CDBB
Capability Framework and Research Landscape Scoping Workshop

Workshop: Capability to understand the behaviour of COMPLEX INTEGRATED SYSTEMS - to predict and manage their behaviour, especially as the complexity and integration of digital built Britain increases

Centre for Digital Built Britain

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UNIVERSITY OF CAMBRIDGE

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Centre for Digital Built Britain

This document captures the working notes from the workshop "Workshop: Capability to understand the behaviour of COMPLEX INTEGRATED SYSTEMS - to predict and manage their behaviour, especially as the complexity and integration of digital built Britain increases", held at Churchill College Cambridge on 10-11 April 2018

The summary sheets are assembled from the separate working groups from each of two streams; Research and Applications.

The details of the outputs from the individual working groups are captured in turn.

This material was used as a starting point for the creation and development of the Capability Framework and the Research Landscape. It is provided as source material for the interested reader.

Rank order	Topic title	
1	Maximizing value of data	-Data obsolescence - communicating and visualizing -Protocols and standards, algorithms
2	Environmental resilience	-Monitoring, IoT relationship between national and Built - Data governance and frameworks, social factors , communication - Collaboration
3	Trust	- Verification, technical specs - Operators and citizens trusting and infrastructure - Treat preparedness - Modelling (processes, practice)
4	Dynamic needs models	-Behaviours dynamics of individuals and organisations - organisations mapping
5	Understanding behaviours - Mindset	
6	Modeling and Predicting lifecycle costs	- new jobs etc.
7	Data capture	- Integration - Systematic Impacts, ontologies, search/find and browse - Reaching different stakeholders
8	Silo effect on research	How to capture complexity of systems
9	Performance Management	- Optimisation means - who defines optimal?
10	Distribution	Multiple stakeholders, operators

Research Topic: …	
Understand the behaviour of Complex Integrated Systems	

Scope:

Scope - In	Scope out	What sub-topics might overlap with other topics?
- DBB + TCT we need to be more integrated - Blockchain (data) - Data specification -> framework - Interoperability -> of IT systems -> of individuals & organisations - Targeted monitoring of assets (sensors-deployment-data use) '- DBB more integrated - Digital thread across life cycle - Obsolescence of systems & data - Digital work flow across lifecycle - Digital twin for lifecycle including simulation - Visualisation & integrated system (VR & AR) virtual reality & augmented reality - Data-driven engineering for improving/optimising structural performances & assessing infrastructure - Time-scales e.g. real-time data vs long-term data curation & analysis - Smart data: How to make sense of data. Information vs data vs knowledge - Data preservation over long time (100 years) - Choosing which data to curate - Need for integration of research to build viable proposition		

Step 2. Scope change by thinking about stakeholders

- Uncertainties identification & management
- Cost modelling, cost visualisation
- Who's funding (or going to fund) this network of digital infrastructure? (additional cost of sensors…)
- How to demonstrate benefit to stakeholders? Visualisation/qualification of benefit?
- User friendliness, mobile platforms
- Push vs pull for integration
- Transparency, privacy, ethics in integrating systems
- Communicating insights from data to the layman (clients, end-user, asset owner)

Step 3. Scope change by thinking about spatial differences

e.g. National/Regional	e.g. City/local	e.g. Asset specific
- Resource/time to mine/use manage data - Energy need for data - Cost of collecting and storing big data (i.e. Amazon and Google server farms) - Public good	- Smart city IoT	

Step 4. Scope change by thinking about the lifecycle of assets and services

Articulate user needs and requirements	Conceive, plan and design (including optimisation and integration)	Build and commission (including optimisation and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	…Assess, feedback and optimisation
- Through-life engineering services (modelling through life performance)	- Lean integrated system					

Research Topic: …	
Understand the behaviour of Complex Integrated Systems	

Scope:

Scope - In	Scope out	What sub-topics might overlap with other topics?
- Information vs/& data interpretation for facilities management - Assets management & live data feed/integrity management - Liabilities/management of risks - Integration assets (e.g. IoT) - Multi-disciplinary approach on BIM - Clear defined information layers e.g. people, process, technology, standard interoperability '- Sharing data across different domains (e.g. energy, transport) '- Interoperability of information layers from different systems components - FAIR, CRISP-DM - Knowledge transfer between industries: O&G & construction/ infrastructure - Risk management of adaptive complex systems - Data privacy/ethics/security/legal - Modelling of complex integrated system performance - Investments/availability of capital/commercial business models - Human dynamics @scale & computational social science - Intellectual property issues - Cost engineering & added value - Collaborations management (different stakeholders		- User interface

Step 2. Scope change by thinking about stakeholders

- Quadruple helix collaborations: -> Academia -> Industry -> Public sector -> Citizens - Human dynamics impact: how people learn/adapt/embrace & apply for the different systems	- Identifying values for end users that evolve through life stages - Understand the needs of end user - Understanding the different subsystems that are part of the integrated system - Understand trade-offs across different values & needs - Top to bottom & bottom up approach to meet in the middle - Investment ↓ ? ↑ opportunity	- Clear the needed information and requirement of different stakeholders ↔ support feedback, value co-creation - Decision making tool for end user? Relating to investment & value

Step 3. Scope change by thinking about spatial differences

e.g. National/Regional	e.g. City/local	e.g. Asset specific
- Different regulatory and policy frameworks across different domains - Types of projects based on the industry & the project scale: -> Oil & gas -> Construction -> Infrastructure '- Key performance indicator tool depending on spatial difference/setup - Possibly different values for different end users across urban-rural gradient	←Interoperability→	

Step 4. Scope change by thinking about the lifecycle of assets and services

Articulate user needs and requirements	Conceive, plan and design (including optimisation and integration)	Build and commission (including optimisation and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	…Assess, feedback and optimisation

Research Topic: …	
Understand the behaviour of complex integrated systems to predict and manage their behaviour	

Scope:

Scope - In		Scope out	What sub-topics might overlap with other topics?
- Digital/IT systems capabilities to manage legacy, risk-risk & metrological data - Operation model of framework for data exchange across timelines - Buffers/redundancy/storage - How to reconcile short-term or long-term data/knowledge - Predictive capabilities in log term behavioural - SOS semantic landscape consensus - How complex are each of the systems we are integrating & how complex are their interdependencies?	- Human intervention - BIM focus on build/capex but at other end less discipline more commercial - Federated data, data ownership, trust to share for a reason - Complexity-sensitive capabilities - Capturing short term behaviour dynamic - Data privacy/GDPR "greater good" trust in integrated systems - Economic/business models to enable complex integ. systems	- Do not include capabilities which solve problems that are out of scope - Utopian model is out, need for sufficient abstraction	- Dynamic-intense boundary between this topic and "Outcomes and outputs sought by Stakeholders" topic - Analyse/interpret data to create efficient information topics - Govern, manage, optimise DBB

Step 2. Scope change by thinking about stakeholders

- How humans interact with information - Matching information from systems to particular user needs, e.g. provenance, confidence - Multiple sources of data/the truth - International stakeholders: world bank, utility providers, global supply chains…	- Role for re-insurers, resilience, global connectivity - Transparency - The definition and organisation ecosystem landscape - Intra-organisational barriers - but what more for inter org collaboration

Step 3. Scope change by thinking about spatial differences

e.g. National/Regional	e.g. City/local	e.g. Asset specific
- Local action has impact on central planning - Disaggregation (of control) requires increased inter-operability between levels	- Access levels/power of self-determination	

Step 4. Scope change by thinking about the lifecycle of assets and services

Articulate user needs and requirements	Conceive, plan and design (including options and integration)	Build and commission (including options and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	…Assess, feedback and optimisation
- Sectoral needs but recognising x sector integration						

Research Topic: ...	
Understand the behaviour of complex integrated systems to predict and manage their behaviour	

Scope:

Scope - In		Scope out	What sub-topics might overlap with other topics?
- Design & analysis methods are not able to incorporate new data - Understanding the difference between complex integrated systems & integration of complex systems - Legacy & new - Emergent properties - Bottom up, top down '- Data provenance in complex systems - Design, build & operate in the face of transdisciplinary uncertainty - Risk, trust - who realises the benefits?	- Identifying & collating case studies -> Data & narrative -> Best & worst practice -> Iterating to advice - Assessing historical data for digital integration - Next-generation systems engineering - Knowing governance & reg parameters - Knowing what is already in place - especially underground	- "Traditional systems engineering - Supporting the uptake of digital data	

Step 2. Scope change by thinking about stakeholders

	- Learning journeys for stakeholders - Understanding barriers to exploitation of DBB - Permission to fail by trying & LEARN - Research the reward/incentive structures for multi-stakeholder collaboration/data sharing	- Infrastructure segregation design/build/operate breakdown barrier walls - Value the data capture Not all data is needed? All data is needed?

Step 3. Scope change by thinking about spatial differences

e.g. National/Regional	e.g. City/local	e.g. Asset specific
- Governance interactions small/medium/large & data sharing standards/protocols	- Data and off site/on site manufacturing - Exploiting the "I" in IT - Data & information overload What data is useful - to whom - and when?	- Plain language questions to define requirements - What are the functional boundaries? How do they relate to each other? And to political and geographic boundaries

Step 4. Scope change by thinking about the lifecycle of assets and services

Articulate user needs and requirements	Conceive, plan and design (including optimisation and integration)	Build and commission (including optimisation and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	...Assess, feedback and optimisation
						- Data integrity & provenance standards & governance

Research Topic: ...	
Understand the behaviour of complex integrated systems to predict and manage their behaviour	

Scope:

Scope - In		Scope out	What sub-topics might overlap with other topics?	
- Not about production of standards (top down) but "API model" - processed for production of standards - Technology development will continue so legacy will never need to pay - Threat modelling -> Infrastructure dependency -> resilience - Buildings/old assets before they are in use - constant legacy issues throughout life - Need to know vs need to share	- Data ownership & data sharing - Ability/inclination to share information home & workplace - How to analyse the end-user requirements to inform the system design - How technology diffusion can be introduced & accelerated to a complex system '- Standards to emerge based on practise - People are unpredictable technology/ process is not enough	- Probably not a single "data substrate" a la IP - (internet) more classes of stakeholder	- Human behaviour -> of individuals -> of groups ...idiosyncratic vs predictable - Socio technical look at systems so not inst tech social constructor - Distributed computation among multiple stakeholders e.g. machine learning - Collaborative production	- Trustworthiness of computational infrastructure and of computations - Multiplicity of mechanisms (internet not phone network) - Liability of information sharer/user ethical obligations - Standards for data processing - Change management

Step 2. Scope change by thinking about stakeholders

- Architect now doing things for asset manager, in 30 yrs who does things based on architect & builder of 30 yrs ago - End stakeholder is probably unknown at design stage - Designers need to know users & uses, not just think they know them -> instrumentation of systems (Not like the internet)	- Open data allows for unanticipated innovation/economy - Capturing the requirements of all users & stakeholders before defining the system requirements - Process innovation and collaboration

Step 3. Scope change by thinking about spatial differences

e.g. National/Regional	e.g. City/local		e.g. Asset specific
- What about international? - Spatial & temporal -> Always dealing with legacy -> Always doing incremental development Constant process - Best practice difficult to share across country -> pace of change slow	- Councils don't have much budget to innovate - Local or even national viewpoints lead to few opportunities to identify best practice in short time scales	- Interoperability is important (system & systems) - Big data - Cloud computing - Uncertainties problem	- Single asset, single operator? (at any given moment?) - Incremental change of asset (as-built more common than new build)

Step 4. Scope change by thinking about the lifecycle of assets and services

Articulate user needs and requirements	Conceive, plan and design (including optimisation and integration)	Build and commission (including optimisation and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	...Assess, feedback and optimisation

Research Topic	
Understand the behaviours of Complex Integrated Systems	

Step 1. What are the major research clusters/themes?	What are capabilities and research that will be needed as DBB matures from 'deliver' to 'operate' to 'integrate'?					
	Deliver *(create the built asset)*		***Operate*** *(manage asset through life and deliver the services that derive from and depend on the asset)*		***Integrate*** *(deliver services and benefits based on integrated systems and organisations)*	
	What capabilities and enabling research?	***Which people / institutions are working on this?***	***What extra capabilities and enabling research?***	***Which people / institutions are working on this?***	***What extra capabilities and enabling research?***	***Which people / institutions are working on this?***
- Maximizing the value of data **- What new algorithms & protocols do we need?** **- Data & system obsolescence** **- Uncertainties quantification & management** **- Modelling/predicting cost** **- Whole-lifecycle cost**	- Data itself	- South Gloucestershire Council (Emerson's Green, FRP footbridge) - CSIC	- User interfaces - Integrating with legacy systems (CAD etc.) - Asset(s)	- WSP (engineering consultancy)	**- Proposition 1**: accept that data will be diverse -> Tools to make sense across system **- Proposition 2:** ensure that data/information consistent -> Protocols -> Standardisation -> Frameworks **- System**	- BSI IoT community launch 'Hypercat' (interoperable standard) - Data for London?
- …to maximize: stakeholder/user engagement **- Communicating/visualizing value of data collected from assets**			- Develop engaging visualization techniques for different stakeholders	- LocLab "Gamification" of real environment (Waterloo Bridge)		

Research Topic	
Understand the behaviour of Complex Integrated Systems	

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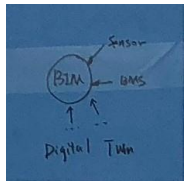
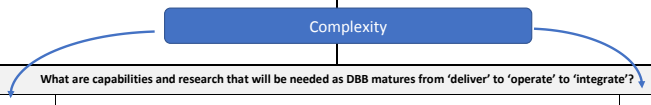
- Data **- Environmental resilience in the face of changing climate & economic pressure** **- Identify sensor for level of pollution. Use of drone to identify flooding impact**	- Data management & governance interoperability, standards - Data requirements to ensure resilience of the built asset - Sensor fusion	- Local authorities, environment agency, DEFRA communities - Interdisciplinary approach (decision making, social science, engineering, computer science)	- Managing risks & liabilities - Data ↓ databases ↓ information ↓ interface		- Social & technical platforms	
- Transition to a low carbon economy	- Electric vehicles, smart grids, solar panels to understand demands for energy - Sharing data from smart meters, internet of things and smart appliances	- Customers BHS, OFGEM communities	- Regulatory framework to share data with different actors - Understand where tipping points occur - Develop near real time monitoring capability of energy networks			
- Risk management **- Smart integrated system management** **- Complex system performance management/measurement**	- As-built BIM As-is BIM - should match & update - Risk management in the context of digital asset modelling and stakeholders involved - Big data - How to measure performance/benefits considering the perspective of all stakeholders - Optimisation & ground truth baseline for new systems		- Asset management systems & subsystems (integrity management) 			

Research Topic						
Understand the behaviour of complex integrated systems to predict and manage their behaviour						
Step 1. What are the major research clusters/themes?	**What are capabilities and research that will be needed as DBB matures from 'deliver' to 'operate' to 'integrate'?**					
	Deliver *(create the built asset)*		***Operate*** *(manage asset through life and deliver the services that derive from and depend on the asset)*		***Integrate*** *(deliver services and benefits based on integrated systems and organisations)*	
	What extra capabilities and enabling research are needed?	***Which people / institutions are working on this?***	***What extra capabilities and enabling research?***	***Which people / institutions are working on this?***	***What extra capabilities and enabling research?***	***Which people / institutions are working on this?***
- Understanding behavioural & social dynamics for within CIS - Complexity of stakeholders & organisations for CIS - Complexity mind-set & also identity shift	- Or in construction lacks theory - Interpretation of real-time smart systems, agility needed - rate of change first	- UK BIM alliance	- Psycho-geography Frankfurt school based (David Harvey etc.)	- Sector specific: -> Energy: SSH, ESC -> Transport: TSC, CCAV -> Cities: FCC		- Seth Bullock, Nigel Gilbert, Mark Birkin, Leeds CDT human data analytics - Customer experience analytics CSA - John Orr, Human-system interactions, Cambridge
- Operationalisation of CIS - Context/population endogenous dynamics needed - Theoretical developments e.g. dynamics, co-evolution, failure of CIS itself		- ITRC/Mistral/DAFNI	- Methods to understand endogenous dynamics ↔			- ETH Zurich/Singapore/CSIRO
- Sectoral/spatial/temporal & parameter dimensionality of system	- Quantum computing/performance - Representation of data needs step change	- ITRC/Mistral/DAFNI		- ITRC/Mistral/DAFNI - UK CRIC urban observatory	- ITRC/Mistral/DAFNI	- Smart/future cities catapult
- Data privacy & governance implications for CIS design						- ATI, Warwick, Cambridge, Cranfield
- Modelling business models in CIS	- AI/machine learning	- Ibuild/R. Dawson ICIF/SPRU	- FPSA ↔ **F**uture **P**ower **S**ystems **A**rchitecture			



Research Topic	Delegate names
	Brian Collins **Giovanna Biscontin** **Simon Lamb** **Joanna Leach** **Jennifer Whyte**

Step 1. What are the major research clusters/themes?	What are capabilities and research that will be needed as DBB matures from 'deliver' to 'operate' to 'integrate'?					
	Deliver *(create the built asset)*		***Operate*** *(manage asset through life and deliver the services that derive from and depend on the asset)*		***Integrate*** *(deliver services and benefits based on integrated systems and organisations)*	
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- Data -> Curation -> Provenance -> Aggregation						- ATI - Library communities - KIM project - Information science (JML)
- Implications of emergence (BC) - Systemic impacts	- Connecting the old with new (data) (SC)		- Reward transdisciplinary & endeavour (Multi RC)			- Collaborative working, see book "The power in numbers" (JML) - Complementary agendas: -> Collaborative networking -> Knowledge exchange -> Interdisciplinary -> Learning ecosystems -> Co-production (JML)
- Query/search discovery - Ontologies	- Simplifying the complexity by isolating each element (SC)					- Cardiff university - UCL - ATI (SC)
- How to change stakeholder appetite for research in DBB - Reduce effects of silo behaviour EVERYWHERE (BC)		- Education innovation (GB)				- Business models -> KIF project -> Ibuild project - Economic geographers - Economists - Risk (JML)
- Visualising the digital twin - Model integration	- Methods to integrate and iterate design/construction (GB)					- CSEI

Note: the most urgent / important topics have (x) next to the text and the number indicate the group priority 1 being the highest

Research Topic	
Understand the behaviour of complex integrated systems to predict and manage their behaviour	

Step 1. What are the major research clusters/themes?	What are capabilities and research that will be needed as DBB matures from 'deliver' to 'operate' to 'integrate'?					
	Deliver *(create the built asset)*		***Operate*** *(manage asset through life and deliver the services that derive from and depend on the asset)*		***Integrate*** *(deliver services and benefits based on integrated systems and organisations)*	
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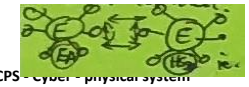
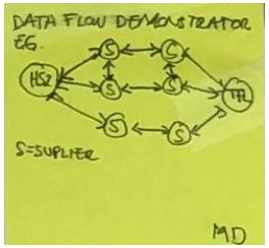
- Modelling for process design **- File evolution of scheme based on practise (rather than pre-standard)** **- How to model/understand the different aspects in system scaling (assets - buildings - cities - national)?** **- How process innovation can increase efficiency of data sharing in asset management** **- How to model conceptualise the social constructs in digital tech design** **- How to model & monitor the life cycle of the systems?** **- How to use the agent-based modelling to simulate complex systems and understand the interactions between them** **- How to use the digital term concept to enhance our understanding on complex systems integration**	- We need a body to curate "processes)	- IETF W3C	- Building smart IDM could be a staging point			
- How do we create a platform for standardised processes **- Democratic data sharing - beyond "traditional" data users** **- How do we share/access the relevant subset of data without losing control of whole dataset** **- Distributed of compute resource of ownership computation ②**	- Platform/frameworks for distributed computation algorithms for distributed data processing				- How to create production of ongoing services on top of dist. computation)	
- Making sense of big data (data analytics) **- How to enable current & future stakeholders to understand & use data infrastructure?** **- How to support human-data interaction**					- How should best practice in data curation/process/ interaction be captured & infused into practice?	
- What are the opportunities from digital post occupancy evaluation? **- How to integrate system design requirement with condition monitoring requirement of the complex systems** **- What is the real impact of design decisions (unintended consequence & why) design into a build**						
- Interaction between privacy data sharing law and DBB stakeholders **- What are the digital equivalents analogues to design standards and should they be enforced?** **- How to build trustworthy infrastructure for DBB?** **- Intelligent systems that can understand users & environment ①** **- How to use AI in modelling, processing & decision making**	- Development of formal verification techniques in this domain - Ground-up design & build of a verified computational platform - Threat modelling: -> of the assets coven DBB infra -> of the DBB infrastructure itself	- "REMS" project (Cambridge xxx lab, Imperial, Edinburgh) Trustworthy tech SRI	- Ubiquitous & compatible instrumentation, logging, audit, provenance - Liability management - Contractual obligations	- "Databox" project (Cambridge, Imperial, Nottingham) W3C, IETF	- Interoperability of verification & provenance mechanisms -> over space -> over time	

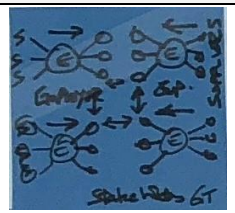
1B. Complex integrated systems		
Rank order	Topic title	
1	Pilot BIM open shared data store (across >1 project)	
2	Beyond Grenfell	Data capture and use across lifecycle/legacy assets - democratizing data
3	Living Laboratories	-Measured building performance for operation, design and delivery value - Sphere (Bristol) EDK - Cross disciplinary study of human behaviours in 100 homes (BRE iPark - Bregroup.com/ipark)
4	Dynamic brief and Learning outcomes	- Smart contract evolving brief - thru life - e.g. schools: education outcome vs. built environment contribution
5	Cyber Physical Pilot - How digital and physical interact and Integrate	- Specification - Attributes - Deve-ops for physical infrastructure

Application Topic: …	
- Understanding the behaviour of complex integrated systems	

Step 1. Scope: What topics should we include in this part of the framework – and what demonstrators would illustrate / stretch the boundaries?

Scope - In	Scope out	What sub-topics might overlap with other topics?
- Feedforward (learning from performance) - Ownership gov vs private Public utilities vs private - Cyber physical - organisational links - HTML for building data - one system - How to chose what to keep? & when? - CPPS - cyber - physical construction system - Creating anticipated infrastructure. Digital twin model. Cyber physical asset and the whole life enterprise model. IFC, GAL, City, GML, Cardo. HTML: approach - Multiple employer data streams, how do we store the data & in what format?  - CPS - cyber - physical system application - Examples of complex systems: road network, water infrastructure - To integrate complex systems. We need a data language & structure 	- There will never be a perfect digital model. Maybe we shouldn't try to get the perfect model from the beginning - What is the data for? Find the use-case first - What the client gain for sharing data	- Legal aspects, security aspects, contract delivery points - Ontologies to show levels of info - Unique identifiers - common language - Levels of granularity of data needed

Step 2. Scope change by thinking about stakeholders (Are there new / different aspects of the topic and its demonstrators?)



- Most information are produced as documents, Standard Co-ordinated information. 2D & 3D information. PAS 1192 part 5 - addresses Cyber security. Scope change xxx about data storage
- IPD and multi party collaboration - using i.e. NEC4, MPDT and contracted delivery dates, and who is responsible for collaborative sharing of information

1) HS2, environment agency, highways England, local council - need a <u>data flow demonstrator</u>
2) What data should be exchanged
- How should it be (data)
- Legal issues? - how to structure contracts to enable these outputs
- Commercial model - open = cheaper, data sharing is part of price

Step 3. Scope change by thinking about spatial differences (e.g. to consider how can scale make a difference to the demonstrators we would propose)

e.g. National/Regional	e.g. City/local	e.g. Asset specific
	- Boundaries between physical and digital worlds will i.e. satellite data live monitoring of earth movement as an example - Objects, assets, interconnections, assets can be anywhere	- Digital twin model to describe cyber-physical systems - e.g. water systems - Implement a database system (not file-based system) for data exchange - Pan asset, what defines assets of interest? - Interpretation & granularity & time

Step 4. Scope change by thinking about the lifecycle of assets and services: Are there new / different aspects of the topic and its demonstrators if we think through the lifecycle of the assets and the services?

Articulate user needs and requirements	Conceive, plan and design (including optimisation and integration)	Build and commission (including optimisation and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	…Assess, feedback, feedforward and optimisation
			- Think about the people: well being, productivity - £1% new build £99% maintain, update	- API's - more thinking of services rather than product		

Application Topic: …	
Understanding the behaviour of complex integrated systems	

Step 1. Scope: What topics should we include in this part of the framework – and what demonstrators would illustrate / stretch the boundaries?

Scope - In	Scope out	What sub-topics might overlap with other topics?
- Understand the pace & direction of technology change - Interoperability of systems - Resilience of CI systems - Interoperability of CI systems to system - Anticipate behaviour (people) and emotional drivers around security - What do we understand as the behaviour of existing system? - Common dictionary & definitions, is it needed? - Ecosystem which facilitates secure & democratised temporal access - Assumption increasing integration -> Consolidation? -> SME's - Making reuse of knowledge cheaper/easier - Continuity of systems e.g. emergency planning - How do we remove the noise? - Who could manage/predict behaviour? Responsible, accountable - Management of real estate of data - Knowledge rules, capture & re-use - Safety - Identifying key interactions of systems - What is a system? Components, people - All systems must have a guardian agent - In all systems there need-must be a feedback loop - Failure modes for systems -> Planned/designed -> Unintended/ignored	- Current situation - Hostiles are <u>not</u> stakeholders - International appears to be out of scope for CDBB -> opportunity for CDBB	- Both data and information topics - Govern, manage, optimise Main topics! and reduced overlap with rest

Step 2. Scope change by thinking about stakeholders (Are there new / different aspects of the topic and its demonstrators?)

- Investors
- Future service providers
- Include the machines - AI
- Stakeholders
  -> Asset owners
  -> Service/receivers/providers
  -> Machines & their owners
- Natural environment: badgers, newts
- Future stakeholders
- Children unable to play: space, pollution, security
- Young people "generation rent":
  -> Isolated
  -> Vulnerable
  -> Non property owners (would be)
- "Cloud" data storage hosts [risk & vulnerability]
- The disengaged
  -> Digitally excluded
  -> Marginalised economically
- Governance models centralised vs voluntary
- International
  -> Google
  -> Foreign state governments
- CI system multi agency/actor, model

Step 3. Scope change by thinking about spatial differences (e.g. to consider how can scale make a difference to the demonstrators we would propose)

e.g. National/Regional	e.g. City/local	e.g. Asset specific
- Rail network - National grid-storage -> Demand -> Supply -> Capacity	- Train stations - Garden city - Local substations, local generators	- Train -> Metrics -> Location -> Speed -> Signalling -> Track - Train -> Capability -> Crowded -> Capacity of network - Consumption energy

Step 4. Scope change by thinking about the lifecycle of assets and services: Are there new / different aspects of the topic and its demonstrators if we think through the lifecycle of the assets and the services?

Articulate user needs and requirements	Conceive, plan and design (including optimisation and integration)	Build and commission (including optimisation and integration)	Manage and Operate (refine and enhance, optimise and integrate)	Provide valued services to users (and minimise downsides for non-users)	Retrofit / Renew / Decommission (with attention to the whole cycle)	…Assess, feedback and optimisation

Application Topic	
Understanding the behaviour of complex integrated systems	

Step 1. What are major demonstrators that are required?	**What capabilities / functionalities of the demonstrators illustrate the maturing of DBB from 'deliver' to 'operate' to 'integrate'?**					
	Deliver *(create the built asset)*		***Operate*** *(manage asset through life and deliver the services that derive from and depend on the asset)*		***Integrate*** *(deliver services and benefits based on integrated systems and organisations)*	
	What would be the big challenges?	***How?***	***What would be the big challenges?***	***How?***	***What would be the big challenges?***	***How?***
- XGOV object style library (BIM NGI) **- Common data language & structure**	- Agreeing a storage structure	- Published standard	- Industry (software) solutions	- Driven by clients understanding the outcomes	- People doing their day jobs	- Education
- Database of example data/case studies **- Physical IoT project in building publishing data for open tests** **- BRE iPark bregroup.com/ipark**	- Sourcing data	- Crowdsourced? Contributors get to use data	- Publishing near-real time data to allow prediction	- API access to data of IoT devices	- Granularity of data (i.e. measure in mins or hours) aggregation of granular data	- Type library/data model/ontology
- James Dyson building, smart building Cambridge University Engineering dept [CSIC] **- Data mining AI/case studies in intelligent buildings. CIB - Dr Tong Yang board member** **- International council for research & innovation in building & construction (CIB)**	- Accumulation of data for analysis & monitoring	- Environment impact assessment CFD simulation Numerical modelling Computational fluid dynamics - Environmental engineering Heat exchangers, heat transfer Green building CFD coding Solar thermal, thermal comfort	- Environment sustainability Urban planning Renewable energy Energy efficiency in building		- Look at social needs -> Training & education within communities	
- IoT software defined infrastructure prototype on model (AIH) **- Cyber-physical system -> CPS prototype on model (AIH)** **- Cyber-physical production system - CPPS on model (AIH)** **- GML city model (AIH)**	- Design - Security by design	- Accurate specifications, requirements of models	- Automation, robotic systems, IoT(s)	- How to overcome technology-related challenges	- Integrated systems	
- Living laboratories **UKCRIC labs** **Open city - Leeds? Bristol?**	- Knowing what to build in the first place -> Measure construction -> Digital twins - Automation - robot construction -> Driven by measured performance	- Prototyping -> Try different things -> Skills & education -> New materials	- Cost: sensors, storage, operation - £30K for F.O. (fibre optics) - Synchronised data, trusted data, Long-lasting data - Wellbeing & productivity? -> B.E. underpins -> Why no value associated? -> How does data help	- What is the low hanging fruit -> What needs to be measured? (tops vs xxx) - Networks for sensing -> How to extract knowledge & why extract knowledge	- What is the value proposition? - Cost of systems Low value sector	

Application Topic	
Understanding the behaviour of complex integrated systems	

Step 1. What are major demonstrators that are required? **Pilot case study**	**What capabilities / functionalities of the demonstrators illustrate the maturing of DBB from 'deliver' to 'operate' to 'integrate'?**					
	Deliver *(create the built asset)*		***Operate*** *(manage asset through life and deliver the services that derive from and depend on the asset)*		***Integrate*** *(deliver services and benefits based on integrated systems and organisations)*	
	What would be the big challenges?	***How?***	***What would be the big challenges?***	***How?***	***What would be the big challenges?***	***How?***
- "Beyond Grenfell" tower blocks **- Democratise data** **-> Governance** **-> Control**	- Automated regulation - Automated compliance - Securing data -> Not for hostiles	- Levels of access to data - secure - Sandpit e.g. FCA for regulation change in banking	- Motivation e.g. Grenfell fire, health & safety, wellbeing	- Building regs e.g. like Singapore - Knowledge capture of appropriate data	- Emergency services - use planning data for scenario planning & risk e.g. 2D plan problem - Scale across all stakeholder e.g. local government	- Monitor & manage assets & incorporate into a feedback loop - Distributed ledger technology -> For asset data
- Schools - learning outcomes **- Dynamic brief vs outcomes**	- Overcome perverse incentives e.g. hours - Brief which pervades across the life cycle - Outcome based procurement	- Automated quality checks - red flag - Smart contracts - Digital	- Continuous monitoring of performance - Involving life cycle asset management view	- Asset management plans - Performance measurement - Spot the performance difference: outstanding, failing		
- Innovation management						
hest						