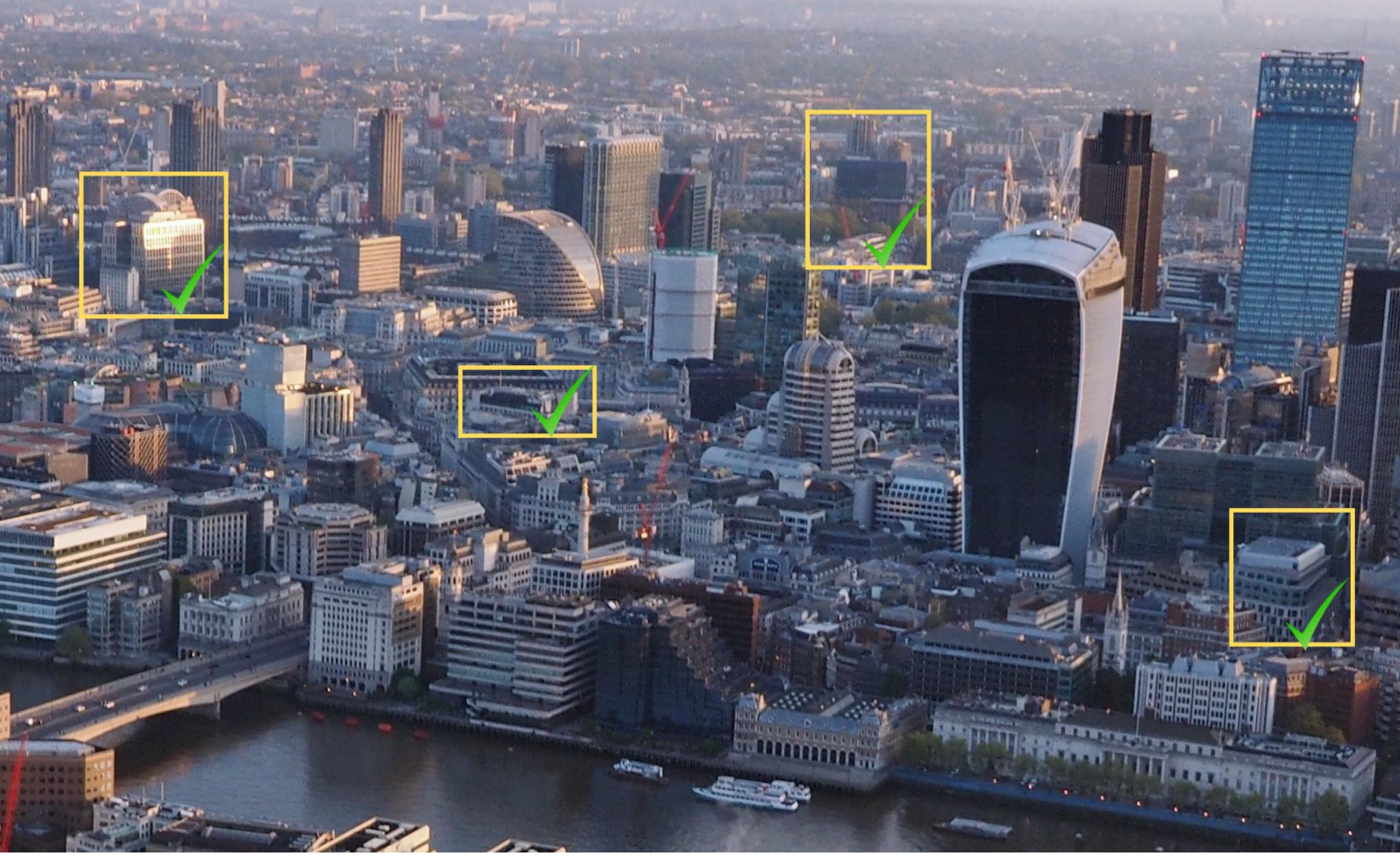

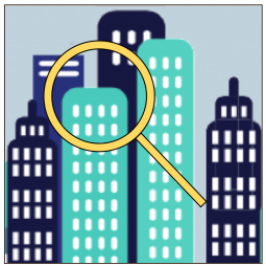

D-COM : Digital COMpliance

D-COM: Digitisation of Requirements, Regulations and Compliance Checking Processes in the Built Environment

Final Report

cdbb

Centre for Digital Built Britain

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Please Note: The views, thoughts, and opinions expressed in the report belong solely to the author(s), and not CDBB

Forward

As an industry we have begun to recognize the magnitude of accurate and reliable information to support decision making and evidence better and safer service provision by those who will use the completed asset, from residential accommodation to a new rail system. The last decade has positively seen a sharp increase in the production of structured data and information models to support this agenda.

As information modelling and management become central planks in our built environment, we must now examine how we can better automate our workflows. So where do we start? Arguably there can be no better opening than with the digitisation of our regulatory processes and compliance checking in relation to same. D-COM plan to set out a logical and achievable plan, help prioritise compliance on the agenda and create a nexus for neighbouring communities to integrate within.

The D-COM network in their initial findings have shown the need for this work to happen and indeed the positive response to compliance checking shifting from a manual endeavour to once that is supported by computer driven automation allowing a swifter and more integrated process.

I would encourage you to take time to read this report and consider the need for the D-COM 2025 road map, further research and ultimately the policy recommendations to be made. There is a mutualism between compliance checking and digital workflows and now is the time to make it happen.

David Philp MSc BSc FICE FRICS FCIOB FCInstES FGBC

Global BIM/MIC Consultancy Director – AECOM

CIOB Trustee and Chair of CIOB Digital Technologies Specialist Interest Group

Executive Summary

The concept of automated checking can bring tangible advantages including increased efficiency and a reduction in the costs of compliance checking. The D-COM Research Network was formed to meet the clear need for research and leadership in this area.

Through this initial research, DCOM has shown that the concerns raised in the Hackitt review of responsibility and departures from regulations is a systemic problem. There has been a significant rise in the formation of government expert groups to address some of these failings. DCOM is proposing not simply "plugging the leaks", but a transformation of the regulatory compliance system. Digitising and automating this system will instil transparency and inherently build in the "Golden Thread".

The entire lifecycle of the built environment is governed by a variety of regulations, requirements and standards. The checking of compliance against these is a complex task, which is currently performed manually, thus becoming highly resource intensive. Recently, the increased maturity of information models and data and with the adoption of Building Information Modelling (BIM) processes, means automation of compliance checking is becoming feasible.

Our vision follows two pathways, the first, where we determined the State of the Nation and its views of automated compliance checking. Secondly, to engage with key stakeholders who inform and drive regulatory policy. In following these pathways, we have started to build

- growing a community
- defining the capabilities required to deliver automated compliance checking
- developing a roadmap to deliver a working and operating model

Our work focused around three key themes. These themes were **Technology, Commercial and Political** impacts on the reception of digitisation and automation of compliance checking.

This report describes the outcomes from of this work. The key output of the work is the D-COM 2025 roadmap. Our roadmap offers a comprehensive and methodical list of next steps. This is a plan for the next 6 years that brings the UK to the verge of mass industrialisation of automated compliance checking by 2025. Our roadmap is organised into four phases. These include a phase of research, a pilot or proof of concept, a phase of industrialisation, where technologies developed for the pilot are matured and designed for scalability, and finally, commercial adoption.

In addition to development the roadmap, the D-COM network also measured the "State of the Nation" through a survey, workshop and interviews with regards to the acceptance of automated checking. In each of these activities we maintained Technology, Commercial and Political themes. The results were overwhelmingly positive, with the vast majority of respondents believing that adoption of automation was both feasible and desirable. There were caveats and suggestions, that automation should have human oversight. We recognise that until trust is established, automation, in near future will include Human Aided Design Policies.

Our next steps are:

Stage 2 (i) – Stakeholder engagement: We propose to commence with Building Regulations for our inaugural exercise. This will require cataloguing and prioritising of regulations and is to be conducted together with extensive consultation with Ministry of Housing, Communities and Local Government's building regulation policy unit and with Building Regulation Advisory Committee.

Desired outcomes: Establishing rule developing methodology and governance to ensure statutory instruments, regulation clauses, standards clauses are digitised and protocols that allow the clauses to be accessible digitally. Temper the level of bureaucracy allowing efficiencies to be embedded through automation of processes with a full audit trail.

Stage 2 (ii) – Piloting: We envisage that the digital form of the regulations, standards and requirements will be a cloud-based system. From a technical perspective, rule processes to track

decisions, manage feedback, and removal of uncertainty will need to be developed within the automated compliance checking system.

Desired outcomes: Demonstrate working to a framework that is clear to follow and shows where the gaps are in capabilities and implementation. The development of a system architecture to show relationships and to hold digitised requirements, regulations and standards, with layers of checklist, rules-based algorithms and responsibilities in complying with the regulations. Develop a consistent language and dictionary. Investigate if there is a platform in existence that can be used for this application.

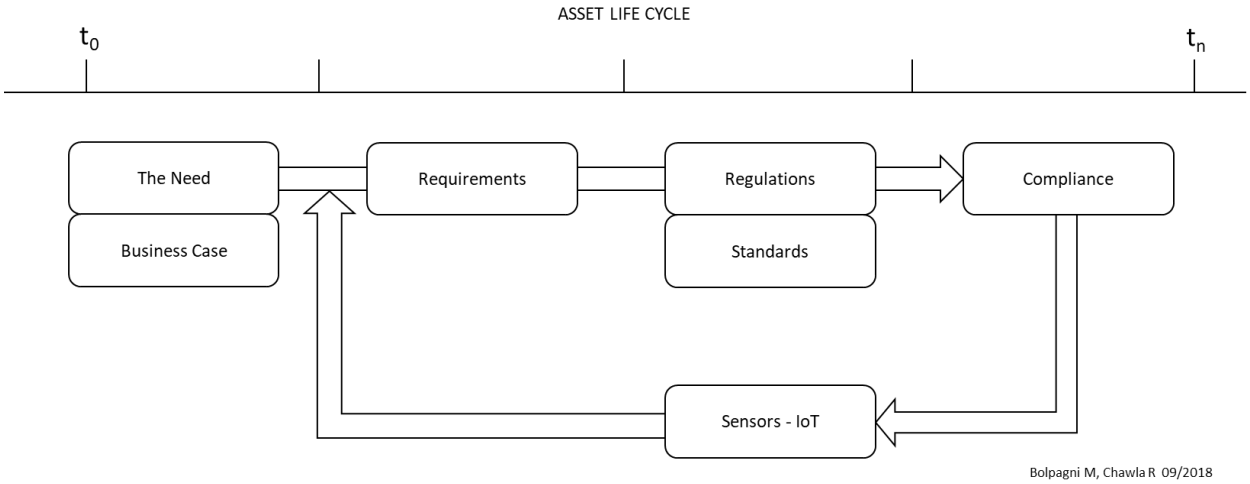

Figure 1 - Proposed Operating Model for Automated Compliance Checking

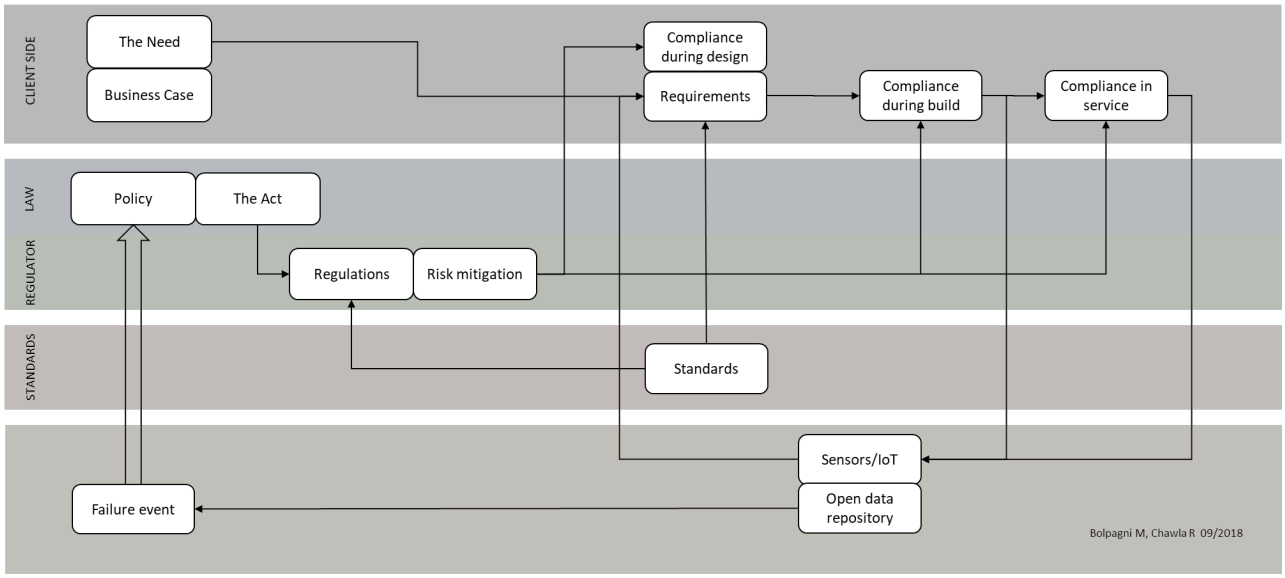

Figure 2 - Proposed Stakeholder Operating Model for Automated Compliance Checking

Stage 3 – Industrialisation: is divided into three stages; building of product or process to 90% of the finished article, trialling and testing of the product or processes – BETA, refining and readying the product or process for scaling.

The process of industrialising compliance checking will require actions in all three themes of **Technology, Commercial and Political.** The political context will continue to inform stakeholders with the effectiveness automation.

Audience specific guidance on digitisation of regulations requirements and standards will need to be created, along with a detailed evidence-based business model for digitization of regulatory compliance.

Desired outcomes: Test bedding the automated regulatory compliance process in a friendly open minded local authority with big and small project compliance. This would be done concurrently using new and existing systems to establish baselines and ability to develop a return on investment model. Develop routes to export automated compliance checking tools to international audience.

A key demonstration would be an audit trail of responsibility in compliance, show the chain of custody of data, record and analyse departures if any, to feedback and inform the regulation clauses for future evolution.

A significant requirement at the end of industrialisation would be a demonstration and proposal of methodologies to scale for the regulatory authorities and public consumption.

Stage 4 – Scaling: Freeze system development for implementation period. Develop a guidance and help material with training programs to allow the use of automated compliance systems. Establish protocols and methods for consumer and user feedback.

Based on operational feedback, program in enhancements to refine consumer experience. Enhance back office and management reporting system to embed efficiencies.

Develop pathways for enhancements to support validation methods, inspection protocols for human or machine, protocols for in services sensor feedback and continuous real time compliance.

Desired outcomes: An automated compliance checking system, with tempered bureaucracy and full transparency.

1. Introduction

The entire lifecycle of the built environment is governed by a variety of regulations, requirements and standards. These range from contractual requirements, requirements specified in the project brief, legislative regulations, and self-imposed environmental performance recommendations. The checking of compliance against these is a complex task that is currently performed on a manual basis thus is highly resource intensive.

So far there has been no meaningful adoption of automated compliance checking. This is because datasets created during planning stages were not sufficiently mature. However, the increasing maturity of information models and adoption of Building Information Modelling (BIM) means automation of compliance checking is becoming feasible.

This concept of automated checking could bring tangible advantages including increased efficiency and a reduction in costs. However, second order advantages span to the whole lifecycle of built environment assets, and their management as part of the establishment of a streamlined and integrated compliance environment within the built environment.

This opportunity presents a clear need for further research in this area and D-COM was established to better understand how the built environment can take advantage. The D-COM vision is shown in Figure 3 and follows two pathways; (a) to determine the state of the nation and (b) to engage with key stakeholders. This involves work in three key areas; growing a community, defining the capabilities required in order to deliver automated compliance checking and developing a roadmap to document how these capabilities are to be delivered.

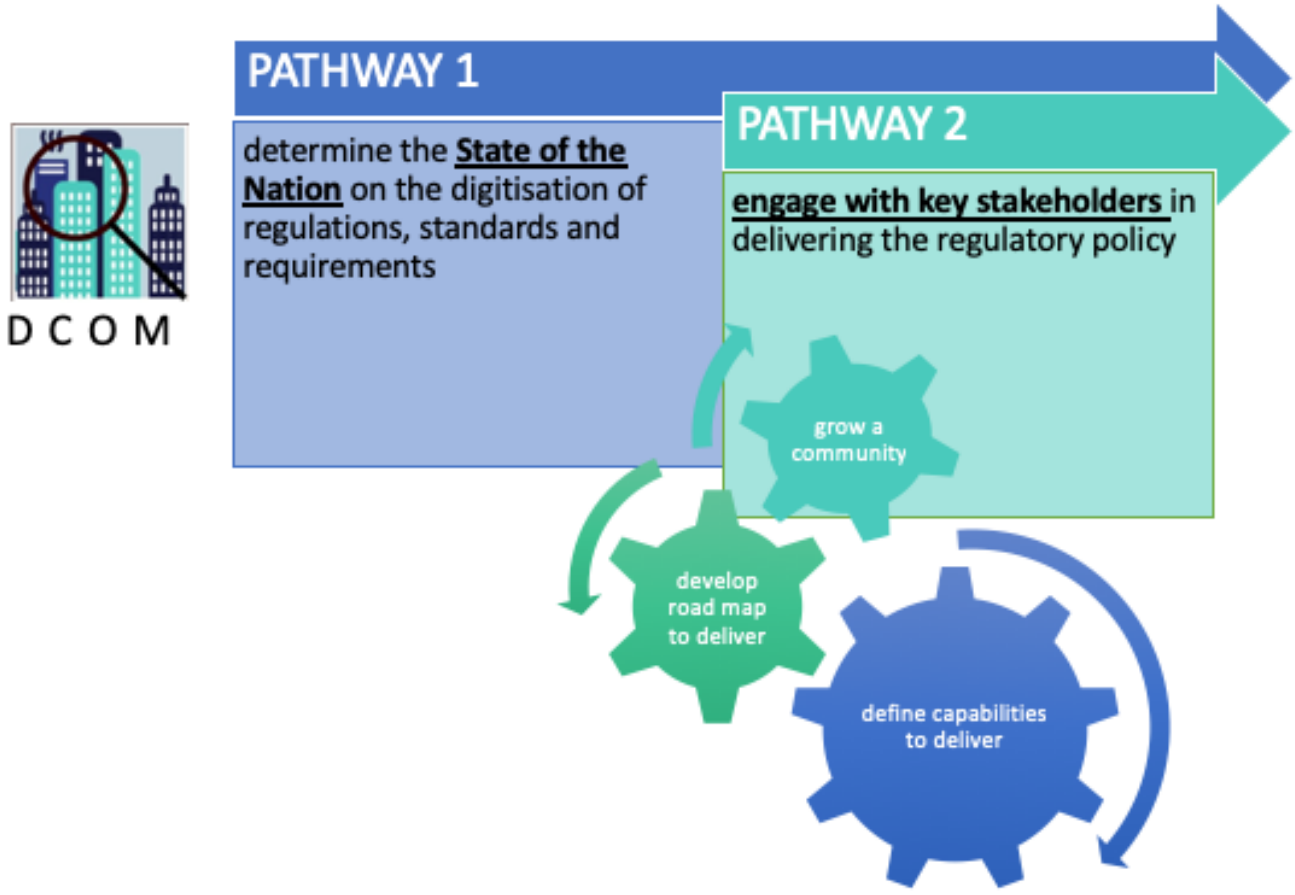

Figure 3 D-COM Vision

More specifically, the aims of the network are to;

- Assess the current state of the art (to cover both academic literature, current software offerings and industrial best practice);
- Consult with stakeholders (to include academia, industry and policymakers) to identify prospective use cases and gather requirements.
- Grow the D-COM network, incorporating new members to ensure the widest coverage of academia/industrial and policy makers as possible.
- Develop a research roadmap for achieving digitisation of built environment regulations
- Define the capabilities required to deliver this roadmap and provide comparison against existing capabilities available in the UK.
- Interact with neighboring networks to ensure complete coverage of the topic, without excessive duplication of effort between networks.

1.1. Network Scope

The scope of the D-COM project has been set deliberately wide, to incorporate all aspects of activity in the scope of the digital built Britain imitative. This scope considers:

- Different types of built environment assets from buildings, to districts, to infrastructure.
- The entire life cycle of these assets from brief and design through to operation and refurbishment/retrofitting.
- The context on which checking systems are operating:
    - Advisory: Where checking systems are used to inform the brief/design processes.
    - Creative: Where checking systems are used as an integrated part of design processes.
    - Decisive: Where checking systems are used to decide whether or not compliance is achieved.
- The different users that will utilise compliance systems in different ways.
- The type of check that compliance systems are performing:
    - Regulations; Rules or directive made by an authority i.e. compliance with legislation.
    - Requirements: Necessary conditions. I.e. compliance with requirements set as part of a project brief.
    - Recommendations: A suggestion or a proposal, often, but not always put forward by an authority, but to which compliance is not mandatory.
    - The varying degrees of automation offered by checking systems, i.e. from preparatory systems (that simply prepare information for checking) to fully automated checking systems.

This scope is illustrated in diagrammatic form in Figure 4.

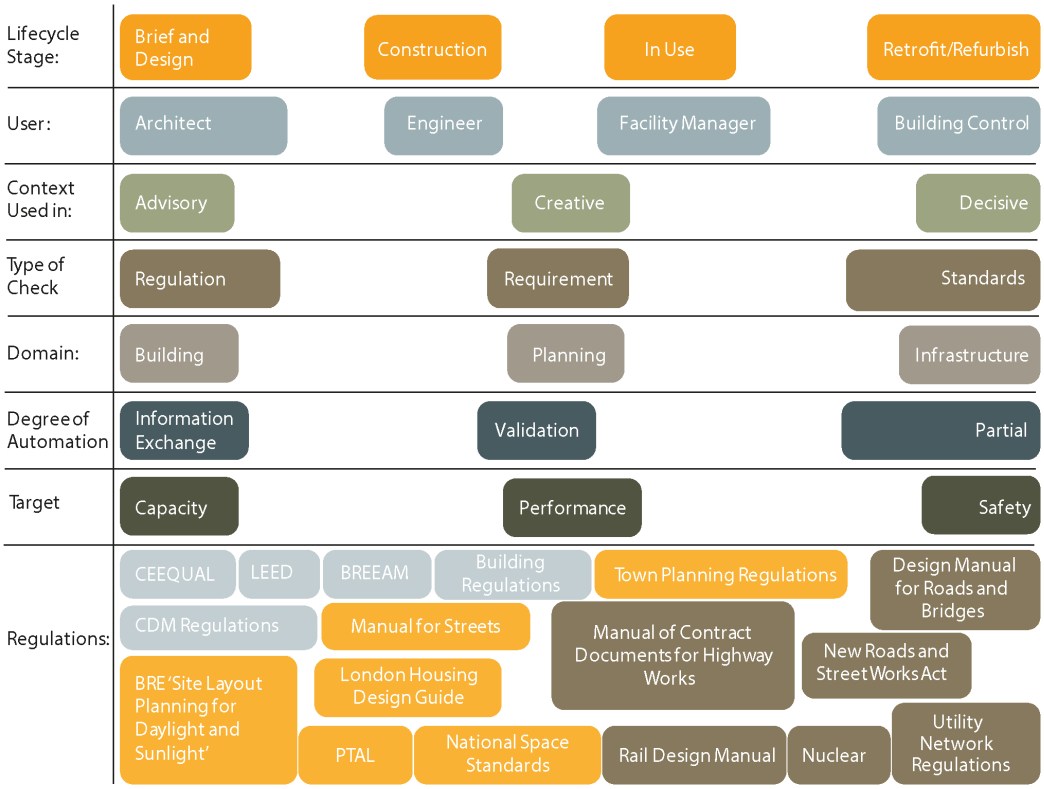

Figure 4 D-COM Scope

In support of this, throughout this document the following definitions are adopted:

- **Regulation** - Rules or directive made by an authority i.e. compliance with legislation.
- **Requirement** - Necessary conditions, i.e. compliance with requirements set as part of a project brief.
- **Recommendation** - A suggestion or a proposal, often, but not always put forward by an authority, but to which compliance is not mandatory.
- **Standard** – a recognised level of quality for good, products or services. In the UK British Standards (BSI) are the national standards body.

This is shown in more detail in Figure 5 which illustrates this hierarchy, of regulations (requirements defined by an authority), requirements, standards and recommendations.

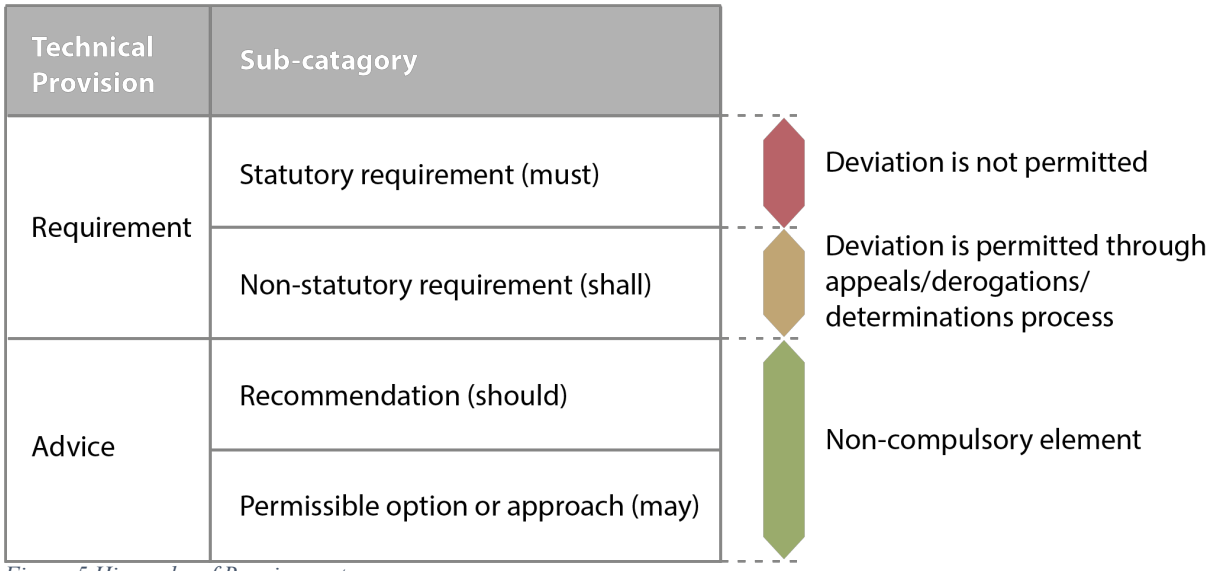

Figure 5 Hierarchy of Requirements

Other definitions utilised in this document are:

- **Capabilities:** New abilities that the industry must possess in order to achieve automated checking.
- **Market Forces:** Changes in the direction/attitudes within the built environment sector that must be achieved in order to achieve automated checking.

1.2. Methodology

Figure 6 describes the D-COM methodology. More specifically, following this methodology, the D-COM network has:

- Elicited a set of initial capabilities and market forces required to achieve automated compliance checking.
- Conducted a survey to; (a) expand and validate these capabilities/market forces and (b) collect initial responses regarding the state of the nation regarding the adoption of automated compliance checking.
- Revised the initial set of capability/market forces based on the questionnaire.
- Held consultation event to; (a) further refine the capabilities/market forces, (b) further understand the state of the nation and (c) elicit future steps for achieving the required capabilities/market forces
- Conducted a detailed landscape review of applicable industrial and academic developments.
- Analyse the results of this consultation, and the landscape exercise to produce a future research roadmap.
- Identified centres of competence based on the landscape review and knowledge of network members.

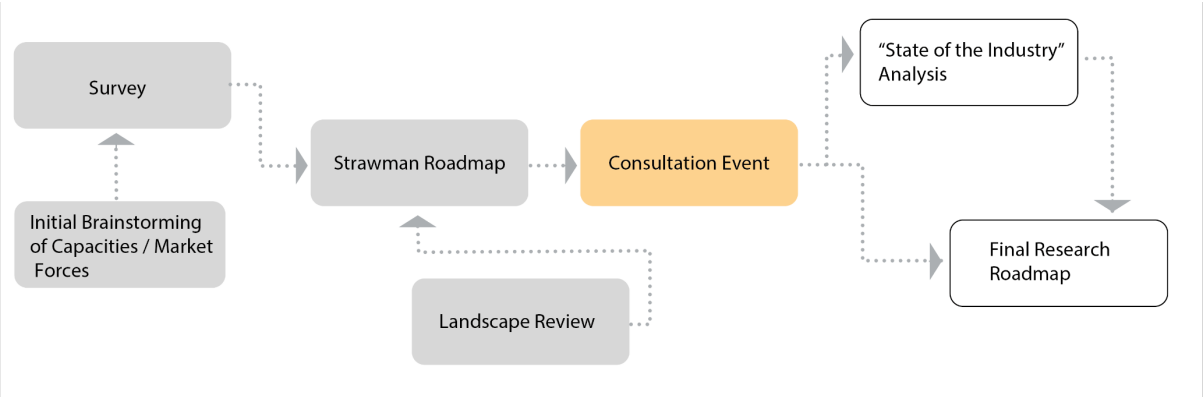

Figure 6 D-COM Methodology

1.3. Network Team & Contributions

The DCOM network consists of 14 organisations, all of which participated with network activities. The detailed breakdown of each organisations contributions is detailed in *Table 1*.

Table 1 Network Member Contributions

Organisation	**Contribution**	**Representative**
Cardiff University	Cardiff University led the DCOM network and made significant contribution to all aspects of the networks work.	Thomas Beach, Simon Lamb
AEC3	AEC3 participated in DCOM workshops, developed the DCOM survey, authored the user stories and contributed to the state-of-the-art review and conduct of interviews.	Nick Nisbet
Azurelope	Azurelope participated in the in DCOM workshops and assisted with social media and dissemination activities.	Andy Holt
Brydenwood	Brydenwood participated in the D-COM workshops, assisted with the consultation event, helped analyse the questionnaire, conducted interviews and produced graphics for the final report.	Rosemarie Andrews
BSI	BSI participated in DCOM workshops.	Kieran Parkinson
Costain	Costain participated in the D-COM workshops, assisted with the consultation event and contributed to the state-of-the-art review.	David Owens
HKA	HKA participated in the in DCOM workshops, assisted in conducting interviews and performed the graphics design for the final report.	David-John Gibbs
Lendlease	Lendlease participated in DCOM workshops.	Edonis Jesus
MACE	MACE participated in DCOM workshops, assisted in reviewing the state-of-the-art survey, assisted with the running of the DCOM consultation event, arranged interviews and assisted with social media activities.	Marzia Bolpagni
Northumbria University	Northumbria University participated in DCOM workshops and contributed to the state-of-the-art review.	David Greenwood, Claudio Benghi
Process Innovation Forum	PIF participated in DCOM workshops, organised the consultation event, and performed questionnaire semantic analysis, in addition to contributing to the design of the survey, conduct of interviews and the state-of-the-art review.	Raj Chawla

Solibri	Solibri participated in the D-COM workshops, assisted with the dissemination activities sand contributed to the state-of-the-art review.	Andrew Bellerby, Simon Gilbert
University of Central Lancashire	University of Central Lancashire participated in the DCOM workshops and assisted with social media and dissemination activities.	Abdulgadir Ganah
University of Strathclyde	The University of Strathclyde participated in the DCOM workshops.	Zhen Chen

1.4. Report Summary

The remainder of this report is structured as follows.

Section 2 describes two motivating scenarios and the D-COM conceptual models used to illustrate the benefits and the concept of the network.

Section 3 describes the process of deriving the required activities that must occur in order for adoption of automated checking of regulations/requirements/standards to move forward.

Section 4 describes the results of a review of the current academic and industrial landscape state of the art in this area.

Section 5 describes the community that has formed around the D-COM network, including the identification of centres of competence that can be leveraged on to deliver the 2025 roadmap.

Section 6 presents an analysis of the current state of the nation, documenting the current views of the industry regarding automated checking. This section presents the D-COM 2025 roadmap which, by cross referencing required capabilities/market forces with the current state of the art, presents a roadmap of activities to drive forward the adoption of digitised checking processes.

Section 7 concludes this report.

2. Motivating Scenarios and Conceptual Models for the Digitisation of Regulations, Requirements and Standards

This section describes the two ways that D-COM has motivated discussions around the area of the digitisation of compliance checking of regulations/requirements/standards. The first is through a series of scenarios and the second is through proposing conceptual models of “before” and “after” digitisation.

2.1. Scenarios

A series of scenarios were drafted as motivating examples for the automated of checking against regulations/requirements/standards. The purpose of these was to enable the network, to convey to external parties the perceived value of the concept and, in addition to show the wide variety of applicable areas within the D-COM scope.

Scenario 1- Building: Checking refurbishment plans of a residential block. This scenario illustrates how an automated regulatory compliance checking system is able to assist a building manager in evaluating proposals for refurbishment work. This scenario is mapped to our scope in Figure 7.

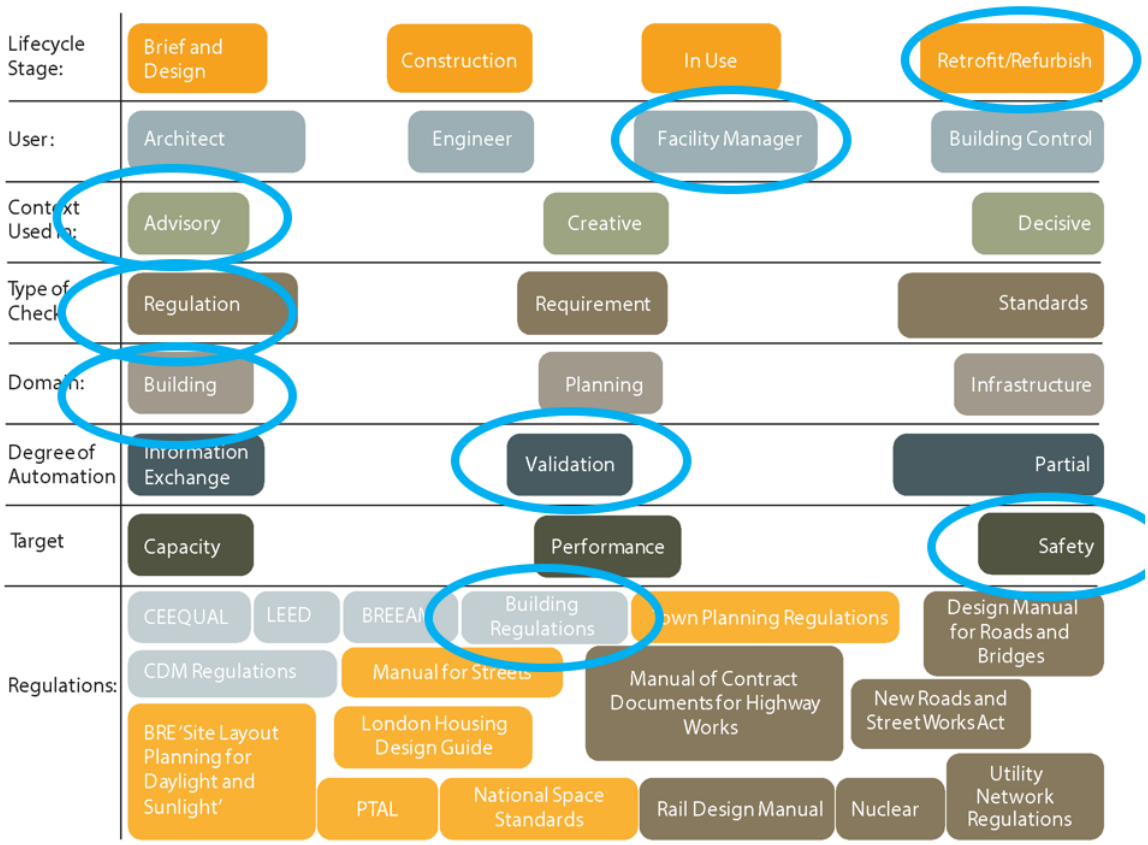

Figure 7 Scenario 1

In this scenario, the building manager has received contractors' proposals for the refurbishment of the common parts of a student residence. Before evaluating the tenders, the proposals are checked automatically against the non-mandatory approved documents on access and fire. The report highlights that one proposal has not specified the details of the self-closing mechanism of the main access doors, and that another has indicated a sub-standard finish on the internal doors. The building manger approves the sending of two emails (automatically generated) each citing the exact regulation, section clause and phrases that are in question along with the bidder's values for the key metrics. The emails contain forms requesting clarifications from the two bidders. They continue working to evaluating the third bid.

Scenario 2 - Infrastructure: Automated engineering of a road junction. This illustrates how a regulatory compliance checking system could also be used in a generative capacity to perform automatic design tasks in the infrastructure domain. This scenario is mapped to our scope in Figure 8.

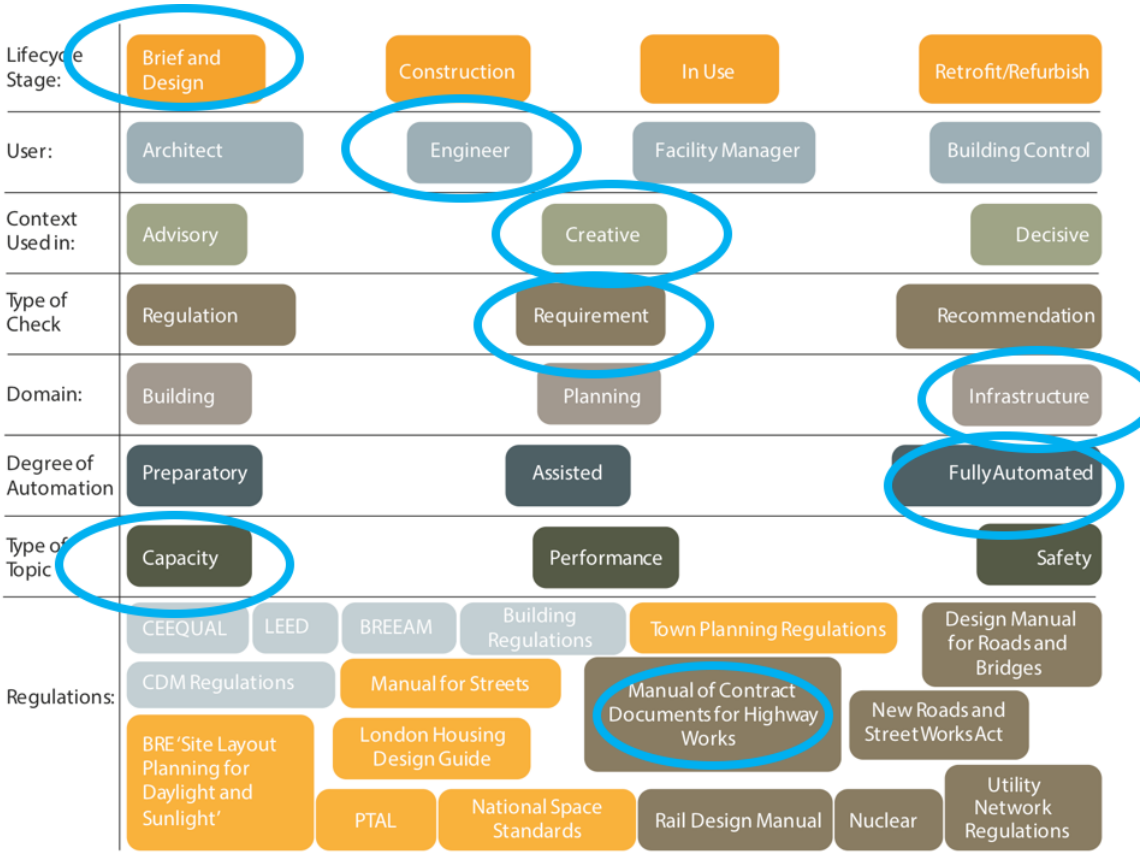

Figure 8 Scenario 2

In this scenario, the design engineer for a redesigned express way opens a message from a road authority confirming that the new 'Autonomous Vehicle Road Configuration Regulations (2025)' have now come into effect. Opening the current design in an appropriate road engineering application, the road junction object displays a message asking if the junction should be reconfigured to support enforced alternating give-way traffic flow. The angles of approach at each merging stream are re-configured to accommodate the new signage and signalling.

2.2. D-COM Conceptual Models

In order to motivate discussion in the area of digitisation of checking the conceptual process must first be understood. Figure 9 describes this process, based on research and the network's current experience.

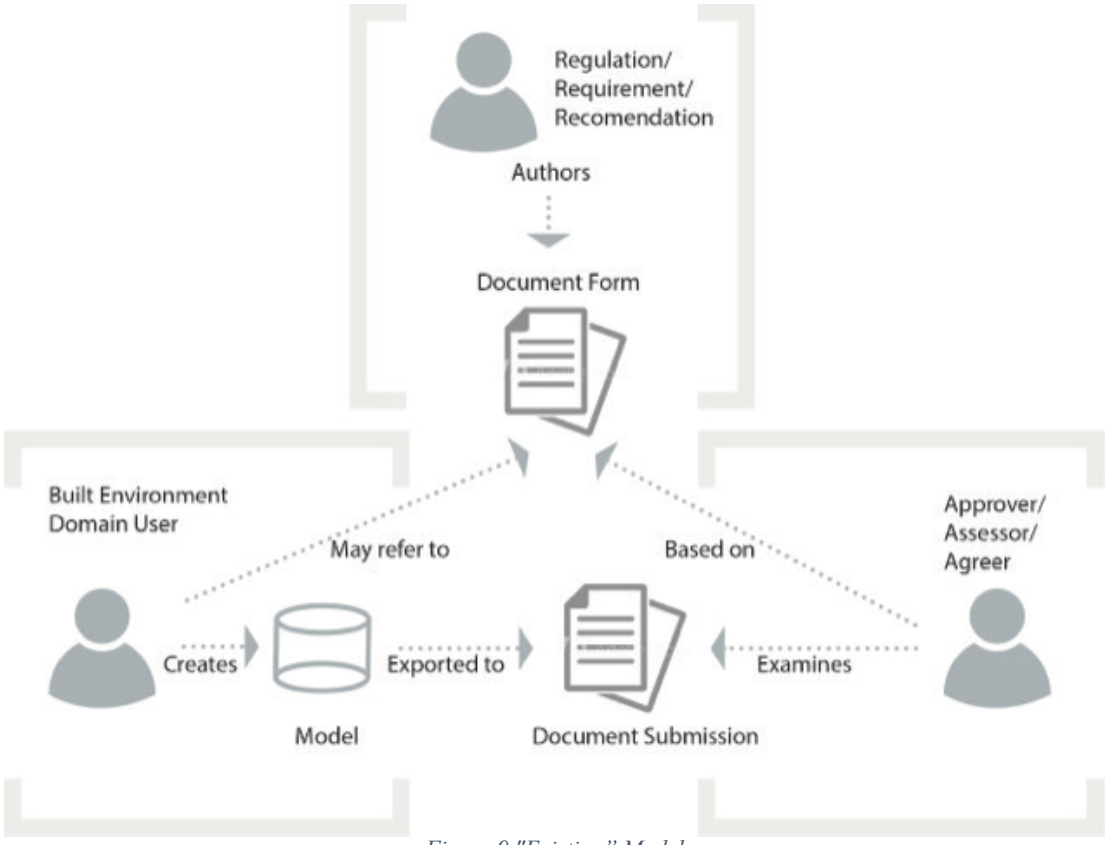

Figure 9 "Existing" Model

Firstly, authors specify the regulations, requirements and standards against which a built environment asset is to be checked against in a documented form. Then, subsequently, an actor within the built environment domain, requires that their work be checked against these regulations, requirements and standards. Then, an approved regulator will examine this document, against the documented form of the regulations, requirements and standards and come to a decision.

However, with the introduction of automation this process changes dramatically, as shown in Figure 10

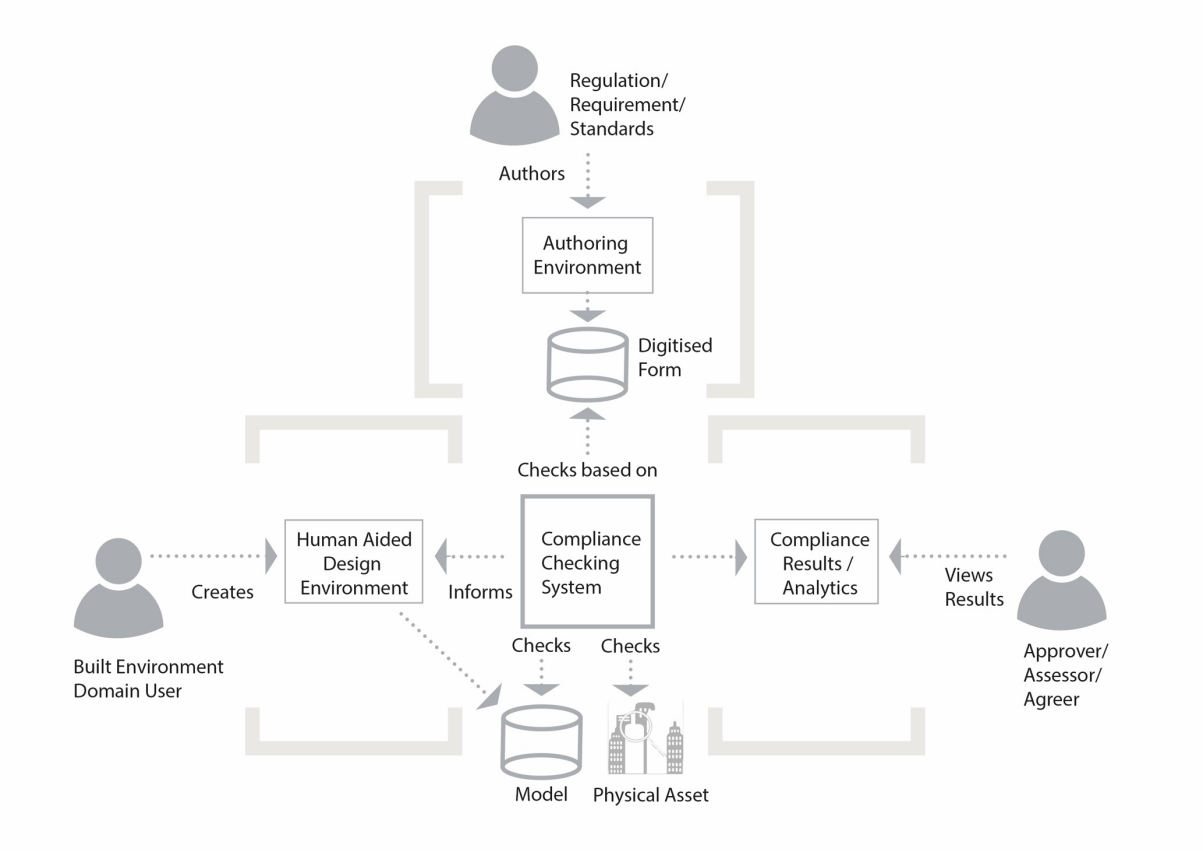

Figure 10 "Proposed" Digitisation Conceptual Model

In this new case, authors specify the regulations, requirements and standards against which a built environment asset is to be checked against either using an authoring tool that creates digitised regulations. Then, subsequently, an actor within the built environment domain, works using a human aided design package on a virtual model of the physical asset. This design package utilises the compliance checking system to automate aspects of the design and ensure the actor's work meets the regulations, requirements and standards.

This is then formally checked against these regulations, requirements and standards. To achieve this, the model is submitted to a compliance checking system. This compliance checking system, then (depending on the level of automation being achieved) either; (a) automatically provides a result, or (b) assist an approved regulator to come to a decision, by assessing some elements automatically. Additionally, compliance checking systems can manage the overall checking process and guide approved regulator through the process even if all decision making cannot be automated. The final element is the ability to automatically check, based on data collected (e.g. from sensors) the physical asset against regulations or requirements.

Thus, the following key changes between Figure 9 and Figure 10 are found:

- Regulations requirements and standards are stored in a digitised form from which human readable documents can be generated.
- Compliance checking systems can aid (or even remove the need for) approved regulator in making decisions by performing elements of the compliance checking automatically.
- Compliance checking systems aid approved regulator by managing the overall checking process (e.g. recording results, ensuring complete coverage of regulations) even if all decision making cannot be automated.
- Compliance checking systems also have the ability to check the physical asset (if it exists) against the regulations in addition to the virtual model.

These scenarios and conceptual models have been used to convey the goals of the D-COM network in our communications with the industry, and also as the starting point for developing a roadmap to drive forward the adoption of digitisation of regulations, requirements and standards.

3. Required Capabilities and Desired Market Forces

This section describes how the capabilities and market forces that formed the D-COM roadmap were elicited. Firstly, through the D-COM survey and then refined at our consultation event and interviews.

3.1. D-COM Survey

The D-COM survey consisted of 19 questions and was designed to fulfil two goals; (a) to test the "state of the nation" with regards to the acceptance of the automated checking against regulations/requirements/standards and (b) elicit a set of initial required capabilities and market forces. The survey consisted of a mix of open and closed questions to allow quantitative data to be collected regarding the state of the nation, but still allow respondents to express their views.

In the survey a set of initial desired capabilities (elicited via brainstorming within the D-COM network) was proposed to act as exemplars for respondents. These were:

- Shared open standards for regulation clauses.
- Artificial intelligence to interpret between regulations/requirements and proposals, such as natural language processing.
- Rule processes to track decisions and uncertainty.
- Brief and regulatory requirements to be contractually enforceable.
- Reduced costs for assessment.
- Ability to pre-check for compliance prior to formal submission.
- As proposed/designed and as built structured asset information (e.g. BIM) to be required for non-domestic projects.
- As proposed/designed and as built structured asset information (e.g. BIM) to be required for all projects.
- Strict legal responsibility for compliance.
- Primacy of structured asset information (e.g. BIM) over documentation and drawings for the purposes of compliance submission.
- Public right to see compliance assessments.
- Standard data and criteria for social, environment and economic impact assessments.

A full copy of the survey is included in Appendix A.

The survey was distributed widely through contacts of the network, CDBB dissemination and social media and a total of 60 respondents completed the survey. This section analyses the elicitation of capabilities/market forces, while the state of the nation is discussed in Section 6.1.

3.2. Elicited Required Capabilities and Market Forces

The initial use of survey responses was to elicit the list of the many of the activities that need to occur in order to achieve automated compliance checking. It became apparent early in this analysis that not all of these can be classified as new industry capabilities, rather they are changes in industry market forces that must be endued by either political decisions, new commercial arrangements and changing positions. Thus, this section adopts to definitions of capabilities and market forces described previously.

The elicitation of these capabilities and market forces took places in three stages, firstly the respondents views on the D-COM proposed capabilities were analysed. Secondly, the free text responses were analysed semantically and, finally, a list of capabilities and market forces was formulated based on this analysis.

Firstly, for the D-COM suggested capabilities, these were each rated on scale or 1-4 (where 1 is not required, 2 desirable, 3 highly desirable and 4 is essential). The average responses to each of these is shown in Table 2. This table shows that all have been rated as desirable or better, thus all of the D-COM suggest capabilities were retained.

Table 2 Survey Results - D-COM Capabilities

Rank	**Capability**	**Average Response**
1	Shared open standards for regulation clauses.	3.85
2	Ability to pre-check for compliance prior to formal submission.	3.46
3	Brief and regulatory requirements to be contractually enforceable	3.45
4	Rule processes to track decisions and uncertainty	3.36
5	Strict legal responsibility for compliance.	3.33
6	As proposed/designed and as built structured asset information (e.g. BIM) to be required for non-domestic projects.	3.26
7	Primacy of structured asset information (e.g. BIM) over documentation and drawings for the purposes of compliance submission	3.21
8	As proposed/designed and as built structured asset information (e.g. BIM) to be required for all projects.	2.85
9	Standard data and criteria for social, environment and economic impact assessments	2.83
10	Reduced costs for assessment	2.71
11	Artificial intelligence to interpret between regulations/requirements and proposals, such as natural language processing.	2.68
12	Public right to see compliance assessments.	2.38

Following this, semantic analysis was performed on the free text fields. This semantic analysis identified a series of influencing factors that appear in various frequency in responses to the survey. These are arranged into 1st, 2nd and 3rd order factors (where 2nd order factors influence 1st order factors and 3rd order factors influence second order factors). An example of this analysis is shown in Figure 11, but equivalent analysis was performed for all questions in the survey

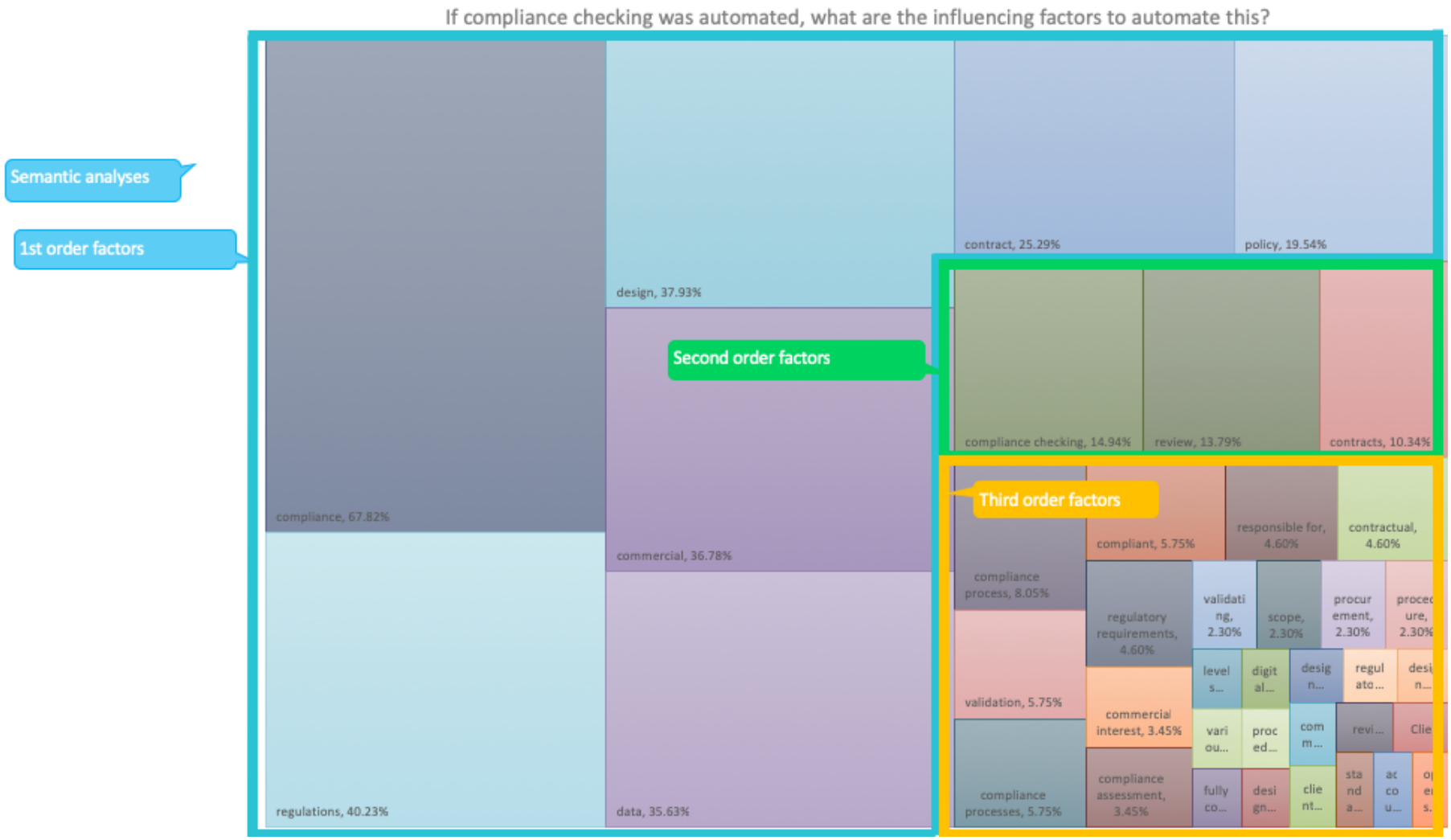

Figure 11 Semantic Analysis

The results of the semantic analysis, along with a holistic review of the free text feedback was then used to formulate a set of initial capabilities and market forces. These are described below, but how these were derived is shown in Appendix A.

Capabilities

- Definition of precise digitisable regulations.
- Standardised data models for regulatory compliance data defining required properties.
- Standardised APIs for compliance checking tools.
- Improved compliance checking process definition, standardisation and management.
- Generative design based on regulations/requirements.
- Linkage between requirements, designers and product suppliers and their data.
- Shared open standards for regulation clauses.
- Clear government direction towards automated compliance checking.
- Checking on as-built assets using calibrated instrumentation.
- New Business Models factoring in: (a) reduced costs for assessment, (b) faster turnaround for assessment & (c) ability to pre-check prior to formal submission.
- Artificial intelligence to interpret between regulations/requirements and proposals, such as natural language processing.
- Rule processes to track decisions, feedback, and uncertainty.
- Standard data and criteria for social, environment and economic impact assessments.
- Ability for software to be certified as performing “correct’ checking.
- Implementation of data “Chain of custody”.
- Implementation of Smart Contracts.
- Achieving wider awareness of the meaning automation of regulations, requirements and standards and its benefits.
- Checking software validation and certification.
- Structured product data standards.

Market Forces

- Increased investment in automated compliance checking.
- As proposed/designed and as built structured asset information to be required for all (or all non-domestic) projects and establishment of the primacy of structured asset information over documentation and drawings for the purposes of compliance submission.
- Increase professional development and training in compliance checking.
- Phasing out of negotiated regulations increasing the transparence of regulations..
- Cultural change to accept automated compliance checking.
- Establishment of a public right to see compliance assessments.
- Brief and regulatory requirements to be contractually enforceable.
- Implementation of a strict legal responsibility for compliance.
- Direct engagement to Ministry of Housing, Communities and Local Government building .regulation policy unit.
- Direct engagement with Building Regulation Advisory Committee.
- Developed green and white papers for presentation to government and establish funding .
- Establishment of dual automated and engineered paths.
- Policy for standard data and criteria for social, environment and economic impact assessments.

3.3. Validation of Elicited Capabilities/Market Forces through Consultation

To further refine the list of capabilities and market forces presented in the previous subsection, a stakeholder workshop was held. A total of 19 individuals attended the workshop including a mixture of D-COM members and external participants.

The event began with a presentation of the D-COM network, and our initial set of capabilities/market forces was presented as a "strawman" for the delegates to debate. To aid delegates these were divided into Technical, Commercial and Political themes. Discussion then began along the following lines:

- In small groups, delegates were asked to discuss the strawman and add their own thoughts to the ideas already put forward.
- The groups were then asked to plot out the paths we must take to get from the current landscape to the 2025 vision across technology, compliance and politics, bearing in mind this is only six years away.
- The next task was to take suggestions for the technology, commercial and political pathways and to discuss what the immediate next steps are: who needs to do what, by when?
- The final session was a free-ranging plenary discussion where the stakeholders could raise any further points, they wished.

Following the consultation, a detailed report was prepared (this can be found in Appendix C).

3.4. Interviews

To supplement the consultation event, and to capture the views of important industry figures that were unable to attend the event interviews were held with 8 individuals. Extracts from these interviews can be found in Appendix D.

The interviews served to verify findings and introduce small modifications to the results of the consultation. The views of these experts however, was extremely useful and some useful key points include:

- Any automated checking system should aim at producing guidance rather than totally autonomous compliance.
- There is already some interest forming in Government Experts Group and D-COM could leverage upon this.
- There is a view that automation may be more practical in conventional projects rather than in multiuse-use, complex geometry projects.
- Automated regulatory compliance checking requires government commitment and stewardship to succeed.
- An alternative to the UK developing its own approach is the risk of external disruption from outside of the industry.

4. Current Research Landscape

This section presents our analysis of the current landscape. Three main topics are identified for this review; (a) the automated management of the compliance checking process, (b) the digitisation of regulations/requirements/standards, and (c) checking of digitised regulations/requirements/standards against structured asset data (models). This review describes current academic and industrial implementations of the automation of compliance checking (both complete and partial implementations) as well as existing non-technical work that is being undertaken within the industry (in parallel to D-COM and in the past) that is working towards the automation of compliance checking. The detailed analysis is presented in Appendix E, but a summary is presented in Table 3. As part of this summary the D-COM network has also assessed the maturity of each result on the following scale; (a) Research, (b) Proof of Concept, (c) Industrialisation (e.g. preparation for commercialisation), (d) Commercial.

It should also be noted that this table also lists several software packages that appear to perform checking of various kinds, but, upon detailed analysis, were found to not perform any checking of regulations or requirements, these has been left in the table to inform readers that may come across these software packages but the "in-scope" column verifies if the item concerned performed checking

of regulations/requirements/standards. It should be noted that this review focuses solely on work in the built environment domain, and not on work compliance checking work in other domains.

Who	Ref	Last Active	Verified In-Scope	Process Management	Digitisation	Checking/Generating	Interoperability with Asset Data	Status
AEC3 Require1	1.2.14	Available 2012 onwards	Y	User Mark-up of regulations or requirements. Reports rules back as table and tree. User developed dictionary. Set up and test project of federated models. Displays overall result and causes. Notifies team by email. Solicits further information if needed	Independent rule engine tracking true, false, unknown. Accelerated heuristics	Checking performed based on rules	Inputs - html/rase and ifc/bim. Generates dmn, basic code, ifc constraints.	Industrialisation
Autodesk Model Checker	1.2.3	Currently freely downloadable (https://www.biminteroperabilitytools.com/modelchecker.php) Model Checker and Model Checker Configurator are part of Autodesk BIM Interoperability Tools.	Y	Set up Revit plugin by selecting a checkset (custom or downloaded from checkset library) and refining which checks to run, specify model(s), run check, visualise results in report GUI, report GUI can link to Revit modelling view dynamically, amend model in Revit, run check again etc..	GUI-based model checker configurator, predefined check sets for some regulations available from web page	Custom checks can be on model, annotative, location, datum elements or views, but can also be on model integrity.	Revit	Commercial
BIM Direct	1.2.6	Currently available (https://www.bimdirect.com)	N	Web portal for employer's information requirements management. Create project, assign tasks to collaborators, create EIR from PAS1192-compliant template, edit project collaboratively, issue tender	Intrinsically compliant with PAS 1192 specifications for collaborative working and information and ISO 19650 standard for BIM-based information management about construction works	No code checking. Maintains EIR's compliance with PAS 1192 and ISO 19650	BIM level 2, digital project management tool	Commercial

BriefBuilder	1.2.5	Currently available (https://www.briefbuilder.com/for-whom/)	Y	Define requirements at building/room level, link requirements to BIM objects, validate against client requirements	GUI-based requirement captures and linkage with 3D BIM objects	Checks models against client requirements	IFC, Revit	Commercial
CARS	NA	https://www.youtube.com/channel/UCFZDP2rDosnlnfg7qZNzikA?view_as=subscriber	Y	Provides ability to draft structured requirements, review, publish and manage regulatory documents, from document and clause level. Allows full versioning and tools to manage audit trail of regulation changes.	. Also will provide tools to digitise regulations – i.e. convert the written information in to machine readable (xml data model) initially with substantial manual intervention for testing but with intention to use natural-language programming. Specifically used for the production of the DMRB (Design Manual for Roads and Bridges) by Highways England.	Does not directly execute rules but will shortly be able to output rules (through API) in machine readable formats that can be executed by road design packages.	As previously, does not directly interface with asset data but can output rules in machine readable formats that can be used by road design tools	Internal use by Highways England

DEMplus	1.2.9	Currently available (http://www.orekasolutions.com/demplusfornuclear/demplusfornuclear_en.html)	N	User inputs nuclear process scenario and involved physical objects via 3D models (including IFC), then DEMplus dosimetry, cutting, collision and kinematic modules are used to provide (possibly immersive) 3D simulation. The tools reports costs, duration, waste and radiation dose.	No code digitisation per se. DEMPlus integrates the ALARA (as low as reasonably achievable) approach to radiation protection	Safety of nuclear processes is evaluated by a human assessor through the reports produced by 3D simulation from DEMPlus	IFC and generic 3D formats	Commercial
DesignCheck	1.1.3	2010 publication from David Greenwood (http://nrl.northumbria.ac.uk/6955/)	Y	IFC models are translated into DesginCheck object schema using an EXPRESSX-defined transformation. Different rule schemas are used according to the design stage. Checking results are text based.	Predefined rules for the Australian building code, written using EDM	DesignCheck selects the subset of regulations to check against according to the design stage. EDM-based object rules.	IFC	Research
dRofus	1.2.2	Currently available (https://www.drofus.no/en/download/)	N	Capture user requirements using GUI. Define early-phase requirements. Import room data from Excel, Revit, ArchiCAD, and IFC. Define additional dRofus room parameters.	No code digitisation per se.	No code checking. Room data validation against user requirements using IFC.	IFC, Revit, ArchiCAD	Commercial
GliderBIM	1.2.8	Currently available (https://gliderbim.com/#licensing)	Y	collaborative lifecycle asset information management	GUI-based validation ruleset editor	automated model validation against rulesets	IFC	Commercial

Jotne EDMmodelchecker	1.2.2	Not advertised as a feature of EDM model server anymore (http://www.jotneit.no/express-data-manager-edm)	Y	Define rules and constraints as an EXPRESS schema, import STEP/IFC file, validate against schema, visualise violations in HTML format (http://jotne.custompublish.com/index.php?id=512200&showtipform=1&cat=78897)	Rules written using Express and ExpressX languages	Built on Jotne's EXPRESS Data Manager, EDM SDK provides bindings for C, C++. .Net, Java and Visual Basic (https://conwik.jotne.com/display/EDM/EDMsdk)	IFCSTEP, IFC and ifcXML	Previously Commercial
LicA	1.1.4	2013 publication from João Poças Martins (https://doi.org/10.1016/j.autcon.2012.08.008)	Y	GUI application LiCAD can be used to interact with LicA. Users can import/design hot and cold piping network models in the 3D view. Checking results are overlayed over the 3D models using colours.	Predefined rules for Portugal water distribution system regulations, developed in T-SQL for integration in SQL-server database	LicA database can be queried by software tools using ODBC, including results of checking routines.	The authors proposed a workflow in which the first step is automated conversion from IFC to LicA internal object model, but no actual implementation?	Research
NBS Toolkit	1.2.7	Free-to-use online tool (https://toolkit.thenbs.com)	N	PAS 1192-compliant collaborative BIM management platform.	Intrinsically compliant with PAS 1192 specifications for collaborative working and information.	No code checking.	BIM level 2, digital project management tool	Industrialisation
PlanX	1.2.4	Currently in beta and not publicly	N	Councils design their instance of PlanX with OpenSystemsLab (during this stage planning policies are converted into	Predefined checking rules for	In addition to web-based GUI, PlanX also provides an API for third-party software	None. Local authorities	Industrialisation

		available (https://www.planx.uk/About)		software code), then instance of PlanX is deployed. Councils can decide to host the instance themselves.	UK local planning policies	tools (https://files.cargocollective.com/c233603/Planx_doc_1.6.1.pdf)	can use PlanX to generate question-based web applications.	
RegBIM	1.1.1	2015 publication from Tom Beach (https://doi.org/10.1016/j.eswa.2015.02.029)	Y	Ability to submit IFC files, specify missing data and produce report in a tree like diagram. Simple Integration with Bentley systems software performed.	Mark-up building regulation documents using RASE method	Checking against regulations specified in RASE using a rule-based approach.	IFC	Proof of Concept
SimpleBIM	1.1.12	Currently available (http://www.datacubist.com/buy-it/)	N	Import IFC file, validate IFC data, trim, edit, enrich, merge IFC resources, relocate parts of models, export new IFC file.	No code digitisation per se. Validation and editing scripts can be created using predefined automation templates or the programming API.	No code checking. Data validation according to target use of the IFC model. Can be used to clean up and/or enrich IFC models prior to checking with a third-party IFC-enabled tool.	IFC	Commercial

Singapore {CORENET} e-PlanCheck	1.2.2	Integrated with currently active Singapore's CORENET e-Submission System (https://www.corenet-ess.gov.sg/ess/)	Y	Prepare BIM models in accordance to CORENET e-submission code of practice, use e-submission software tool to create a project, export application form, submit application form online with BIM models, CORENET can check planning approvals, building plans approvals, structural plans approvals, temporary occupation permit, fire safety certificate, certificate of statutory completion	Building codes implemented using FORNAX development platform (C++)	Checking by proprietary expert system by Nova (ePlanCheck http://www.nova-hub.com/e-government/). Online trial for a limited set of Singapore regulation clauses available at http://www.fornaxcloud.com.	Architectural, structural or MEP models from Revit, ArchiCAD, Bentley, Tekla	Previously Commercial
SMART review	1.2.3	Currently available (https://smartreview.biz/home)	Y	SMARTreview APR for architects to check compliance of building design, SMARTreview CPR to generate planning application for the regulatory authority to review (from APR's results)	Predefined checking rules for the International Building Code	Produces detailed textual checking review in navigable HTML (https://smartreview.biz/example_apr)	Revit	Commercial

SMARTcodes	1.2.10	Last available from ICC website in 2007	Y	Mark up textual regulation documents using SMARTcodes Builder. Mark ups are translated into an IFC constraint model, which can then be used as a rule base in an IFC validation software tool (http://www.aec3.com/en/downloads/BuildingRegulations.pdf).	Use International Building Codes in XML format or mark-up building regulation documents using early RA(S)E method	Performs code checking based on specified rules	IFC	Industrialised
Solibri Model Checker	1.2.1	Currently active (https://www.solibri.com/download-solibri-model-checker-trial/step=1)	Y	The embedded checking process is strongly based on practical needs: 1) Import and coordinate various IFC files 2) customizable structuring of multi-disciplinary models with the help of rule-based classifications 3) Validation of various customized qualitative aspects on the basis of the specified generic structures (e.g. IFC validation, component dimensions, spaces, clearance of openings...) according to best practices or custom rulesets 4) Review validation results and decision making in 3D viewer (can be combined with customized information take off as plausibility check) 5) Communication and dissemination of identified problems	50+ generic Rule Templates which can be combined individually to rulesets using the GUI-based Ruleset Manager. Numerous sample rulesets are delivered as standard content. No programming knowledge required for the application (https://www.solibri.com/learn/creating-rulesets-in-smc-v9-8)	Multi-platform Java-based GUI and rule engine. The newly released Solibri Developer Platform (SDP) allows customers to create customized Rule Templates. For this, programming knowledge is required. (https://www.solibri.com/news/interview-with-pascal-loisel)	IFC	Commercial

Solvassure	NA	https://www.solvassure.com/	Y	Platform that is based around pre-defined compliance checks to activity owners from a rules library, presenting exceptions to nominated stakeholders in real time, with full accountability.	Licensed by the FCA and the PRA. Can include any predefined checking rules from regulations and standards	Gateway enabled system disallowing departures from the regulation compliance.	Any structured database system	Commercial
UpCodes AI	1.2.13	Beta version download (https://up.codes/ai)	Y	Run code check on current Revit model, visualise list of code violations, display selected violating elements in floorplan/3D view	Predefined checking rules for a variety of US state building codes.	Does not impose any constraint on how the Revit model should be created (http://www.aecbytes.com/feature/2018/CodeCheckingUpdates2018.html)	Revit	Industrialisation
usBIM.code	1.2.11	Currently available (https://www.accasoftware.com/en/bim-management-software)	N	Use the online usBIM.platform to manage BIM assets from different disciplines, use usBIM.code to check BIM models. Import IFC model to CodeMaker, add data required for checking with the visual editor, export the IFC file with new data.	(3D) GUI-based editor to add required IFC properties and to create rules (CodeMaker)	Checks against user-defined project requirements. Italian page of the tool seems to give many more details (https://www.acca.it/bim-model-checking-software)	IFC	Commercial
Xinaps	1.2.3	VERIFI3D software currently available (http://verifi3d.com)	Y	Visualise analysis results within Revit (KPI summary, floorplan/3D visualisation of passed/failed elements.	Predefined checking rules for a variety of local accessibility and fire safety standards/regulations	Pathfinding algorithm parameterised by accessibility profiles (e.g. pedestrian, wheelchair, shopping cart, hospital bed...). Similarly egress time calculation algorithm.	Revit	Commercial

Table 3 State of the Art Review Summary

5. D-COM Community Building Activities

This section summarises the D-COM community building activities and list the centre of competence that have been identified throughout the duration of the network.

Over the course of the D-COM network activities a significant number of individuals/organisations have engaged with the network in a variety of ways, which are summarised below. Over the course of 6 months the D-COM network has:

- Grown to include 14 organisations.
- Held 4 workshops for network members.
- Established a website at http://www.dcom.org.uk
- Established a social media presence on twitter and LinkedIn.
- Conducted a survey that received 60 responses from industry professionals, of which 53 of which requested further involvement with the network.
- Held a consultation event attended by 16 organisations and interviewed 6 more.
- In total 84 individuals (not including network members) have asked to be kept informed of network activities in the future.

5.1. Centres of Competence

Throughout the activities of the D-COM network, a set of centres of competence in the area of automated checking against regulations/requirements have been elicited. These have been elicited through several means; (a) network members, (b) direct contact with the network through consultation/interviews and, (c) including of a significant amount of their work in the state-of-the-art review. A list of these centres of compliance is found in Table 4

Table 4 Centres of Competence

Organisations	**Relevant Experience and Current Activities**
AEC3	AEC3 has been implementing, developing and researching automated compliance of regulatory, requirements and recommendations since 1998, culminating in the development of AEC3 require1.
Brydenwood	Bryden Wood are a multidisciplinary consultancy of Architects, Engineers and Data specialists. In addition to data analytics which inform platform-based designs and design for manufacturing technologies. Bryden Wood are working to unlock the power of big data and transform the way the construction sector interfaces with information, developing data tool kits which automate the design process, and interfaces including AR and VR which help organisations understand and engage with their data.
Cardiff University	Cardiff University has been involved in research relating to the automation in compliance checking since 2012. They were the technical lead in the RegBIM project and led the development of a complete methodology for regulatory compliance (from specification of regulations by regulation experts, to data mapping between regulations and the IFCs, to rule based execution). Since the RegBIM project this technology has continued to be developed incorporating the latest advancements in semantics.

MACE	Mace is an international construction and consultancy company founded on the 'pursuit of a better way' of delivering the built environment. In recent years we have helped large public and private sector clients in digital transformation programmes, initially as part of the transition to BIM Level 2, but now more directly at each of enterprise, programme and project level. As part of this digitisation, we are helping clients explore the opportunities of automation, which includes automated checking and validation, and smart asset management.
Process Innovation Forum (PIF)	PIF is an innovation platform where challenges are matched with innovative solutions. It scouts for ideas and innovations and graduates these within the AECO. PIF specialises in innovation management, discovery projects, developing business from innovations, industrialisation of products and processes and scaling to market. It provides business support and diligence for new innovations.
Solibri	With its product portfolio, the Finnish software vendor Solibri has been standing for robust tools in the area of BIM-based quality checking and assurance (QA/QC) for almost two decades. The main product Solibri Model Checker (SMC) offers various rich and flexible technical features as well as a robust workflow to cover the real-world requirements regarding when it comes to the qualitative assessment of building models. Main strengths of SMC are: (a) Relying on openBIM Standards, (b) Define the Quality Assurance Process as you see it, (c) Customizable down to the last Detail and (c) Partner for Research and Innovation across the Globe
University of Central Lancashire	The Grenfell-Baines Institute of Architecture, University of Central Lancashire has been in conducting research on innovative approaches in design and Health and Safety in construction industry and helped SMEs in adopting BIM to enhance their business.
University of Strathclyde	The Department of Architecture at the University of Strathclyde has research strength in design and construction informatics through sustainability engineering for the built environment. The main focuses of relevant research initiatives are to adopt digital engineering concepts and tools in both research and learning to improve the dependability of buildings across various stages of RIBA Plan of Work, and to engage in new multidisciplinary research into BIM for the sustainable built environment.
Northumbria University	Northumbria University has a strong reputation in the use of digital technologies for construction, with a particular focus on collaborative research with industry partners and projects funded by InnovateUK and its forerunner, the Technology Strategy Board. An example is its role in the development of the NBS Digital Toolkit, one of the so-called ‘8 pillars of Level

	2 BIM'. The University is joint owner of BIM Academy, winner of the 2017 Times Higher award for 'Most Innovative Contribution to Business-University Collaboration'.
HKA	HKA is the largest provider of construction claim and dispute resolution services globally. HKA advise on how digital ways of working can address common points of failure and have been commissioned to undertake the most comprehensive BIM assurance review of the UK supply chain to date, advise the Mexican Government on national digital transformation, and investigate the legal opportunities and blockers of emerging digital technologies for i3P.

In addition to these organisations, we came across other organisations, that appear to have competencies in this area. These are:

- Briefbuilder
- Upcodes
- SmartReview
- Xinaps
- Autodesk
- University of Aukland
- University of Porto
- Purdue University
- University of Ilinois

6. D-COM 2025 Roadmap and State of the Nation

This section documents the two key outputs of the D-COM network. The state of the nation analysis and the D-COM 2025 roadmap. The state of the nation analysis is draft from the results of the D-COM questionnaire (described in 3.1 and Appendix A). The D-COM 2025 roadmap was formed based on analysis of questionnaire results, the consultation event and interviews.

6.1. State of the Nation Analysis

A total of 60 respondents answered the questionnaire. The breakdown of their claimed job classifications is shown in Figure 12. This shows that there was a reasonable distribution of individuals in managerial positions, consultants, academia or those jobs involving BIM. The key disappointment was the relatively low number of regulation professionals (only 6) completing the survey. However, despite this we feel the survey has sufficient responses to be indicative of the views of the elements of the industry that use regulations (i.e. those that must design/maintain assets to be compliant with regulations).

Figure 13 shows the answers to the key question of questioning respondents as to what level of automated checking they thought was possible by 2025. Respondents were asked to rate this from three viewpoints; technological, commercial and politically. They were asked to rate automation on the following scale:

- 0 - No Automation: The current document and drawing based procedures are adequate
- 1 - Automated Information Exchange: Automating submission of project information for regulatory compliance
- 2 - Automated Validation: Automating the checking of information for completeness prior to compliance checking.
- 3 - Partial Automated Assessment: Automatic assessment of some key regulations.

- 4 – Automated Assessment: Fully Automated assessment but requiring final human approval.
- 5 - Full Automation: Fully automated compliance checking.

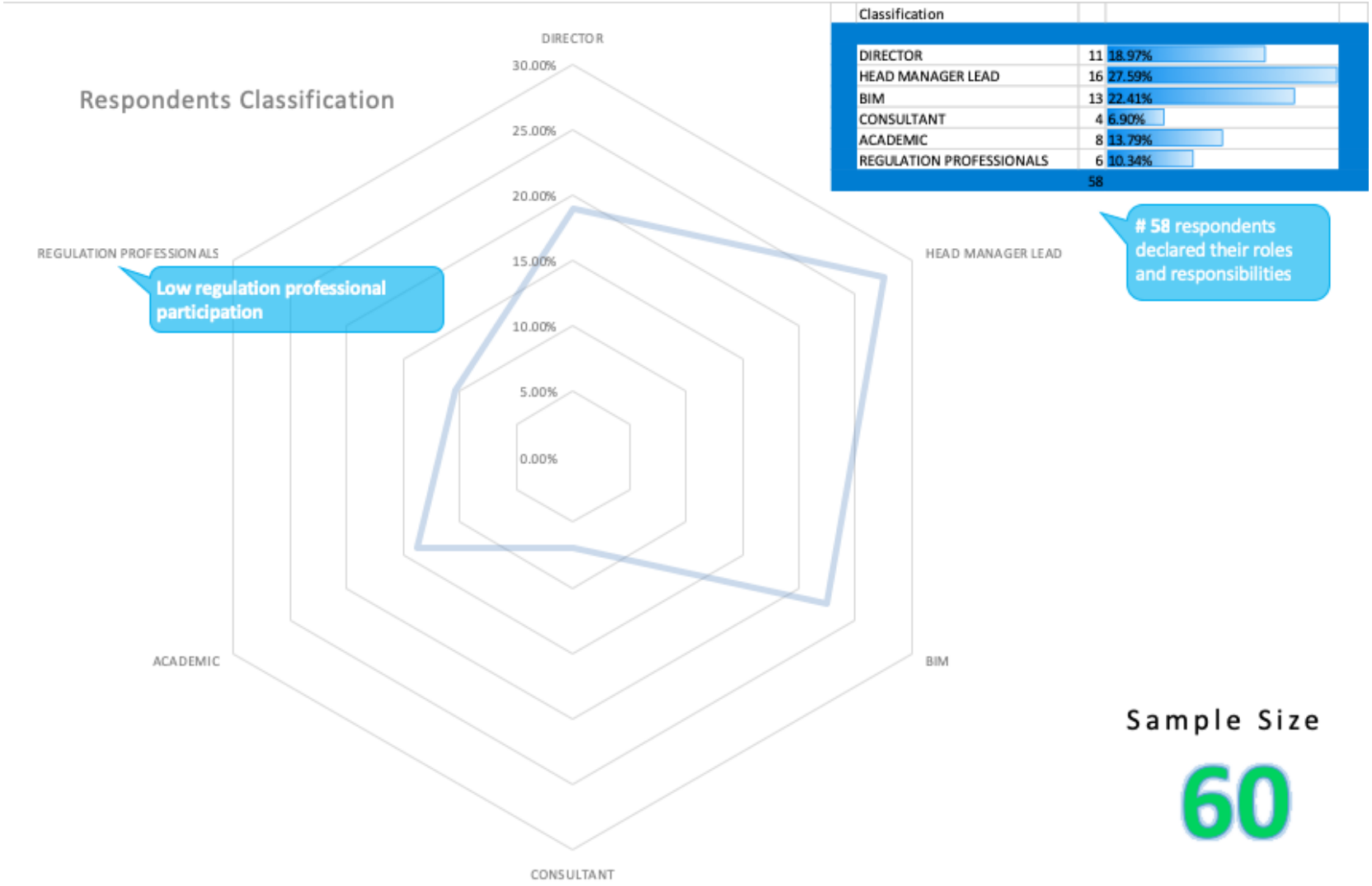

Figure 12 Respondents Classification

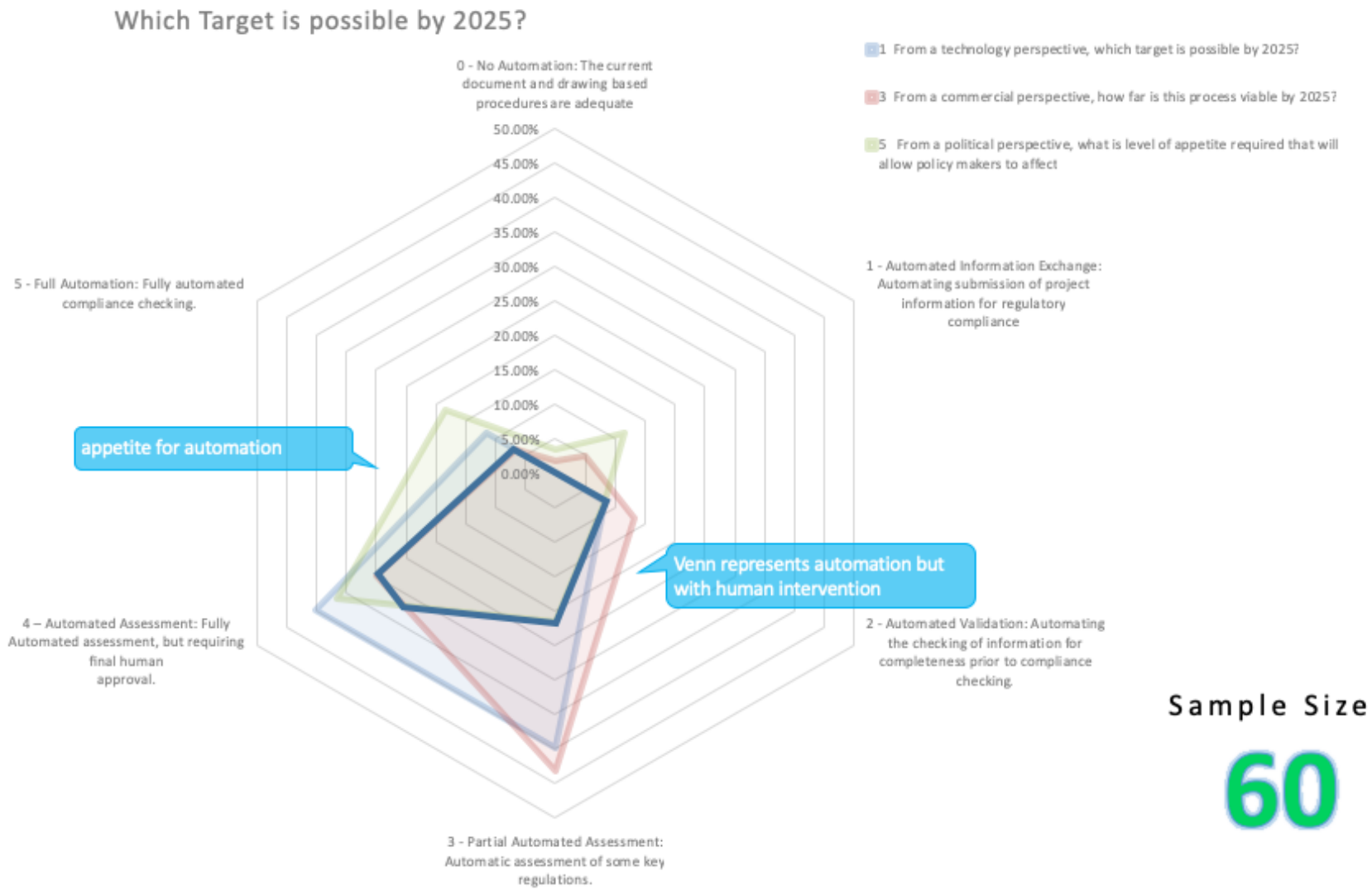

Figure 13 what target is possible by 2025

Overwhelmingly respondents indicated that automation was possible, with the vast majority of respondents believing some level (partial of automation with human oversight) are achievable by 2025. Detailed breakdowns of the responses are shown in Table 5.

Table 5 Automation Responses

Rating	Technology (%)	Political (%)	Commercial (%)
0 - No Automation	0.0%	3.3%	1.7%
1 - Automated Information Exchange	0.0%	11.7%	5.0%
2 - Automated Validation	8.3%	8.3%	13.3%
3 - Partial Automated Assessment	40.0%	21.7%	43.3%
4 – Automated Assessment	40.0%	36.7%	30.0%
5 - Full Automation	17.0%	18.3%	6.7%

These responses have shown us that there is a definite appetite within the industry for automation and that this automation is achievable by 2025. However, as a cautionary note, the responses were very clear that full automation (without human intervention) is not desirable, nor possible within this timescale.

6.2. D-COM 2025 Roadmap

This section describes D-COM 2025 roadmap which has been developed based on analysis of questionnaire results, the consultation event and interviews.

The starting point for the D-COM roadmap is a standard innovation product/process development framework. This framework describes the stages that development of innovative product/process must go through. The framework on which the D-COM roadmap is based on is shown in Figure 14

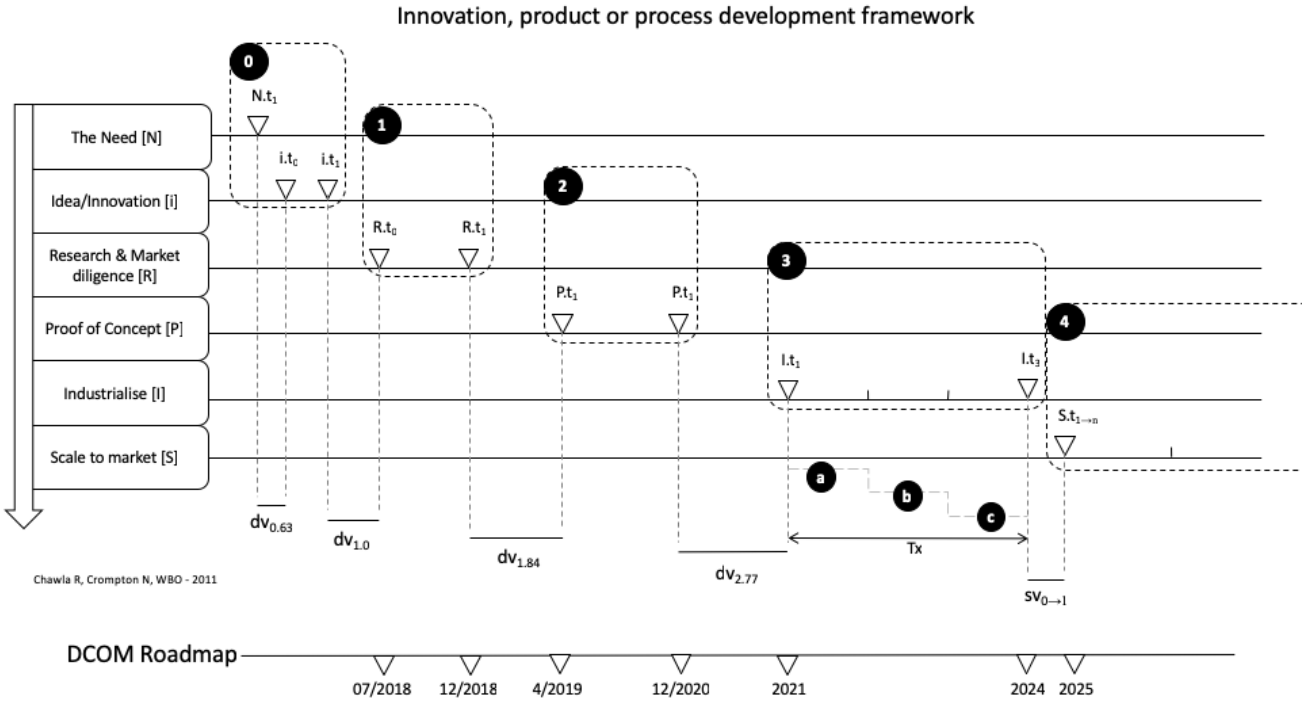

Figure 14 D-COM Roadmap Framework (Chawla R, Crompton N, and WBO – 2011)

More specifically, in Figure 14 the following stages are outlined:

0- Gestation of idea or innovation against a need or a market void
1- Commitment to research and market diligence

2- Development of pilot or proof of concept
3- Industrialisation of pilot or proof of concept. Subdivided into three sub-stages:
    a. building of product or process to 90% of the finished article
    b. trialling and testing of the product or processes - BETA
    c. refining and readying the product or process for scaling
4- Scaling of industrialised product or process

Additionally, in Figure 14 the following terms of introduced

- **dv** - development void: is the decision and transitioning time between core activities during the development of an idea from gestation to industrialisation
- **sv** - sensitivity void: is the determination period that takes the product or process from its industrialised state to scale to wider industry. The period is usually set as 1 year. The threat of market forces or readiness to launch if greater than 1 year carries a risk of stalling due to other actors in the market or loss of maximum benefit or loss of consumer interest.
- $dv_{1.0}$ transition factor: the transition period between the gestation stage [0] and research stage[1] is referred to as 1.0 and forms the basis of time factors derived for other transition periods. e.g. if the actual time period between stage [0] and [1] was 50days, then using the factors dv0.63 would be 50 x 0.63 = 32days. (see Note 1)

Note 1: the factors have been derived from >6k projects using this framework by The World Bank Organisation

Thus, based on this development framework, the capabilities elicited by the network have been categorised into technical, commercial, political and prioritised according to the staged within the development framework. In addition, a series of market forces have also been elicited. The capabilities that make up the D-COM roadmap are shown in Figure 15 and Figure 16. In these figures the colour green represents technical capabilities, orange political capabilities and blue commercial capabilities. The overall roadmap is described in full in Table 6.

In addition to the capabilities documented in the roadmap we also identified a series of market forces documenting changes to direction/attitudes within the built environment sector that must be achieved for automated checking. These market forces as listed below:

- Government direction towards automated compliance checking effectively communicated.
- Required cultural change to accept automated compliance checking.
- Investment in automated compliance checking.
- Policy and transparent rules to demand chain of custody for all materials and associated data.
- Structured data for designed and built assets as opposed to documents and drawings submissions to become compulsory.
- Regulatory requirements become contractually enforceable.
- Open access building regulation clauses/standard clauses.
- Establishment of a public right to see compliance assessments - Transparency and metrics demonstrating compliance and non-compliance.
- Implementation of a strict legal responsibility for compliance with regulations and standards.
- Phasing out of negotiated regulations and increasing the transparency of regulation compliance.
- Creation of an enforcement regime for changes to assets.

It should be noted that there is no mention of security implications and mitigation of risk around digitisation of detailed model – as, in our view, this a key issue that underpins every aspect of digitising the built environment. Secondly, we have no specific mention of proof of concept prototype development as a capability in Table 6, this is because this is represented as part of our overall development framework (Stage 2) and **absolutely key** to the future development in this area.

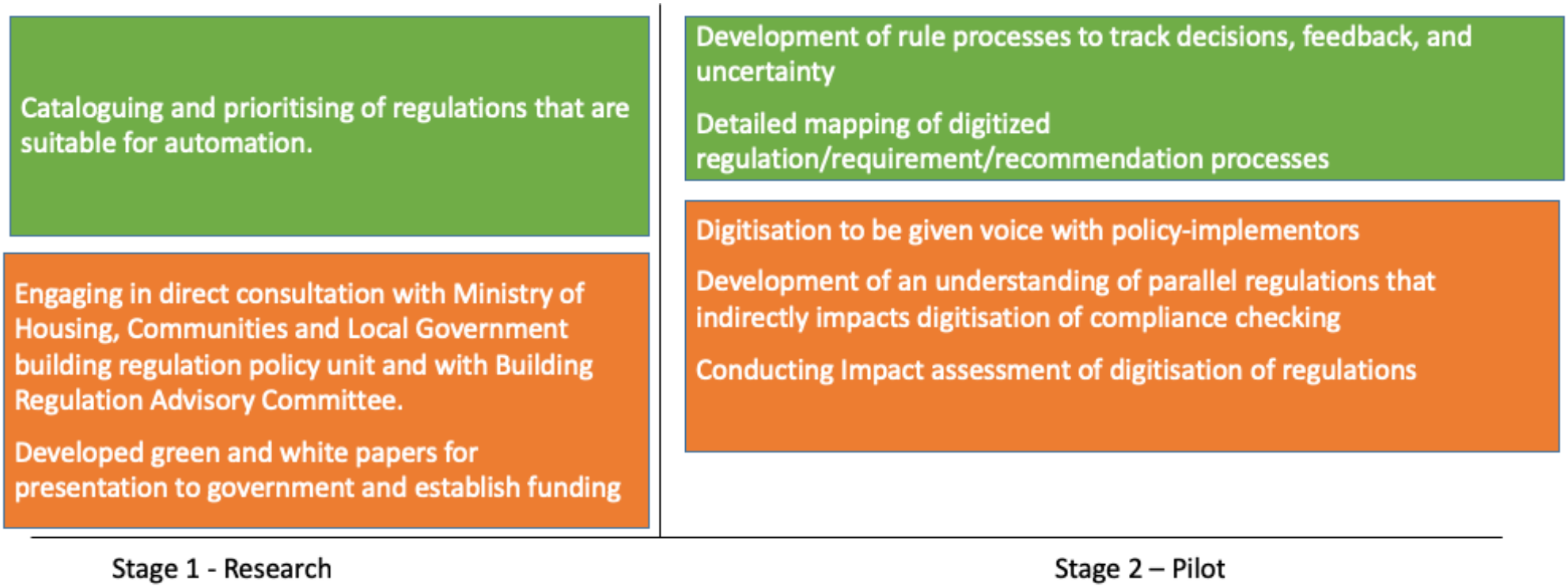

Figure 15 D-COM Roadmap Stages 1-2

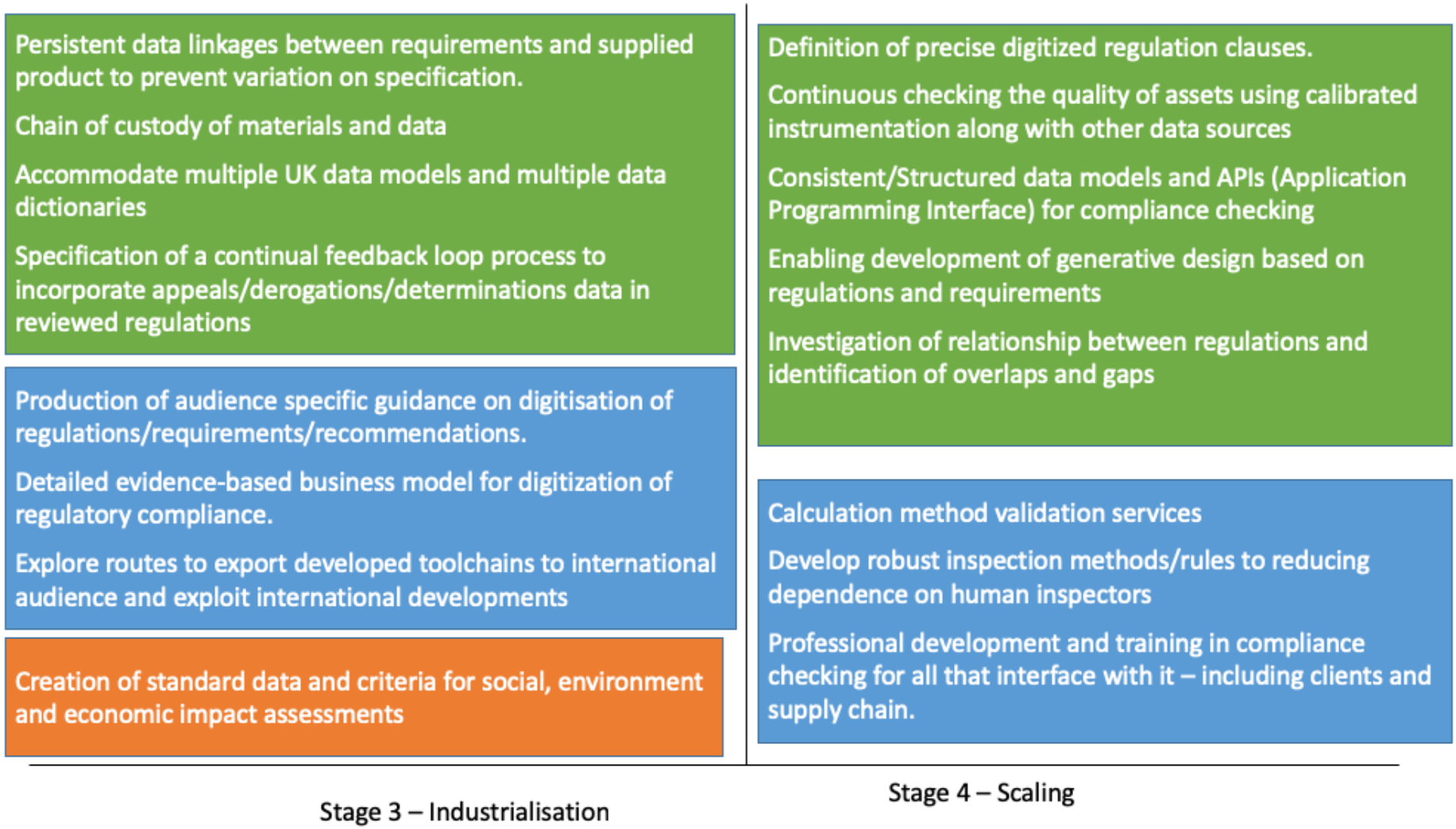

Figure 16 D-COM Roadmap Stage 3-4

Capability	Rationale and Drivers	Development Stage	Enabling Technologies and Behaviours	Barriers to development or adoption	Applicability for case study across D-COM scope	Suggested Research Needs
Technology						
Cataloguing and prioritising of regulations that are suitable for automation.	Determining what regulations can currently be automated is a key pre-requisite. Additional automation must be prioritised.	1	-Engagement from the different domains	-Lack of engagement from policy setters and implementors. - Lack of open access to regulations.	All	Hierarchy of regulations with priorities
Development of rule processes to track decisions, feedback, and uncertainty	Development of compliance checking processes that are able to deliver the required traceability, feedback methods to allow for the requirements of checking at various points in the asset lifecycle.	2	-Existing rule engine/reasoning technologies -Link with work of uncertainty network	-Lack of a perceived market.	All – specifically when performing checking in a “pre-check” capacity.	-Adaption of existing recognised rule engines/reasoners to support built environment requirements

Detailed mapping of digitized regulation/requirement/standards processes	Development of process map of the industry consider automated compliance checking. Phased to consider steps toward adoption.	2	-Engagement from the different domains	-Resistance to change -Lack of political buy-in -Trouble engaging with policy makers/implementors	All	-Development of process through large scale consultation.
Persistent data linkages between requirements and supplied product to prevent variation on specification.	Data linkages to prevent use of replacement products within an asset (during construction or in-use) from invalidating compliance with regulations/requirements	3	-Creation of authoritative sources and data formats for product data. -Appropriate processes to allow for allow for require substitutions to be managed without jeopardising compliance	-Lack of consistent adoption of use of product data across industry. -Cultural change in challenging acceptableness of un-necessary substitutions	All	-Development of processes to manage substitutions within a framework of compliance checking.
Chain of custody of materials and data	Technologies to support the capturing of chain of custody for materials and their data	3	-Existing product data standards	-Aspects of product lifecycle do not have widespread adoption of digitisation	All	-Ability to represent chain of custody within product/asset data models in an authoritative way.
Accommodate multiple UK data models and multiple data dictionaries	Enable checking tools to support multiple dictionaries and data models	3	-Existing built environment data standards/vocabularies	-Variety and inconsistency of data models/vocabularies currently used.	All	-Creation of mappings of controlled language

Specification of a continual feedback loop process to incorporate appeals/derogations/determinations data in reviewing regulations	Defining a process to properly manage reviewing of regulations based on innovations in design	3	-Commitment to consistent processes	-Resistance to change from industry elements that rely on current appeals/derogations/determinations process	All – specifically for design stage of lifecycle	-Consultation into development of fit for purpose process
Definition of precise digitized regulation clauses.	In order to be digitizable regulations must be available for analysis and rewriting so as to reduce the need for interpretation.	4	-Engagement of policy makers and implementors.	-Lack of engagement from policy setters and implementors. -Legal issues with owners of regulations	All	-Methodology and supporting tools to support drafting of digitizable regulations. -Methodology and supporting tools to allow digitisation of human readable regulations.
Continuous checking the quality of assets using calibrated instrumentation along with other data sources	Provides the ability to determine if physical assets comply with regulations/requirements throughout their lifecycle, without the need for extensive human inspection.	4	-Data collection technologies i.e. photogrammetry, LIDAR scanning, IoT devices - Widespread deployment of these technologies -Automated analysis of data collection and comparison to virtual model of assets and regulations/requirements.	-Collection and robustness of data collection technology. -Lack of confidence in technology solutions -Resistance to change	All - specifically construction and in-use stages of asset lifecycle.	-Studying applicability and selecting appropriate data collection technologies -Developing ability to automatically process collected data and performed

						compliance checking on it.
Consistent/Structured data models and APIs (Application Programming Interface) for compliance checking	Development/improvement of APIs to allow widespread interface with compliance systems	4	-Current IFC and supporting open standards	-Inconsistencies in support of open standards in software	All	-Specification of compliance checking API
Enabling development of generative design based on regulations and requirements	Development of approaches to automate the design of assets based on regulations/requirements	4	-Existing automated design tools	-Acceptance of use of automatically generated designs in some sectors	All – specifically design phase in asset lifecycle	-Achieving explicit connection of generative design tools to building regulations and user requirements.
Investigation of relationship between regulations and identification of overlaps and gaps	Utilisation of digitised regulations to perform details analysis of regulatory landscape	4	-Digitised regulations	-Current UK regulations are not consistently digitisable.	Specifically of use for policy makers/implementors	-Methods for exploring the logical structure of regulations
Commercial						

Production of audience specific guidance on digitisation of regulations or requirements.	In order to overcome scepticism and resistance to change guidance will be produced, targeted to specific audiences, to convey the aims/objectives/ benefits of digitisation of regulations/requirements. Additionally, will support more complete and consistent BIM usage. This will also grow wider awareness.	3	-Acceptance of Change -Change Management	-Lack of consistent messaging	All	-Change Management Principles
Detailed evidence-based business model for digitization of regulatory compliance.	Development of evidence-based business model in order to motivate and showcase benefits of adoption of automated checking. Balancing risk	3	-Documented baselines	-Lack of transparency -Multiple stakeholders with dispersed interests -Lack of KPIs	All	-Market Research/Analysis

	and opportunity. Additionally, this will expose the cost time and resource drains current processes impose.					
Explore routes to export developed toolchains to international audience and exploit international developments	Provides support for the digital compliance services market by increasing international market.	3	-Awareness of generic solutions	-Differences in regulatory landscape between UK and the rest of the world	All	Study into applicability of UK developments for other countries regulations.
Calculation method validation services	Providing service to enable software tools calculation methodologies (as utilised in checking) to be validated, providing confidence to end-users.	4	-Trust in automated systems -Validation/verification methods	-Lack of understanding of automated systems	All	-Building trust in automated systems.
Develop robust inspection methods/rules to reduce dependence on human inspectors	Processes/methods/rules to allows/support implementation of new technology	4	-Calibrated instrumentation to perform continuous checking of the quality of assets	-Collection and robustness of data collection technology. -Lack of confidence in technology solutions -Resistance to change	All	-Research and development into processes to make most efficient use of

						available technology
Professional development and training in compliance checking for all that interface with it – including clients and supply chain.	Development of training materials and delivery mechanisms for the entire industry (all stakeholders).	4	-In conjunction with work of CDBB Pedagogy Network.	-Lack of resource	All	-Competency Management
Political						
Engaging in direct consultation with Ministry of Housing, Communities and Local Government building regulation policy unit and with Building Regulation Advisory Committee.	To further engage policy makers/implementors in the digitisation agenda	1	-Government Support	-Lack of engagement from policy makers/implementors	All	-Policy delivery processes in government
Developed green and white papers for presentation to government and establish funding	Presentation of the case for digitisation of compliance checking to funding to establish funding to conduct proof	1	-Government Support	-Lack of engagement from policy makers/implementors	All	-Policy delivery processes in government

	of concept prototype.					
Digitisation to be given voice with policy-implementors	Ensure that digitisation is part of the future plan for built environment regulations	2	-Government Support	-Lack of engagement from policy makers/implementors	All	-Policy delivery processes in government
Development of an understanding of parallel regulations that indirectly digitisation of compliance checking	Understand how other regulations influence the digitisation of regulations/requirements in the built environment	2	-Continuous policy review	-Rapidly changing legislation	All	-Analysis of parallel regulations
Creation of standard data and criteria for social, environment and economic impact assessments	To reduce the burden of open ended and undefined expectations	3	-Moving towards data driven policies.	-Lack of engagement from policy makers/implementors	All	-Development of a consensus of what standardised policy should be
Conducting Impact assessment of digitisation of regulations	Conduct an assessment to discover the impact of digitisation of regulations in other areas.	2	-Government Support	-Lack of a coherent view of the construction industry.	All	-Impact Assessment -Development of recognised economic model of the sector.

Table 6 D-COM Roadmap

7. Conclusion & Next Steps

The digitisation of compliance checking is critical to the delivery of a safer and more efficient digital built Britain.

Compliance against regulations, requirements and standards is essential. Failure to comply can have catastrophic effects and current manual based checking processes are timely, costly and have room for error.

These challenges can be addressed through automated checking, which brings the required time, cost and quality improvements, and could also transpire into export opportunities. This is aligned with the long-term UK Government industrial strategy targets set in Construction 2025, as well as providing a solution to support recommendations in the Hackitt review, which UK Government has committed to implement.

This government pull is complemented by a market push, which was evidenced in D-COM's engagement with key industry representatives. Opinions were gathered through questionnaire, a consultation event and interviews to ensure the findings reflect the views of industry and the latest state of the art.

The findings painted an overwhelmingly positive response to transforming the built environments existing compliance system. The State of the Nation findings give confidence that the industry can achieve a level of automation checking by 2025 and expressed the importance of considering political, commercial and technological factors along the journey. This included the need for a degree of human oversight until the right level of trust is established in automation.

To build industry confidence and work towards the target of mass scaling automation checking in 2025, the following staged approach is recommended.

> **Stakeholder engagement**: catalogue and prioritise regulations with the view of digitising for rule development.
>
> **Piloting**: develop rules alongside a common language and demonstrate working to identify areas for improvement.
>
> **Industrialisation**: build a product or process to meet majority of needs, trial and test in representative environment and capture key metrics, refine and ready for scaling.
>
> **Scaling**: develop audience specific training and guidance, establish methods for user feedback and continually refine alongside pathways for enhancement.

In accordance with these stages, a comprehensive roadmap has been developed that considers the political, commercial and technological factors required for successful adoption. The findings demonstrate that these roadmap targets are achievable but to meet the 2025 target an immediate start is needed alongside Government support and funding.

Appendix A – D-COM Survey

Appendix B – D-COM Survey Free Text Responses

Item	**Capability/Market Force**	**Origin**	**Description of Origin**
Definition of precise digitisable regulations	Capability	Survey	"Building Regulation Approved Documents are not black-and-white to ensure compliance"
			"The main limit I see so far is in the translation of interpreted rules into fully computable ruleset to validate a building information model. At present some rules have to be textual-based."
			"1. the regulations would need to be in a more suitable format to allow technology to be able to extract relevant rules etc. which would be able to be checked against the model. (ie size of dda toilet cubicle, width of road lane etc) essentially existing regulations would need to be gone through and checkable/quantifiable elements of the regulations identified and quantified to create a checklist of sorts which could be a starting point for checking regulations."
			"Automation suitable for parameter limitations. Some sections in regulations require human guidance i.e. Are open connections between floors in accordance with Diagram 3 of TGD B?"
			"The issues is not technology. The issue is the regulations! Many people have already tried to automate regulations but there are the rules can be interpreted and therefore it is not possible to automate. For example, a regulation might say you can only have 12 risers in a staircase but a human can say 13 is perfectly acceptable. Unless the regulation only allows 12 risers its almost impossible to fully automate as every fail can be passed by using human intervention."
			"Compliance checking requires that the different requirements are described in a more "binary" way"
			"I'm not sure what the technological limitations are but I feel that there are limitations around the way requirements are defined and the way the response to those requirements is provided and submitted. This is more about culture, process and data/information structures than technology"
			"The main issue is to align the way these regulations are written (by the governemnt or another regulatory

			institution) with how we create and insert information within the building models.”
			I do not think the technology part of this is particularly difficult. Where regulations are clear and the information is encoded appropriately much of this could be done now. A bigger challenge is where regulations are supported by guidance such that the path to compliance is less prescriptive.
			“Removal of subjective language to become objective, with large data sets comes the ability to establish trends and viable ranges.”
			“Development of style of rule construction that facilitates automated interpretation. Technologies that cope with variety of circumstances, and enable human led judgement processes where these are most appropriate”
			“For regulatory requirements to be enforceable using automated contracts they need to be output based ie objective standards not the current mish-mash of skill and care, reasonable endeavours, good industry practice etc. This will require new standards driven by the specification and technical team, not the legal team.”
			“Committing to full automated checking will require a review of existing regulatory requirements, make changes and implement. This is a time-consuming task and a large risk if it does not go as planned.”
			“In Health & Safety some thought has been given to coding of Regulations, e.g.AEC3, but “
			“More focus placed on digitisation of requirements / regs required. Who will do this? software Vendors will create a USP if they do. “
			“Regulations and requirements are often subjective with room for interpretation. Re-work regulations to allow for projects to follow either an automated route or an engineered route where boudaries are being pushed. “
			“I believe the technology to check and "automatically validate" against standards is available, I see the problem with the objectivity of the requirements themselves. “
			“in my sphere of Health & Safety there are issues with specific wording of regulations, which require judgements. No current ai processes reliably replicate the judgement process. Some rules and requirements, e.g. to do with Fire safety are more quantifiable, and may be capable of more automation in the short term. A big issue is ensuring that automation maintains adequate grip on "real safety", not just on reflecting that an abstract process has been completed. “
			“The last few governments have been in favour of cutting red-tape, This needs to be turned around with more regulation brought back to the AEC building standards

			compliance checking. The appetite may have changed post Grenfell”
Standardised data models for regulatory compliance data defining required properties.	Capability	Survey	“…linking with building information models…”
			“Lack of datamodel definitions; Lack of interchange platform”
			“Standardisation and exchange protocols”
			“open standard data structure for information exchange that encompases buildings and infrastructure”
			“BIM Authoring Tool Templates”
			“Open standards for digital communication between the regulation, design, construction, maintain and operator functions”
			“- Shared and open standards not only for regulations, but make the use of IFC more feasable during the development of building models.”
			“It does need to be based on standards and standard methodologies for managing this data because of the need to exchange data between parties and validation processes.”
			“interchangeability, and governance of information sharing”
			“integration with BIM including additional properties of materials such as embodied carbon (increasingly important and quasi regulatory - eg planning conditions, RICS Professional standard on whole life carbon see: https://bit.ly/2PNiemH) “
			“Care needs to be taken when developing standard data and criteria that these do not become tick box exercise and that proper assessment is undertaken“
			“Shared open standards for the information to be validated“
			“Establishing standard formats, and educating the organisations in the ability to issue suitable information. “
			“Interoperability between software platforms. The vendors need to further address this issue, especially Autodesk. “
			“There is a lot of variance in the information provided which needs to be validated“
			“Data Modeling urgently needed“
			“Data interchange platforms; Machine Readable EIR and Data Specifications; Poor implementation of standard complaince (IFC); lack of data sharing to create training sets for ML“
			“the plethora of systems including manual (paper based) that do not talk to each other or are fundamentally unsuitable. This limitation could be overcome by agreement and adoption of common standards“
	Market Force	Survey	“Very few with investment”

Increased investment in automated compliance checking			“lacking of Investment to achieve the automated assessment.”
			“Funds required to standardise the approach. Additionally, main vendors should follow and adjust their systems to suit. “
			generally investment is not being made in R&D in this area.
			“Investment in standardised planning models by HMG might be a start. There is currently no recognition by HMG of the value to UK PLC of information models, mirroring built assets, which facilitate compliance through the Opex phase”
			“The political reality of asking local authorities to integrate systems in a time of budgetary restrictions must also be considered”
Increase professional development and training in compliance checking	Market Force	Survey	“I believe that the training of people and companies to understand what and why the base data being recorded is required for will be pivotal”
			“Professional work processes also need agreed standards.”
			“It would require retraining, which will be easier for larger practices. Current BIM models are littered with junk data which would need to be weeded out and tidied for an automated check to work. A standard procedure would need to be put in place that needs to be adopted by all companies and AEC software providers“
Standardised APIs for compliance checking tools	Capability	Survey	“2. a database or api which could be incorporated into open format checking tools such as solibri/ navis etc which can use the previously mentioned checklist and create rules for the model to be checked. this to a certain extent would need to be formattable and granular so users could choose to what extent the model would be checked ie part M compliant, only compliant with these sections of part M then list them.”
			“API standards & policies”
			“Open APIs to built asset software to allow for regulatory compliance applications to be written“
Improved compliance checking process	Capability	Survey	“3. a reporting function which would highlight which sections of the regulation haven't been checked or excluded from the check due to no

definition, standardisation and management.			model information which the regulation can be checked for (this could possibly be symbol coded with symbols to represent: 1. it has been excluded manually by user as not relevant 2. no recognisable model data exists to check the regulation against 3. regulation included for the model to be checked against. 4. specifications which are still by and large separate to the model would need to be more integrated”
			“Not well described proceces, and not enough focus on using open standards.”
Generative design based on regulations/requirements	Capability	Survey	“Use of generative design techniques.”
			“Use of generative design techniques.”
			“Adequate complexity such that automated systems don't become lowest common denominator design tools. “
Linkage between requirements, designers and product suppliers and their data.	Capability	Survey	“Full linkage between digitised requirements, design and the suppliers.”
			“Needs to be an industry wide agreement on product data. “
Shared open standards for regulation clauses.	Capability	DCOM Network	100% voted this as desirable or higher in the survey
		Survey	“Although a degree of automated assessment is possible through current systems, these are all based on individual set up and rule creation to validate specific required assessment aspects. These would need to be collectively merged and nationally aggregated to ensure consistency of validation, along with agreements in process and availability for agnostic open programming.”
			“The key technological limitations today are that the core standards and clauses are not available in an open source format to allow for machines to interact with the clauses.”
			“Various standards exist including organisational (local) standards”
			“Open and available rules tables that can be separately assured”

			“Policy should be based on open standards allowing automation in the first place. “
			“Organisations spending a huge amount of time investing in digitisation of regulations / requirements wont want to share these with others freely.”
			“Regulations are often only partially open. Access and reference to regulations must be free in order to create as wide a commercial playing field.”
Clear government direction towards automated compliance checking.	Market Force	Survey	“Slow response time for change. Without government aspirations/processes to implement change, the incentive for development of the required technology isn't there, meaning political and technology advancement will both be slow.”
			Clients should be more trained on digitization”
			“policy needs to be changed to reject incomplete data, and incomplete checking.”
			”Government manadate supported by specifications (you shall) not Codesof Practice/Recomendations (you should) or Guidelines (You could).”
			“Policy and mandate required“
			“BIM level 2 is not being pushed from Central Government. Need a housing mandate and local government mandate“
			“Government has already said it projects should be BIM level 2 which is the required level of info., the Hackitt review has said a single thread should run through the project, just needs people to say we need to make it happen. “
			“There is the desire to digitise the construction industry, but this is mainly being progressed through innovation from private companies rather than government departments“
			“Requires drive from the Government authority bodies to use such tools. As an example, the Singapore Building and Construction Authority require all planning and building control submissions to be submitted using their system (in BIM only). The system then processes the models and carries out key checks before sent for human interpretation. “
			“Mandate and policy needed from govt and industry to develop technology solutions tailored to the UK building regulations market“
			“In spite of Political initiatives, the appetite to do more seems relatively low.”
			“There is the desire to digitise the construction industry, but this is mainly being progressed through innovation from private companies rather than government departments”

Checking on as-built assets using calibrated instrumentation.	Capability	Survey	"Compliance checking using photogrammetry to confirm that what is built is commensurate with what was approved."
			"Robotic setting out and installation to automatically check in tolerance positioning. UAV, LIDAR and photographic techniques to aid conformance validation."
			"Building Regulation fees that allow for full review of the design and installation. This could be addressed by utilising VR/AR/MR technology to allow remote or automated inspections"
			"Automation requires root and branch and policy makers need to accept this will need to start by picking off areas rather than solving the whole."
New Business Models factoring in: (a) reduced costs for assessment, (b) faster turnaround for assessment & (c) ability to pre-check prior to formal submission	Capability	DCOM Network	96.9% voted this as desirable or higher in the survey
		Survey	"Checking should be free until you "pass" and then you pay. Tools should support the creation of information and not the checking after the fact, which causes delays."
			"Faster turnaround & ability to pre-check"
			"If done right compliance checking should bring commercial benefits in terms of costs and time."
			"Commercial acceptance would be enhanced if the rules engine and rules table approach was either based on or available as a commercial product that client organisations could adopt/extend for their own compliance assessments."
As proposed/designed and as built structured asset information to be required for all (or all non-domestic) projects and establishment of the primacy of structured asset information over documentation and	Market Force	DCOM Network	96.9% (for non-domestic) and 90.6% on survey voted this as desirable or higher
		Survey	"the issue with domestic projects is the client sees little benefit from a BIM model at present however for consistency it would make sense that all projects be required to use the automated compliance checking however until this becomes beneficial to domestic projects or alternatively BIM modelling reaches a point where it is no longer adding additional initial costs to a project (which I don't see happening any time soon) I think this automation should initially target projects which also require a BIM model (this does not necessarily exclude all domestic projects - large scale domestic units where one owner runs them all could prove beneficial in the near future and could also benefit from automated compliance checking."

drawings for the purposes of compliance submission.			
Phasing out of negotiated regulations increasing the transparence of regulations.	Market Force	Survey	"If everything is automated, then the ability to negotiate innovative solutions is lost."
			"it's not technological, it is the regulations, they are commonly negotiated, which technology is not capable of."
Cultural change to accept automated compliance checking	Market Force	Survey	"Who gains by knowing the asset is compliant? Explain that all stages and all stakeholders, from start to demolition, including from developers to owners and operators, as well as all levels of contactors benefit. Payment disputes should reduce and payment should be quicker. Automation must be shown to be reliable and accurate, with concept of checks by people to resolve any ambiguities or disputes."
		Survey	"There does however need a cultural change to trust the automated regulatory compliance."
			"Cultural change to accept the changes"
			"the willingness of people to hand over tasks to computers. this requires a mindset change and staff not feeling like they wont have a job at the end of it"
			"Changing and understanding of a process and transition from todays approaches"
			"Limitations area around uptake and testing. Reluctance to trust tech and automation is the biggest barrier. "
			"The public sector is easier to make change in terms of policy making, however the private sector would be a longer process."
Establishment of a public right to see compliance assessments.	Market Force	DCOM Network	79.1% on survey voted this as desirable or higher
		Survey	"Transparency, open data and democratisation of use."
			public access to data""
			"Transparency during the compliance process"
Artificial intelligence to interpret between regulations/requirements and proposals, such as natural	Capability	DCOM Network	93.7% on survey voted this as desirable or higher
		Survey	"Once these are available, the automation using simplistic rule based checking and AI checking can be implemented"

language processing			
Rule processes to track decisions, feedback, and uncertainty.	Capability	DCOM Network	100% on survey voted this as desirable or higher
			“Should allow for the tracking of decisions made throughout the life of the built asset. “
			“Any checking system needs to develop as a support tool illustrating issues to assist decision making on the path to compliance rather than a binary fail/pass with no feedback.”
			“Much of the work in the retrofit market will not have a "golden thread" to link previous work and/or compliance checks submission”
Brief and regulatory requirements to be contractually enforceable	Market Force	DCOM Network	100% on survey voted this as desirable or higher
Standard data and criteria for social, environment and economic impact assessments	Capability	DCOM Network	96.9% on survey voted this as desirable or higher
Implementation of a strict legal responsibility for compliance.	Market Force	DCOM Network	96.9% on survey voted this as desirable or higher
		Survey	“Unfortunately strict legal responsibility for compliance will be complicated. The clients paying the Bills will need to rely on Professionals of all kinds to achieve compliance. Success in H&S has come through fostering collaboration and shared "pain/gain", rather than strictly carving up liabilities. This must be true right through the asset lifecycle. Safety of the asset has primacy, not documentation of a process. “
			“strict legal compliance is desirable and possibly essential in some cases, however may not be possible where there are several compliance approaches, or where

			interpretation is required. Inevitably there must be some flexibility for some aspects which may require human intervention. “
			“Do not rely on commercial contracts alone to drive compliance.”
Ability for software to be certified as performing “correct’ checking	Capability	Survey	“Software has to approved by government that it is doing the checking as required. “
			“Software has to approved by government that it is doing the checking as required“
Implementation of data “Chain of custody”	Capability		“improved chain of custody using blockchain technology to validate quality and environmental/ethical credentials of materials. “
Establishment of dual automated and engineered paths	Market Force		“Engineered route where boudaries are being pushed.”
Implementation of Smart Contracts	Capability		“Trust in smart contracts. Overcome with use first on payments and adopt once trust established (like NEC3 or PBAs)”
			“one of the standard contract publishers are considering smart contracts except how to automate their own suites”
			“Approval to smart contracts with legislation. Overcome by implementing law commission recommendations (when available).”
Achieving wider awareness of the meaning automation of regulations, requirements and recommendations and its benefits	Capability		“Be crystal clear on distinction between rules (regulations) and standards.”
			“For this clients need to actually see value in their assets both physically and digitally.”

			“Policy makers understanding of how the industry currently works and what inefficiencies there are. This is often shockingly poor/non-existent.”
			“Whatever is introduced needs sufficient lead time to enable industry actors to be ready. Awareness raising effort with support and guidance particularly for SMEs is essential for successful outcome. Cost benefits need to be established and articulated to challenge any negative perception of additional cost and demonstrate value add - this may be particularly important for overseas investors who are used to different rules elsewhere so as not to stifle investment or projects proceeding.”

Appendix C – D-COM Consultation Agenda and Results

09.30	Registration and tea/coffee
10.00	**Welcome and introductions** Rachael Mills, Workshop Facilitator, SE^2 **DCOM: our work so far** Thomas Beach, University of Cardiff
	Workshop 1: The 2025 Vision Drawing on the responses to an early stakeholder survey, DCOM have developed a strawman 2025 vision for the purposes of today's event. This session will give us time to interrogate the strawman so we have an agreed working model to use for the rest of the day.
11.30	Tea/coffee
11.40	**Workshop 2: Pathways to 2025** What do we need to do to reach the 2025 vision? What are the pathways in terms of technology, commercials/procurement and politics/policy? What capabilities do we already have? Who are the critical stakeholders? And what is going to block our path?
13.00	Lunch
13.40	**Workshop 3: Strategic actions and next steps** This session is an opportunity to look at the technology, commercial and policy pathways in more detail and to map out exactly what needs to happen when, and by whom.
15.00	Refreshments
15.20	**Plenary debate** Our last session will be a roundtable discussion, reflecting on outcomes from the earlier sessions and looking at how these impact on and are affected by wider issues. This will also be your opportunity to make sure we've considered all the priorities that are important to you and your sector. **Closing remarks**
16.00	Close

Workshop 1:
In small groups, delegates were asked to discuss the strawman and add their own thoughts to the ideas already put forward. The key points fed-back into the plenary session are summarised below:

<u>Technology</u>

- Checking of as-built assets:
    - It's a much bigger piece than just saying "as built". It's continuous checking – whilst built, as built, in use – using calibrated instrumentation. "As built" doesn't cover how it's

constructed. It's different once it's been built. We need to be more sophisticated through the construction process and check as it's being built, track the changes that happen through construction.

  - Should we say "as built" or "as constructed"? What we're doing is checking the quality of the asset rather than anything else.

- Generative design:
  - This is about a transformation of how the industry's working, taking the smarter approach, not building from scratch each time but using data and experience.
  - Procurement and certification of built asset needs to be confirmed against the digital model. It's a question for the D&B process and how that would be addressed from a digitation perspective. For example, you need the architect's digital model to check what's installed on site. Without that, there's a gap. You need to check it's being built to the digital design. Also, with regard to Building Control: when are they on site, how often, what key objects do they need to sign off?
- An example of a proof of concept case study needs to be put together, for example, using the fire regulations: how would you digitise that process, how would you remove the ambiguity of that regulation? It's about identifying ambiguous clauses and working out ways they could be rewritten.
- Some of the considerations are very regulation dependent, eg, there were far more grey areas with Health and Safety regulation than perhaps with other regulations. There's a need to consider technical capabilities across the board (skills).
- Consistent data linkages are essential.

<u>Commercial</u>

- Rules for the custody of data: if one organisation is producing models and another is producing the data, how do you put that into the same space and who takes responsibility for checking that data?
- We need to be clearer in how we communicate what smart contracts and smart clauses are. Also, if you're using smart contracts and some sort of AI to parse clauses, then material needs to be machine readable, but is that realistic in the timescales?

<u>Political</u>

- There are both large crossovers and gaps between various regulations and standards. This is about providing a scenario where you could digitise but also contextualise what you're doing. You need use cases to map and see holes and overlaps between regulations so that you are able to clean up the regulations and the standards that go around them.
- What is the incentive to comply and what is the penalty for not complying with the Regs? At the moment, there's not a huge amount either way. Transparency in demonstrating compliance would be good. If you can show that these companies are complying, you know where everyone stands. Then you can demonstrate what you're capable of doing to the political / regulatory bodies who tend to respond to evidence.
- Legislative bodies need to be involved in DCOM.

The following questions and comments were also raised in plenary discussion:

- Retrofit could be more difficult than the new build space. For example, if you wanted to consistently asset the UK, something as simple sounded as that.
- Regulatory check only happens when you're doing something with the existing building. However, that may well change after the Hackett report with a requirement for checks on tower blocks.
- Asbestos was the last time we did that sort of thing. It was almost impossible – you had to empty the space to drill and check for asbestos.
- This means you need a risk-based approach – new build should be easier to do, modifications to existing estate will have varying degrees of difficulty.
- Any sort of destructive interrogation of a building is challenging. Or if you don't have the records, that would have to be logged differently
- This could factor in to the valuation of estates and decisions about demolition. Risk should go up if there is a lack of records. Your building from the 1950s might have something in it, you can spend a lot of money investigating it or look at replacement.
- This in fact seems like insurance. If you can't provide evidence that work has been done or if you're not insured, then your gateway doesn't allow you to go on to the next stage.
- Premiums could go up based on a lack of data about the estate.

Workshop 2:
The groups were then asked to plot out the paths we must take to get from the current landscape to the 2025 vision across technology, compliance and politics, bearing in mind this is only six years away. One group specifically focussed on a timeline for approved documents for newbuild and where modifications are made to existing buildings. The noted that there is three-year change cycle: year 1 you develop the idea, year 2 you test it, year 3 it's business as usual:

Now	Consent to repurpose content from owner
	Seat at the policy making table
	Demonstrate value of digitalisation
March 2019	Government backing / support for CDDB digitising of regulations and compliance checking
	Requirement for digital capture to assist inspector
	Filter out computable regulations (digitisation) – subjective rule review
	Digitise the government
March 2020	Open source checking for computable Regs
2022	Compliance platform
2023	Go live approved docs portal
	Pay on pass, not pay on submit
	Cut time in CAPEX stage

This group feedback the following points in plenary:

- Primary assumptions: we're talking about new build and existing buildings when you're making interventions covered by regulations.
- Transformational projects in other industries usually take about three years to become business as usual, for example, Soft Landings, a lot of software development.
- We should look at the Regulations and filter out what's computable into one work stream. Then there's a parallel work stream for the things that are subjective (i.e., where the wording of the Regulations is based on "similar", "appropriate", "relevant") and you need a human being with intuition or where there's not sufficient data to show the range of suitable solutions.
- Early priorities are about talking to people and persuading them it's a good idea. We need to go to the people who run Building Control in local authorities and explore the opportunity. If we digitise the regulations, then Building Control will be able to spend more time on site signing things off rather than in the office looking at drawings. What can we speed up that's just drudgery? Digitise that and unlock people to go and do the things that only people to do, which is to go on site. Data will tell you when, who and what but it won't tell you why.
- You can't get an inspector on every site at every stage, but the technology exists to take a photo that's geotagged or use phones that turn into scanners. An inspector might not have to inspect, though there is still a question of enforcement. Local authorities could implement a requirement to take a photo as part of your planning or building control application.
- If we go down the digital route: how fast could we have an open source platform in place for testing? We thought 2022 with go live in 2023.
- It's key to get a seat at the table with policymakers. Because of the Hackett Review, there's going to be a lot of policy change. If the intent is to make the Regs digital in any shape or form, the time to do it is now. It's about that connection to the appropriate Government Departments.
- If you want to take paragraphs out of Regs and put them in a database, you have to ask the document owner to be able to do it.
- There's going to need a big educational piece for everyone who interfaces with the Building Regulations: from architects to small builders. That's parallel to any of these things. We need to go out to industry and say what's going on.
- It's not beyond the realms of possibility to do a prototype – say I want to do a loft conversion under permitted development, get three or four options, let the householder choose and do their own application. Digitisation could lead to democratisation.

The other groups had the following points to make:

<u>Technology</u>

- We are in a position now where we've gone from no consistent data standards for products or anything to having a mass under-development but we need to start now swapping notes on them and possibly consolidating them into a harmonised consistent data model for asset data, building data, regulation etc. We've gone from zero to lots and now we need to start rationalising and consolidating through some sort of body.
- Hand in hand with the political driver is technological reaction. Innovate UK competitions have done a lot and are the accelerator particularly when there's no big great pools of R&D money out in industry.

Commercial

- As a public procurer, we are obliged to use harmonised standards without any additions, whether it suits us or not.
- The Government Construction Strategy catalysed this and put in place a requirement on Departments. That's slowed so we need another politically mandated assertion to drive this. The "big spend" nature of Government then compels the rest of the market and the industry to react.
- If there is political exertion, then something like Highways England's licence to operate can be influenced through regulations. It has a behavioural as well as a political manifestation.
- HMT Green Book means that you need a business case for regulation and compliance checking: it needs a robust sound business case. What is the benefit to UK PLC? This needs to be documented so you can do the competitions and demonstrations so that the system can go live in 2025 – whatever the system may be.
- There needs to be a pull from industry and the public for this type of approach to delivering our buildings. Grand Designs is a reflection of the built environment – how do we get Kevin McCloud to show that going through planning was easy because it was digital?
- It's hard taking the construction industry as a whole along this journey. You can start by focusing in on a sector and say 'this is what can happen'. By the time you hit 2025, you're capturing the majority.
- It could also be applied to thinking about competence of the industry. People are creating registers, putting competencies into a distributed ledger for transferability; taking that kind of concept, there's a lot being done on how you measure competence. Hackett is starting with people working on HRRBs; there's going to be an overarching body looking at competence. Digitisation could help with audits, specific scenarios, compliance. You might be competent in a specific type of building and digitisation could help show whether this is transferable.
- For the small builder, it needs consideration of how accessible and achievable everything is on site. That affects how you would approach making guidance and regulation available and how you make competence something you can achieve and demonstrate.

Political

- Our ability to influence standards across Europe could be curtailed by Brexit.
- You can see how many regulations and codes there are – we need a way to bring them together and make them accessible for different audiences. Instead of it being document A, B and C, it might go across a plan of works. You could start with regulations and then go down into the other things that go towards it. It should be audience specific and that includes people like clients and people who are living in and using those spaces.
- It is important to map the current landscape to see where the gaps and opportunities and to look at case studies to show the benefits of digitisation. We should select some areas and show the

Workshop 3:
The next task was to take suggestions for the technology, commercial and political pathways and to discuss what the immediate next steps are: who needs to do what, by when?

Technology

- Importance of having a process map

- How can we encourage a shift in the way that the building domain is seen? The sector needs to be more data-centric rather than focusing on individual pieces of software.
- We need to understand security implications and mitigation of risk around digitisation of detailed models
- Consideration of accessibility of the Regulations, first from angle of whether they should be available in formats other than just written documents (e.g., for blind users) and then from the point of view of affordability and accessibility of technology to interface with these formats. Who needs to access data and in what formats? What's the lowest cost technology option for them?
- Identify the low hanging fruit and be pragmatic about it – some things may have a good reason for not being digitised and some things may just be badly written (and therefore difficult to do manage through a digital process).
- Many things related to buildings are still dependent on a wet signature. You could have a complete digitised system but the last page might be something which has to be printed, signed and scanned. If money can be digitised, why can't these documents?
- Case studies from related domains (e.g., petrochemical, automotive, aerospace) to look at the applicability and transferability of approaches and systems

<u>Commercial</u>

- Case studies to disseminate experience and drive practical change for different scales of business, from Tier 1 to Tier 4, and for people who aren't in a tier structure.
- Industry vanguards – where are they and how do you find them? A lot of leadership comes from government and policy driven organisations, but there are others within the innovation space.
- Incentivisation: how do you incentivise uptake? Possibly through tax breaks or through insurance. There are two challenges especially with smaller organisations: how do you get the information to them and how do you ensure that they read it? Most will have insurance so can you incentivise through this (e.g., lower premiums, quicker pay-outs) if they start using digital processes.
- What is the impact of digital on ownership in relation to approved documents? Do you look at user charging mechanisms? This could mean a move to micropayments per API call rather than a £350 per manual (BSI-type) approach.
- Security concerns: some digital situations (forms) can be easy to fake compared to some document formats (PDFs).
- There's also something around a change in motivation from price to value: how can digitisation achieve or help that in order to drive the agenda? A main metric for the success of digitisation would be improving productivity, but do we have a good understanding of productivity and what would measurement be based upon? There is a need to identify who has the data around this. We need to demonstrate the business case for digitisation if we're going to get incentives into the commercial sector. If we can demonstrate the value of this change, Government will respond.

<u>Political</u>

- Obtaining seats at the table with a group of people who maintain and implement policy. We need to inform policy makers what digital actually is, clearly represent it to them.
- Initial engagement to check the mood of policy teams to see what the appetite is particularly in the context of Brexit.
- Evidence based business case is important to demonstrate the value digitisation can bring.

- Produce a case study where documents have been converted to data – for example, how Ordnance Survey have gone from paper to digital models.
- Sectoral evidence from adjacent sectors to understand their digital journey. For example, regulation of bridges has already started on this journey and that could become a case study. The key point to demonstrate to policymakers is the benefit to the end user – whatever we do in terms of digitisation, someone doesn't have to put effort in to understand it. We also need a business case to show what a bad example looks like; a risk analysis to show what the impact is if you don't change anything and a risk analysis of what good looks like.
- There needs to be a plan for finance, funding and resources for how this is going to be delivered. There is funding for research but at some stage there will need to be funding for implementation. There's a lot that's been said in the Budget about digitisation but it is grey and needs clarity. We need to show that we can do one sector properly.
- There needs to be some system engineering carried out so that this can then be rolled out to other regulatory authorities.

Plenary:
The final session was a free-ranging plenary discussion where the stakeholders could raise any further points they wished. To help the conversation, we asked a series of questions:

What do you think Brexit is going to do for the UK construction industry?

- We can't answer that until we know what the Deal is. For example, if the price of copper goes up, it'll be more expensive to import cables. And there could be delays to bringing materials in, which would have an impact. It could make a big difference: if you can't get product or materials, if there's a delay or a cost, there will be a difference.
- There are things that we have direct control over and things that we can influence.
- Brexit has put a pause on a lot of other things that could have been considered; we now have to wait for it to be done before we can think of anything else.
- People are spending a lot of time worried about what the future is but not delivering things that could be done now.

A successful outcome of the research network would be a change to the regulatory system – are we looking for something else?

- Innovation carries a higher cost than BAU because of the R&D input – this needs greater recognition among policymakers and funders.
- If you're doing something new, there is a cost for innovation and then costs come down. You can't base it on talking to a manufacturer and asking about the cheapest price. This isn't always recognised by innovation agencies. It is something we can do: look at how we can influence costing and procurement to encourage innovation.
- Alternatively, you do R&D away from the coalface. If you're making cars, you wouldn't innovate on the production line. In construction we do it all the time, changing things as we go.
- We're trying to create a new production line. No-one's going to pay for you to create a whole new production line that works in a completely different way.
- Contractors don't always want to get involved with prototyping, they don't want to cost it up.
- Government Construction Strategy talks about new forms of construction and new forms of procurement. Ideas around offsite manufacture of buildings are being done at small and

domestic scale, but it's not happening on the commercial side. It's not about building the whole project, it's about creating the components.

- What we need from the political side is assurance that changes at the political level will not affect digitisation. It should be independent of whoever is in power.

Are we advocating turning into a lobby group?

- Possibly, if it can help us to get this ring-fenced. It needs to be monitored and governed but also protected. There are other organisations that already do this.
- Current regulations are flawed; things aren't being checked properly and there are other ticking time bombs out there and being created week by week. Doing nothing is remiss of Government. Doing something is the right thing to do.
- It's wider than Building Regulations. It's the Housing Act, it's CDM – which regulations and processes are we looking to digitise? There are 1800-1900 regulations, so we have to pick somewhere to start. Regulations around roads and bridges have gone way ahead of the buildings agenda; that work can be applied equally to buildings.
- We also need to think what cuts through every discipline and every sector: planning and building regulations. (That's not necessarily the case in highways.)
- We're talking about digitising regulations so we can potentially automate compliance checks, but the operating experience has to be digitised as well.
- How much of that would be retrofitting? How much kit is tracked to see how it is being used? You could have automated surveys of an asset, data tracking and constant monitoring. This might be traffic flows, people flows, sensors. How do you collect, analyse and audit data? How does this square with privacy laws?
- HSE inspectors carry out and document inspections. A lot of it is paper based and it's free text and descriptions. The real value is often in the free text descriptions so there has been investment in textual analysis. HSE carries out about 20,000 inspections a year and needs to be able to analyse its data. It's very hard – if we started from scratch, we'd do things differently, but everything is set up to support existing operations and ways of working. It's about a case by case basis for inspections, it's not set up for data scientists to crunch all of the information.
- Highways has several different databases and has had a 10-year programme to bring them together for data science applications.

Do you set a line in the sand and say from this point on we're digital?

- It's very complex. You have contractors collecting data in their own way, and we know what we want (which might be different). That said, some contractors have optimised their platforms and their processes to be very efficient and if we as purchasers are saying they can't use those platforms, we're forcing them to be inefficient and we're facing higher costs. What would be better is to say "we're not forcing you to change, we're going to figure out a way of connecting to you".
- A lot of legacy systems were never designed to be opened up. A problem is silo'd working over the life cycle of the asset. It's like running 4 separate 100m races rather than a relay. Everything works on its own but it doesn't join up.
- Some systems were not designed to communicate. We're looking at how you can use distributed ledgers and private chains to drive data through a different system rather than forcing people to open up (which they may not be able to do for technical or security reasons).

How can we advocate for this? How can we demonstrate the value of the data that we're producing, that it's not costly to create data?

- Business as usual is to accept crap, spend time fixing it and build it in to your fee. The way out of this is liability, requiring rebates for inefficient processes, forcing people to work more efficiently rather than just tolerating the inefficiencies of business as usual. You almost need an amnesty: we as an industry will admit our failings but without anyone coming after us. That's a tricky conversation to have! There's a blame culture in construction. We should be able to admit we can do better and then do it.
- You don't want to penalise people who have optimised their systems. Let's invest in the connections.
- The automotive and aerospace industries have very restrictive silos; there are efficiencies you can bring from BIM etc., but they won't use them because they work in this silo way. What we can learn from these industries is about building digital models, scale models, testing against the data, fixing, building a real size one, testing, fixing. Their clock cycle is weekly where ours is in years. The feedback loop is fast for them. For buildings, it's 6-7 years to get good feedback on how a building is performing; that's how long we have to wait to learn what's working. We could step back from doing things at the coalface and fix some of these things in a laboratory environment.
- Prototyping can help you work through how things are then put together on site – what can be lifted by hand, what by crane to reduce the amount of crane lifts to save time, recognising that final fix is manual. Similarly, with building road laybys, they now come in a four-unit module, prototyped, tested, with everything already built in. It's about doing small bits which are quick wins – you don't do a whole motorway module, you do a layby.
- What you need isn't necessarily a design, it's a process for how you go about designing. We haven't got a process map for developing anything in the built environment. That's where you'd want to a lab or an R&D environment. You apply computation to things that are rules-based and then spend human time doing different things – optioneering.
- Knowing the design and build procedure, you can then test the actual construction, the assembly of components. Usually we don't have that in the construction industry because buildings are a one-off, but if you can create and test components, you have more certainty. We have an end product that is the whole assembly.

Appendix D – Interview Extracts

Summary of points

Political

- The business model in the construction sector is about reaching static points; this is not the real world, everything keeps moving, projects are on-going. This static stage point is the traditional way, not the innovation. Political direction is required to make this innovation happen across the whole range of regulations. The political will to make this happen seems to have faded.
- Government initiative for BIM was excellent; the government does not have this focus now. The opportunity is to join up government departments; embrace disruption and encourage awareness of digitisation.
- Mechanisms are needed to get start-ups involved the way the government procures these skills needs to change.
- There may be a political decision to ask for something too small to test so that no one can blame them; it is safe politically. There is a social aspect to this; it is not a great climate for experts, transparency and openness are required — no black boxing.
- An organisation can open source their rules but not their expertise. The rule may be exposed but not the returned data.
- If the UK is going to do this for the building regulations, in general, the move may appear utilitarian, less trust is likely. If people knew more about what is checked, if people had access to the rules and data, they may trust more.
- Seed projects applications would be the way to accelerate this. Not in the singular, at different levels in different sectors. Demonstration projects that show this is possible. These need to be significant projects not too easy, need to do something different; show a data structure, will challenge the business model. Knowing the art of the possible. Political action needed to bring this about. There is the risk in the pilot that moves the value in investment away from the single projects to the future business as usual benefits. A question of scale if too small not weighty enough, smart motorways was perfect for this, the scale was right, cannot be dismissed as evidence.

Commercial

- I hope a language will come from this, which will allow us all to write the rules in the same way. Could be commercial, i.e. making available via data.gov.uk, publish to human and machine. So that the rules are available to all so that the supply chain can take rules on board. As the project develops, you can check against the rules without stifling the ability to evolve the rules. Rules will and should evolve.
- Do you need designers to apply rules? If you have rules why not apply them yourself. Why employ people. Currently, departments outsource to cover risk, when a digital route has been verified this risk will diminish.
- The way to verify the digital design process is to run projects in parallel. Highways England did this the work was in development for three months. The next phase was a nine-month refining process using three live schemes. Producing comparable schemes, by traditional and digital means, generated in parallel, the digital is just quicker to output. The digital rules were then adjusted to create an outcome more like the human output. We could show benefit quite quickly. The progressive deployment follows.
- Environment agency within the next six months have asset requirements Rules now; stage 2; something with supply chain next summer; stages of deployment; layering Terminology

guide requirement. Test social side internal skills. Priority, assets you build most. Maybe 5 years to serious deployment.

- Procurement needs to change, to bring about innovation. Innovators are not the same people as those interested in the ongoing projects. The incentive of future work is not a draw for people purely interested in innovating; therefore, there is no incentive to undertake work if not profitable. Mechanisms needed to get start-ups involved the way the government procures these skills needs to change.
- There is a significant cost in the industry is communication between CEs with current system this could be reduced with blockchain or the like.
- Data on built assets was not that important historically. It is not that hard to survey if you need to know. However, as an example of the emerging realisation; there was a highways incident caused by a bolt falling from a sign, no one knew what had happened, a bolt may be insignificant, but was not an insignificant risk, we are just waking up to understanding these risks, retaining data has been expensive in the past, so we have not really done it, now it is cheaper, we are increasing our team, and getting smarter with what they do with data. Now we do want to know about assets. Ten years ago, no one would have asked because it was impossible.
- Digitisation does require an intelligent client — understanding how it fits into their business. Structured data, looking at formal regulations, rather than internal rules, need something to map algorithms to therefore you need standard ways of presenting the data. There need to be Data standards. Ideally, there could be an interface between departments such as highways and EA.
- With highways, you have had a journey, you have been able to validate and challenge, real innovation. Is the industry ready? This is a cash cow; consultancies make money from this, why would they adopt something that undermines profit. Could be v. disruptive. Costing may be riskier in innovation, but once proven costing is simple and assured, the risk is reduced, less insurance cost.
- Supply chain, currently tend towards big organisations, digitisation can disrupt this, we need a structure that suppliers can access, the organisation has control over what they access, the rules need to be applied when the data comes in. Verify data at the point of acceptance.
- Having asset data online has helped; now no need to respond to requests for information, everyone has access online, the number of people accessing has expanded from 600 a year when on a spreadsheet to 6000 in first four weeks of online.
- Dealing with RFI's due to freedom of information can be a big burden for public departments. This could help address some of typical requests.

Technical

- It is essential to have data standards to enable digitisation.
- Start small with digitising simple standards. Rules must be human and machine-readable.
- The issue with the relevant guidance was that it had been built up over a long period and is layered and contradictory.
- Digitisation needs to be progressive. Start with straightforward things that can be captured immediately. Machine verification/human validation; the balance will change over time.
- Rules start hard and get softer with review, with a hierarchy of rules; some need to give if not all rules cannot be met — fuzzy rules.
- There is no solution which complies with all the rules. Some rules need to soften; a hierarchy is required.
- The question is how to record comments when no formal process as today. Hackett report says you must. Transparency of process is important; one suggestion is to use VR to record comments – not how we thought info exchange would work.

- Need agility to start, be reactive, huge idea of scale, baby steps any of which might be wrong. A balance between small and large scale organisations needs to be involved.
- Another tension is the validation, not just codifying a further line in the sand is testing validity all the rules. For example, the government wanted to change the length of the refuge area on motorways we were able to test this by running lots of scenarios through the system. Find that it was a terrible idea and should not happen. This could be the end of the age of experts.
- We need a human-readable translation, need some way of visualising; no black boxes. Building rules outside programs communicating with humans.
- Through communication of process with diagrams for stakeholders and the highways client, gave the client a means to give feedback and suggested tweaks, which was useful validation. It was very important to have interfaces for humans. The process needs to be flexible with different interfaces; not everyone wants to consume in the same way. A big selling point is a versatile presentation of data — building trust. Then you can start generating feedback loops, adjusting rules. Therefore, it worked well in infrastructure where construction is just part of the operation. Whereas, in the building sector use is disjointed from Construction. It's not construction and then operation it's just operation.
- Not about learning tools, just decide the right thing then find the right people, make it as easy as you can. There is a lack of skills in the industry, the mechanising process needs to change the people doing the work.
- What we always suspected is that there will be a change in the supply chain. Less need for expensive agents.
- Need to provide rules on data coming into an organisation and verify at point of acceptance.

Blocks

- The block is the documents. Most rules you can't check digitally, some rules transfer directly to machine-readability some do not, contradictory documents, and part of the process is finding redundant parts of rules. Review of regulations and guidance includes a clean-up of redundant guidance. You still need a human readable/digestible form to understand an algorithm.
- Innovators who evolve the digitised rules and interfaces are not usually the same commercial entities who will undertake the individual projects. The procurement model needs to change to attract innovators.
- Training – is it being asked for in the right way? It needs to be easier than it was traditionally, otherwise people won't do it.
- Skills – Access is in issue. Current lack of technical skills in the industry, or they might just not be in the supply chain. These skills may exist in other sectors.

General comments:

- Importance of validating design intent early, especially against the 'employer's requirements.
- Importance of checking intermediate and temporary states during phasing and during construction.
- Impact of robust checking on procurement rules, insurance and pi

Concluding comments:

- Enthusiastic
- Verification throughout lifecycle especially proof-of-concept

- Need for consistent methods for all actors.
- Need for appropriate tools around these methods.
- Need for government commitment and stewardship
- Doable.

One big thing:

- Compliance saves lives and ensures quality of life'

Technology

- Distributed leger technologies for chain of custody of materials and data
    - **above five discussed below (we started from the bottom!)**
- Generative design based on regulations and requirements
    - **Some may be appropriate for sub-systems and sub-problems.**
- Artificial intelligence for automatically parsing regulations & requirements and proposals
    - **Not in the 2025 timescale. Rewrite or deploy human transformation**

Commercial

- Open source standards clauses
    - **not source, access!**
- Checking software validation and certification
    - **US may expect this, UK may not. Only needed if checking is completely autonomous.**

Political

- Policy for standard data and criteria for social, environment and economic impact assessments
    - **as part of a drive towards information driven planning process.**
- Adoption of Smart Contracts
    - **not required, not necessary, not achievable. rely on additional 'Z' clauses to ordinary contracts**
- Policy to demand chain of custody for all materials and associated data
    - **yes, going to be required for many parallel reasons.**
- Developed green and white papers for presentation to government and establish funding
    - **three points above: need commitment and stewardship from Government.**
- Establishment of dual compliance paths automated and engineered
    - **anxiety about premium cost or lower cost service, especially if only some aspects are automated.**

General comments:

- User stories seem feasible.
- Mistake in User story 1, "building regs" should be "non-mandatory approved documents".
- Should aim by guidance rather than autonomous compliance.
- Some interest already in Government Experts Group
- Automation may be more practical in conventional projects rather than in multiuse-use, complex geometry projects.

Concluding comments:

- Anxiety about business / charging model
- Genuinely important
- Alternative is the risk of external disruption from outside.
- Supportive of the inclusion of technical, commercial and Political dimensions.

One big thing:

- How to move compliance into the digital era.

Technology

- Checking of as-built assets using calibrated instrumentation
    - **As important to get sanctions and penalties for non-compliance**
- Persistent data linkages between requirements, designers and product suppliers
    - **"Golden thread" already on the sector agenda**.
- Distributed leger technologies for chain of custody of materials and data
    - **proof or sanctions in the specification/selection/substitution chain.**
    - **the above are secondary to devising a fair and equitable financial model (Latham).**
- Generative design based on regulations and requirements
    - **especially sub-systems**
- Artificial intelligence for automatically parsing regulations & requirements and proposals
    - **More plausible to rethink and rewrite.**

Political

- Policy for standard data and criteria for social, environment and economic impact assessments
    - **Reduce the need for negotiation. More rule based planning.**
- Developed green and white papers for presentation to government and establish funding
    - **above three vital. Engagement already underway.**

Appendix E – State of the Art Literature Review