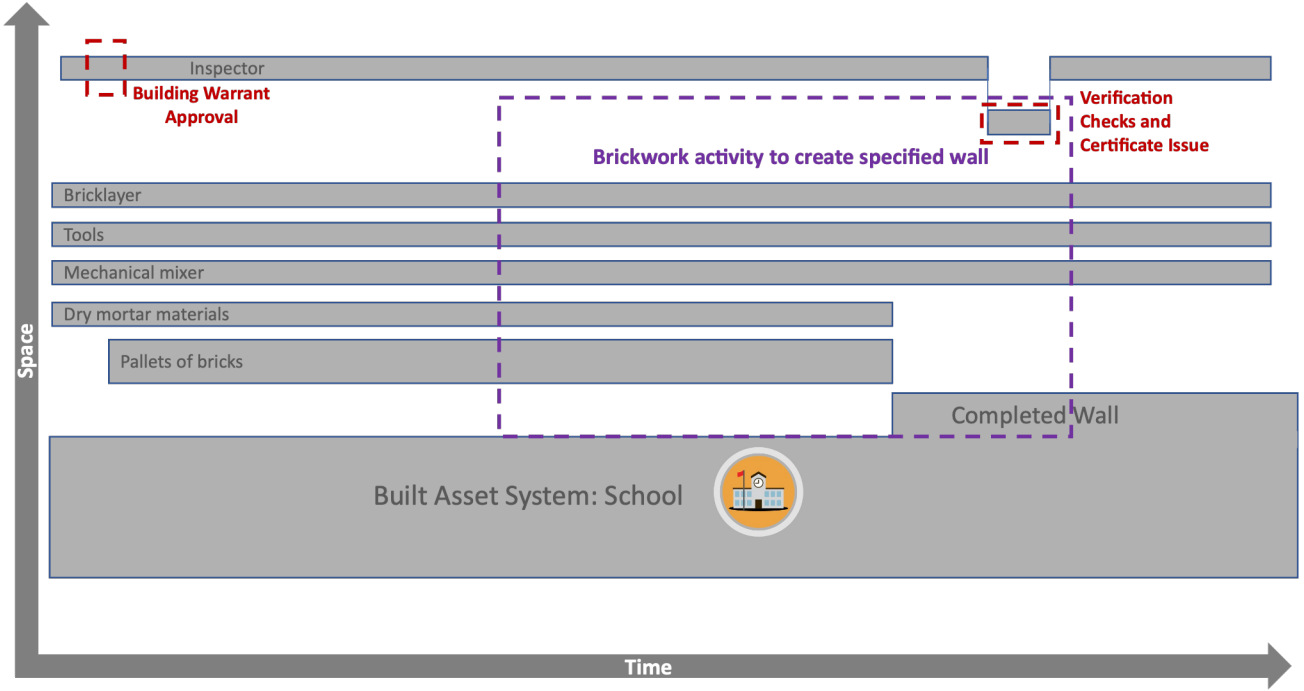
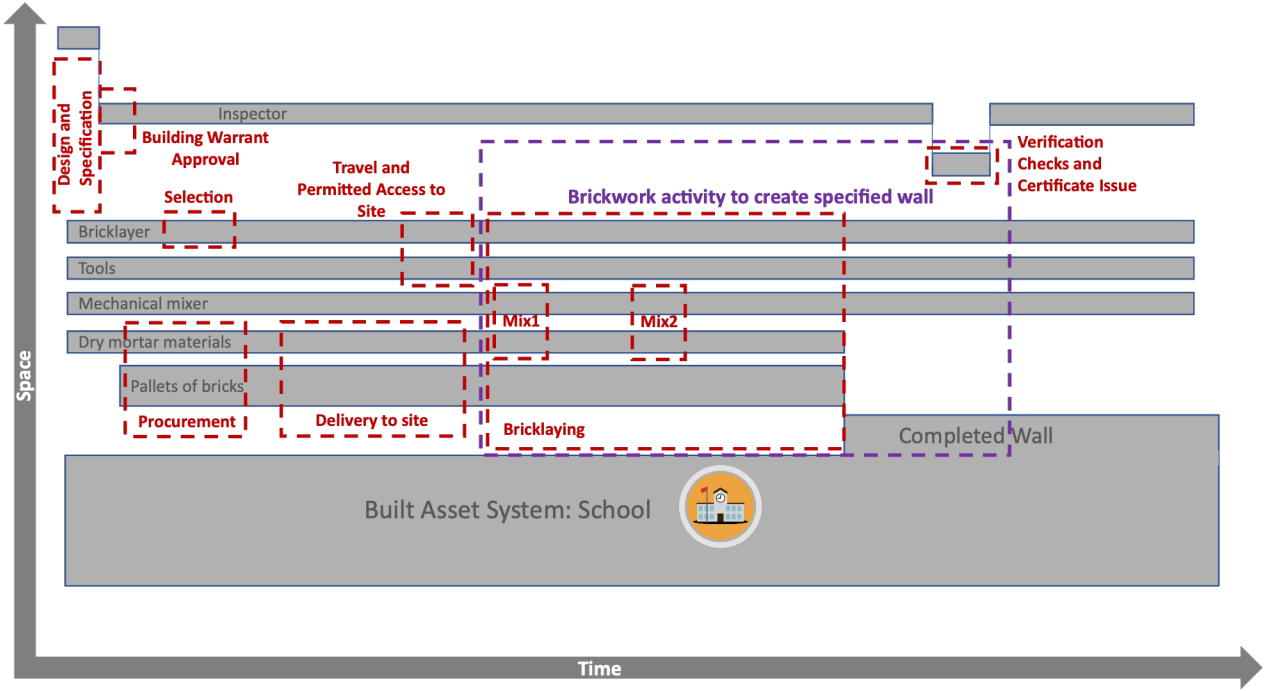
Activity models

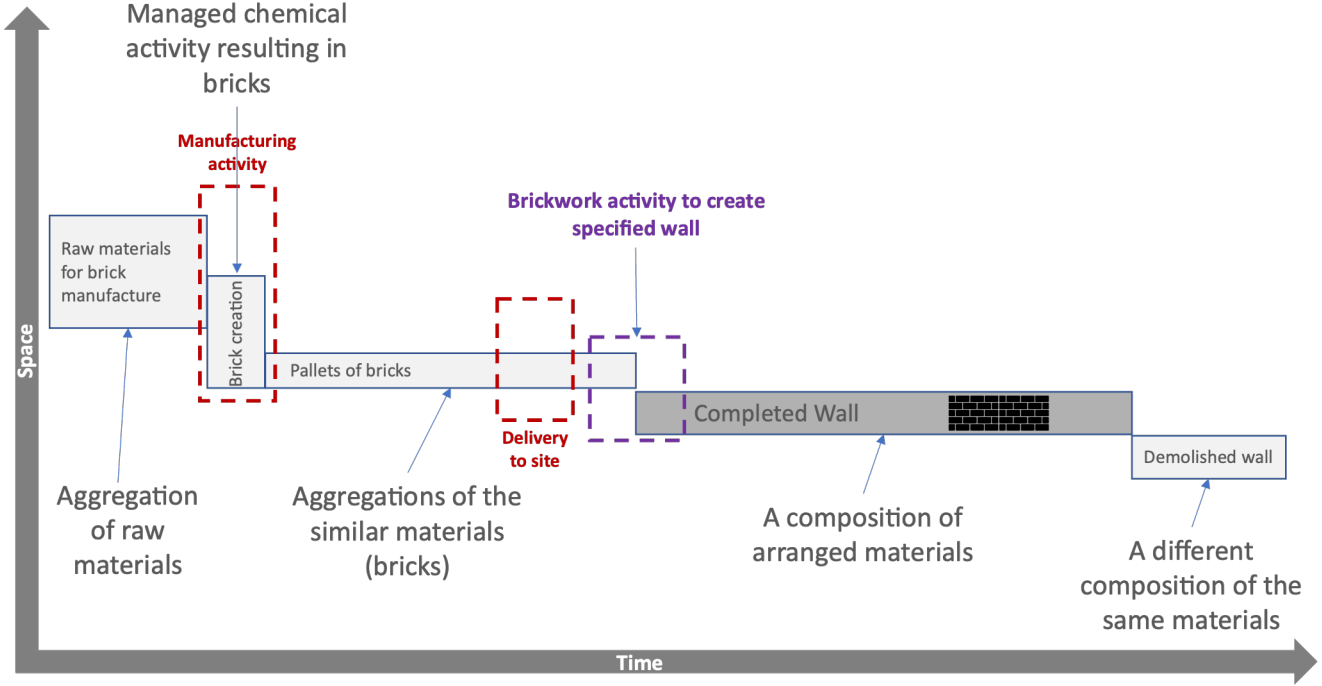


Example: A new brick wall at a school

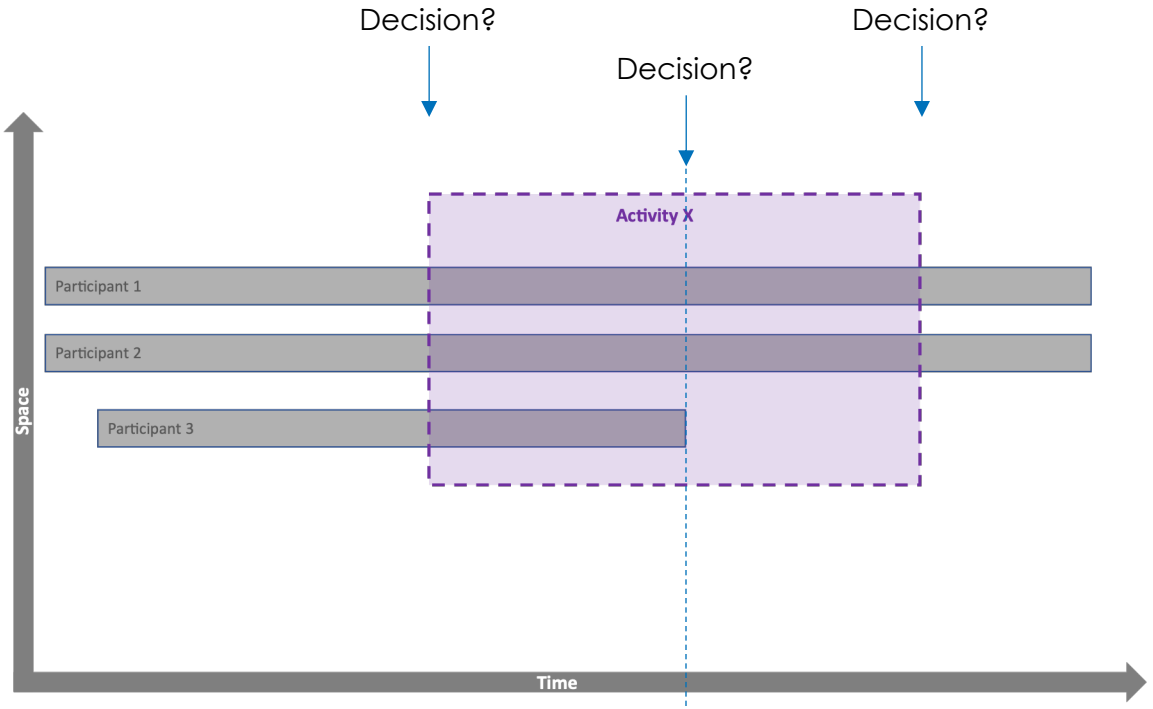
Activity models - participants



Activity models – participant lifecycles



Anatomy of activity



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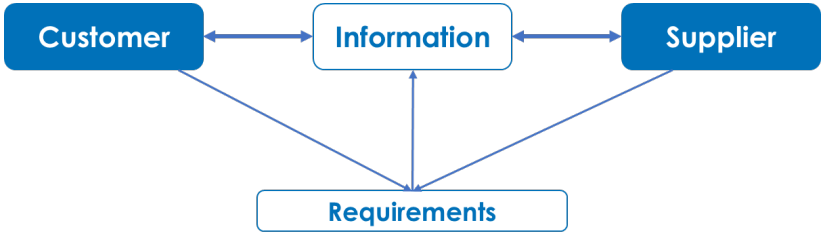
Identifying decisions and information required

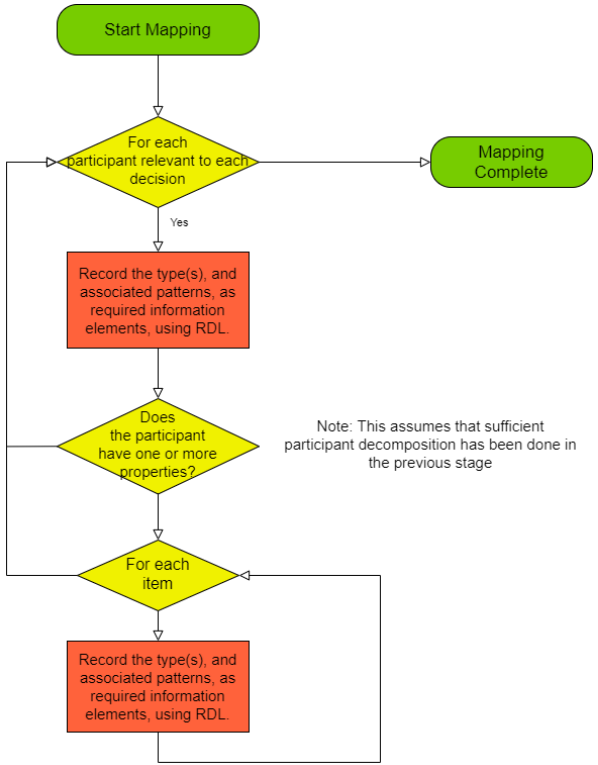
- A methodical mapping of critical properties of information quality (definitional) and population characteristics (value characteristics)

- The activity analysis provides a basis for the process of agreement. What is really needed? Cost-benefit trade-off.
- Agreement requires a process involving the parties requiring the information and those involved in providing it.
- The process of agreement is only complete if there is a mechanism for the requirements to be satisfied:
  - including the activities that will result in the information being created and
  - the information management system(s) that will take care of it until it is needed; preserving (or improving) the quality.

- All can be, in the limit, expressed in terms of the TLO (FDM)



Mapping activity and participants to a formal model



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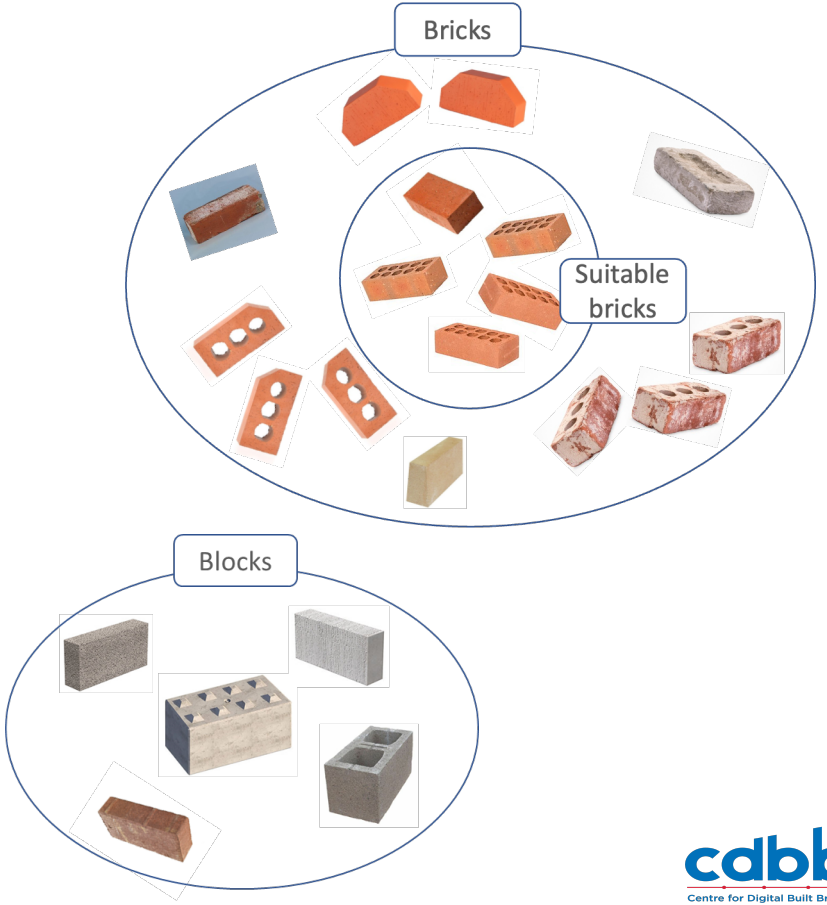
Sets and parts

- Euler diagrams of types (sets and subsets) of bricks

- Selection gets easier if there is a good **Reference Data Library** (see David's presentation)
- On large activities this can be a considerable number of classes and patterns required to make use of them.
- The quality of the RDL is key
- If the sets (largely classes) that are required aren't available then the should be formally requested
- A rigorous quality management approach to the RDL additions



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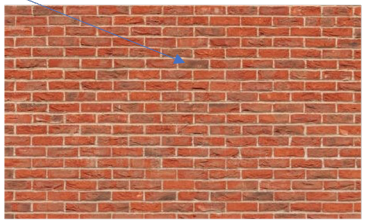
Sets and **parts**

- Each used brick is a member of the set of bricks that the wall is composed of
- Each particular brick has a lifecycle.
- The materials become part of each brick during manufacture
- Subsequently each brick has a unique existence
- Information about each brick, batch of bricks and their context can be relevant to a decision. If so, the information requirement should be captured.

- The lifecycle of the brick may not end in the wall
- If demolished the parts of each brick may still be useful… and they will still exist



Each brick is a part of the wall. There is more to the wall than just the bricks.

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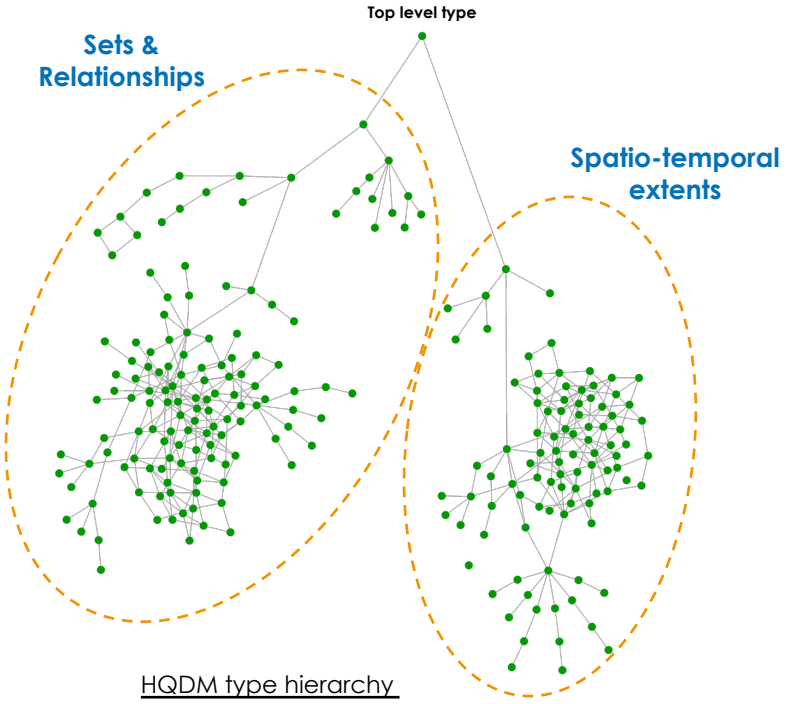
Consistency through use of an integrated model



HQDM type hierarchy

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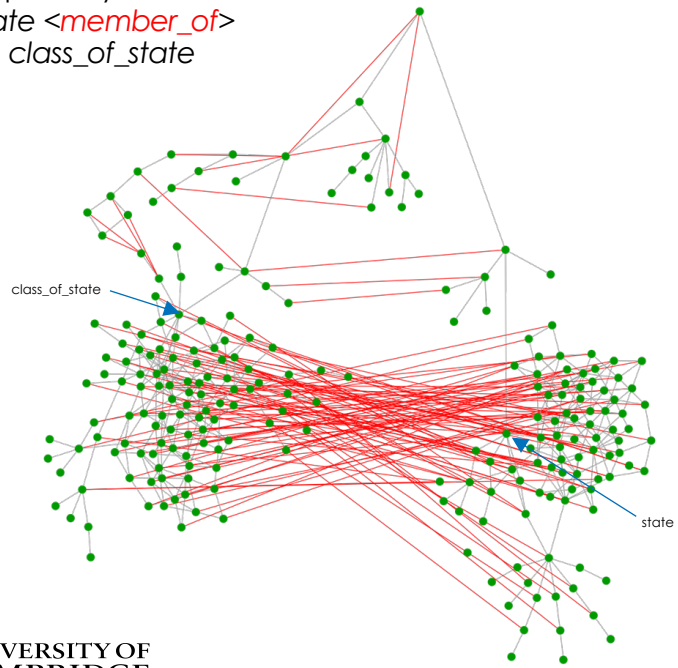
Sets and Parts in an integrated model

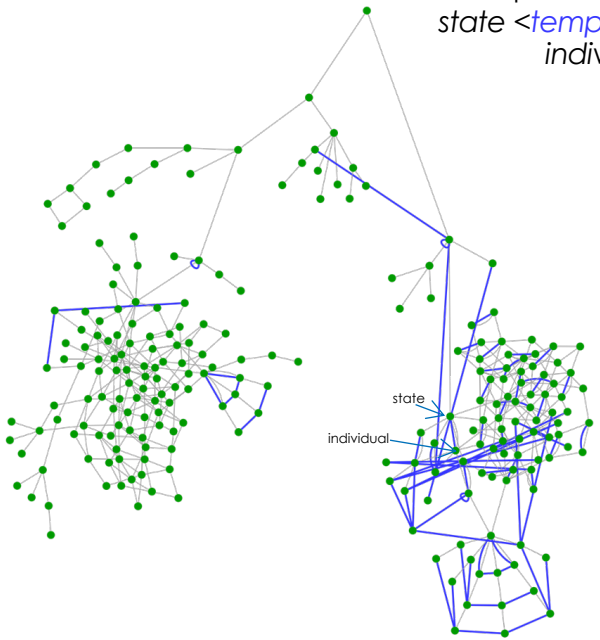
Set membership

Example: Any instance of
state <*member_of*>
class_of_state



Parthood

Example: Any instance of
state <*temporal_part_of*>
individual



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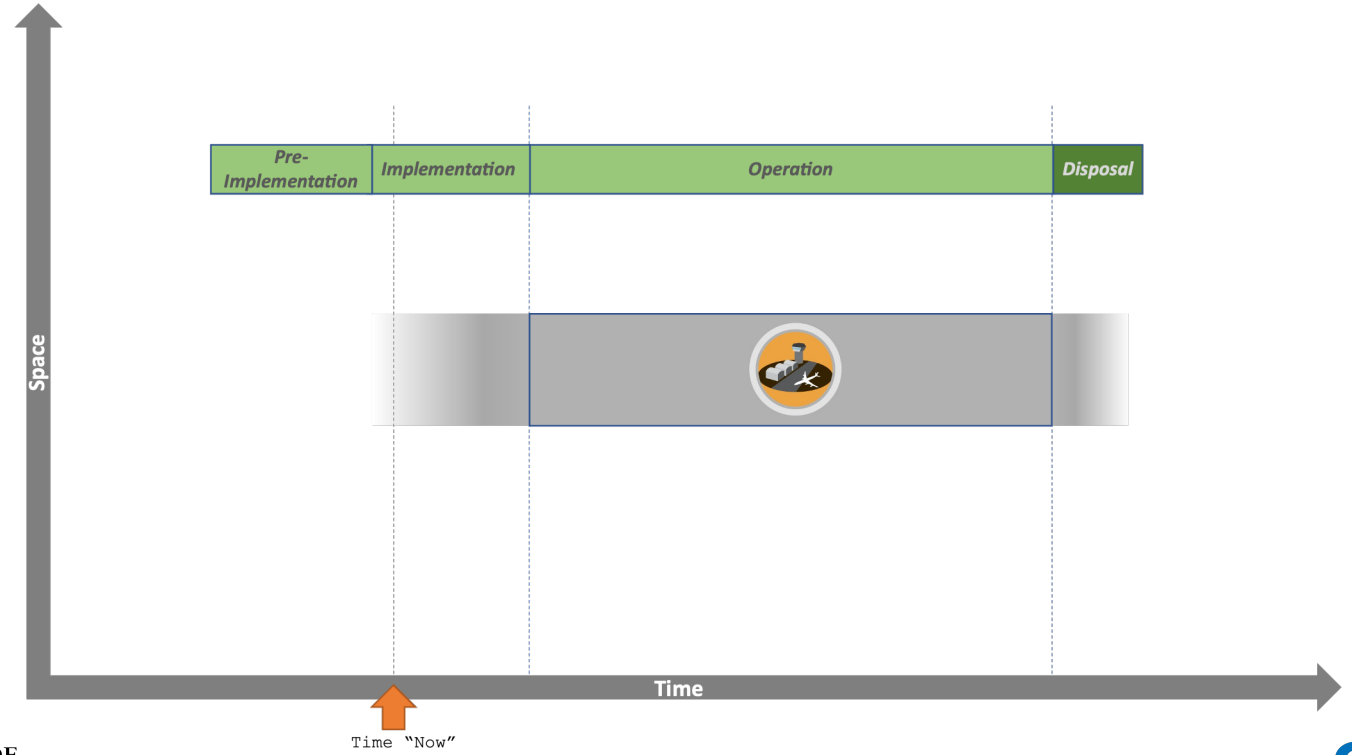
Activity lifecycles and process models



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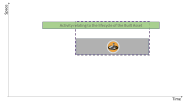
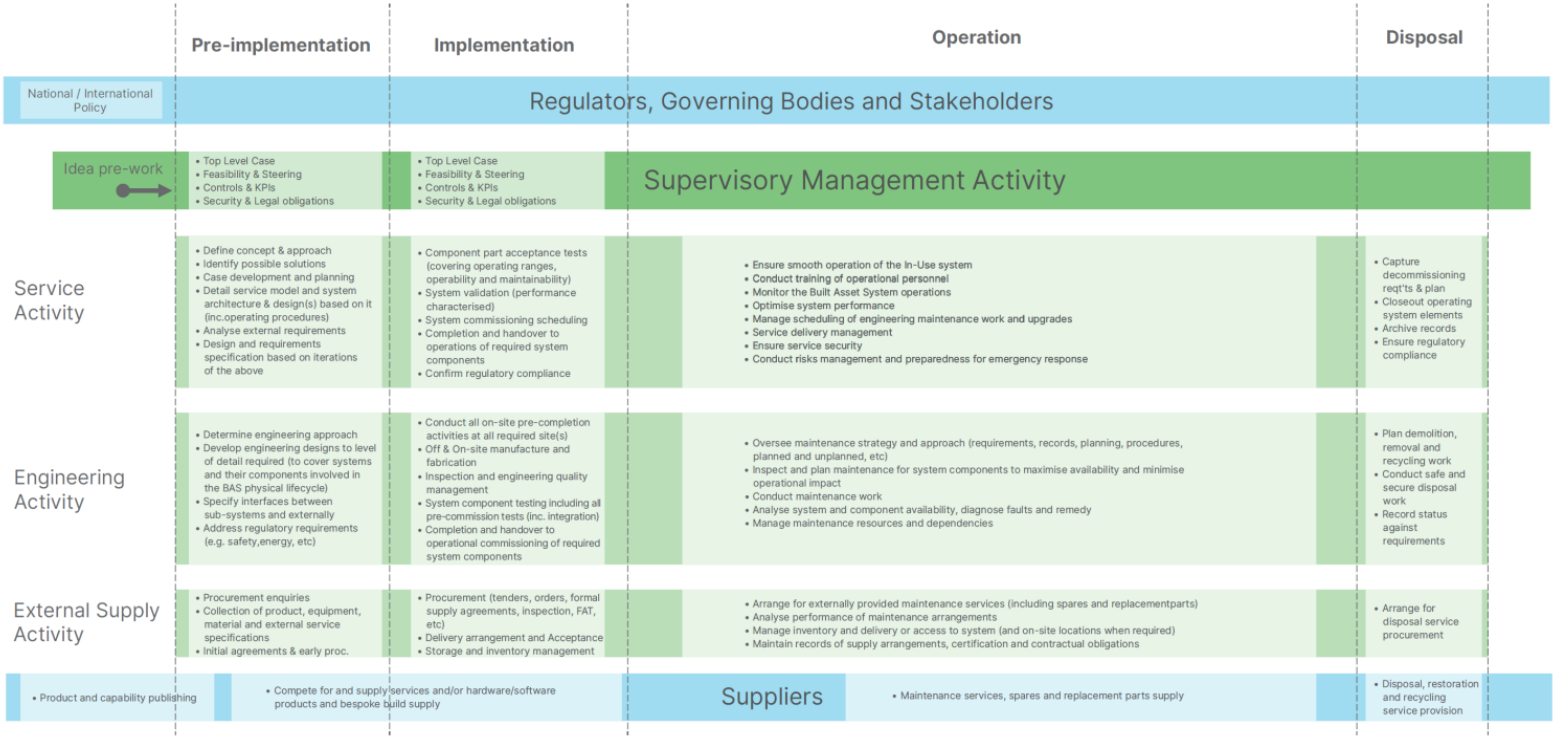
A Built Asset System Engineering Activity Model





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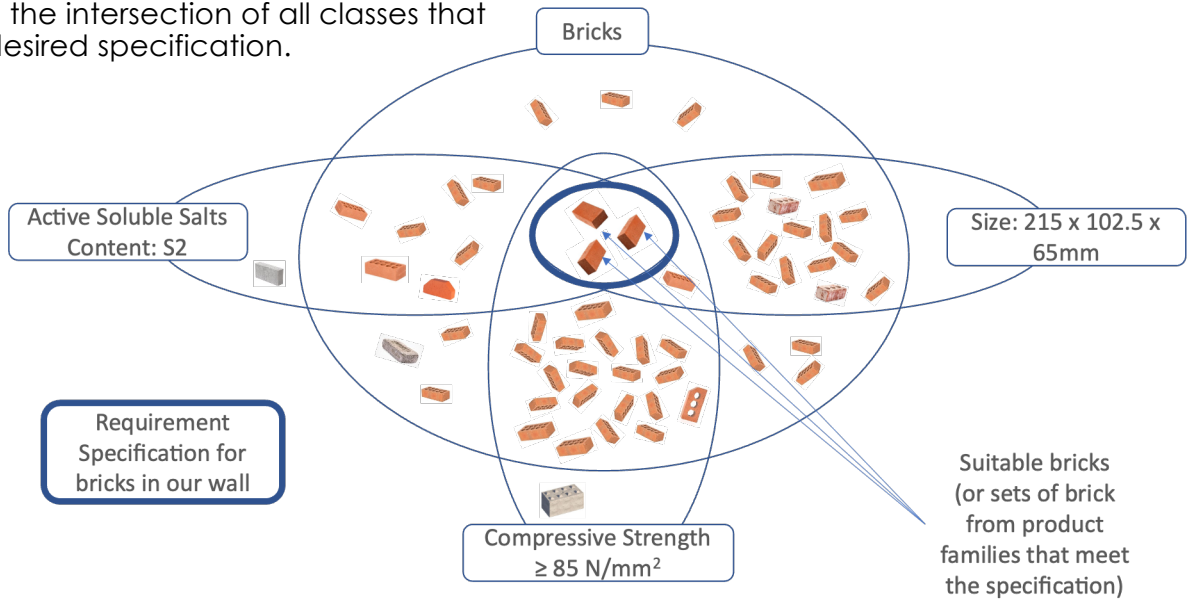
Requirement specification

- Our requirement is to have particular bricks that are suitable, built into our wall as it is implemented.
- We can use our Information Requirements relating to these bricks to create a requirement specification… the intersection of all classes that comprise our desired specification.

- Through a consistent approach to requirements and requirement specifications there can be a generally applicable means of using data for them.



Information Security

- Securing information is 'just' part of achieving the required data quality
- (Security) Risk management is a type of activity that requires good decisions
- It is very hard to secure information if you don't know what is represented by it
- Inconsistency undermines information security:
- How can security policy, compliance and specific controls be applied consistently if the data in the system isn't consistent?
  - NIST SP800-162 ABAC Guide requires consistency but doesn't explain how to achieve it.
  - A system-wide* approach to consistency, supporting extension, offers the ability to manage information a grounded

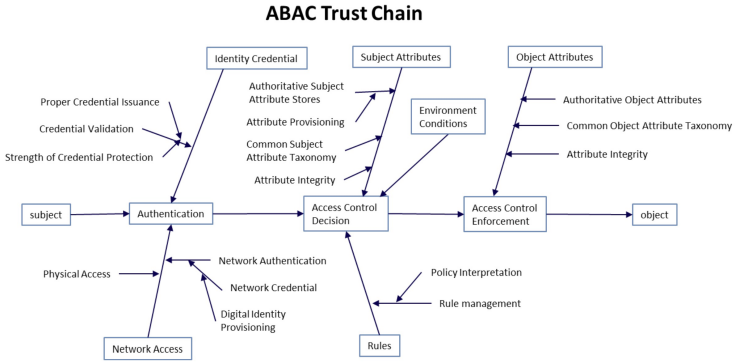


Figure 8: ABAC Trust Chain

NIST SP 800-162, Guide to Attribute Based Access Control (ABAC) Definition and Considerations

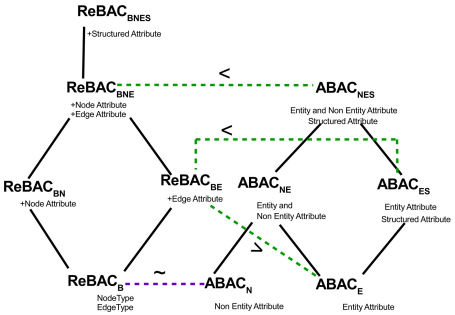


Figure 12: *Non-Equivalence of ReBAC and ABAC Structural Classification*

Classifying and comparing Attribute-based and Relationship-based Access Control, Sandhu, et al. 2017 (**assumes consistency**)

*- this is the entire scope of the information system(s) in question

(Draft) Methodology

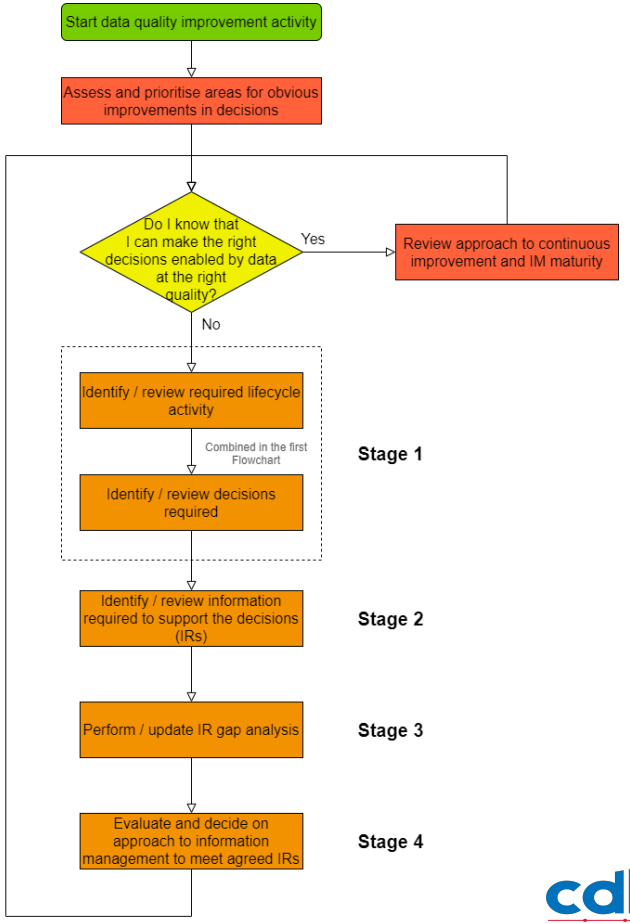
- Based on continuous improvement
- Quality management cycle

How to make a start:

- Recognise the need to improve data quality and initial area for performance improvement
- Apply methodology

1. Identify lifecycle activities and decisions
   - 4D analysis
   - Participant lifecycle view
2. Identify information required to support those decisions
   - Specify required quality, checking against 8 critical properties
3. Information Quality gap analysis
   - Investigate quality gaps and what it would take to address them
4. Evaluate and decide on information management approach to meet requirements
   - Business-focused selection of implementation options and the acceptable cost-benefit trade-off.

- Repeat methodology



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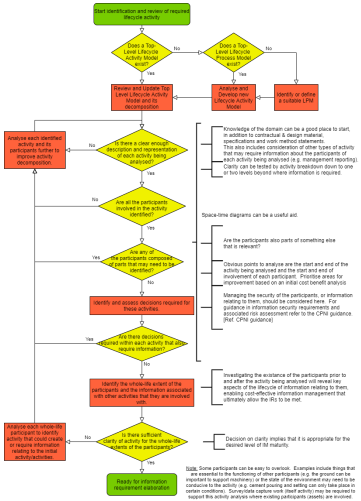
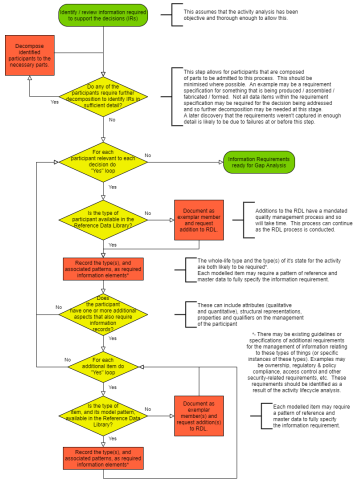
(Draft) Methodology

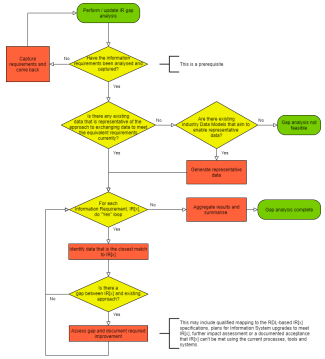
Step 1 Activity analysis



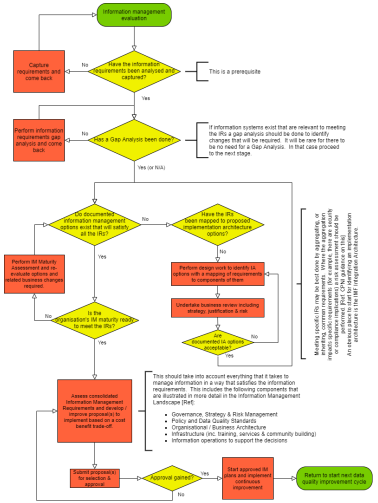
Step 2 Requirement identification



Step 3 Gap analysis



Step 4 Information management approach



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Recap

- Information (quality) requirements can be determined through activity analysis
- Business Processes depend on a good understanding of the activities that they shape
- A methodology has been developed, based on activity analysis, to determine information requirements and the IM approach to meeting them
- Consistency in representation is key to lifecycle information management, re-use and information system integration
- Information security depends on risk management activities and the ability to consistently implement protection of information and physical assets
- Specifying information requirements in terms of a consistent model offers checking and automation that can't be done without it

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Example NetZero scenario

- Based on the approach and method consider what could be involved in assessing buildings for lifecycle energy footprint.
- What is the purpose of the monitoring - decisions?
- What's involved in the lifecycle? How would this impact the assessment?
- How could different buildings, types of component parts, lifecycles of the parts, etc influence the result?
- How can the assessment be done as the number of buildings being assessed increases, as the buildings change, as their environment changes?

Fair measurement, reporting and decisions locally, nationally and internationally will depend on trusted use of data.

IEA SHC/ECBCS Task 40/Annex 52 – Towards Net Zero Energy solar Buildings
M&V protocol for Net ZEB. A technical report of STA

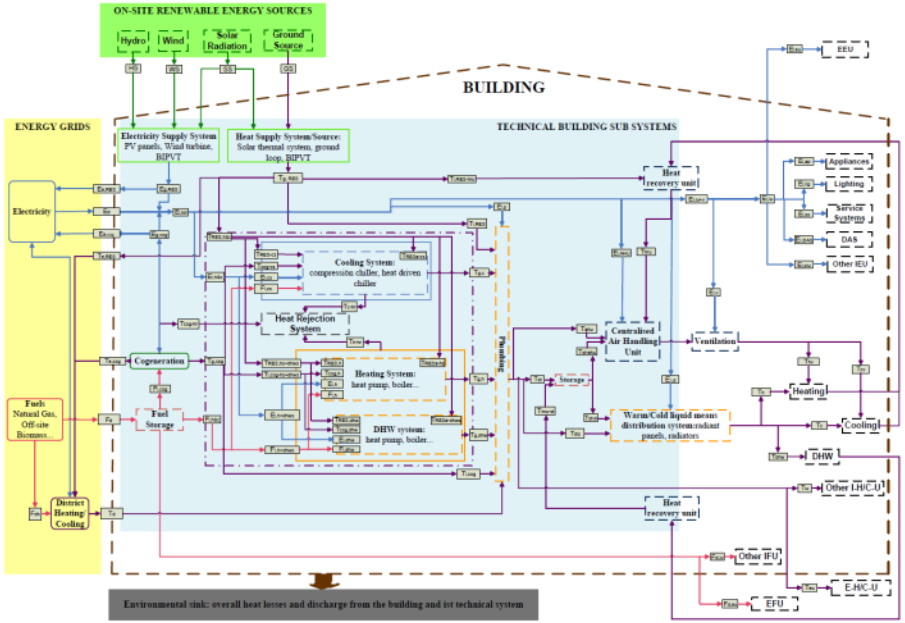

Figure 4-1. Standard reference diagram for monitoring