National Platform for the Built Environment

Increasing productivity through digital technologies

23 September 2015

Background

In September 2015 the National Platform held a workshop to look specifically at the ICT & Automation roadmaps that it had produced in 2007. The workshop sought to update the original roadmaps, consider the key achievements against those roadmaps and identify the new challenges that are presenting themselves in this important area.

Roadmaps

- Collaborative prototyping to define & deliver client requirements
- Efficient, seamless sharing of information across the built environment stakeholders
- Ability to interact with realtime information regardless of physical location or timezone
- Mass adoption and application of offsite manufacturing, automation and mechanisation

National Platform for the Built Environment

Workshop Questions

- Do the drivers remain valid? What new drivers are emerging?
- Are the products / services / technologies still valid?
- Progress: Which elements of the roadmap priorities have we achieved?

Workshop Questions

- What challenges are new and emerging?
- What research projects have met these challenges and are currently looking at these challenges?
- What research is needed to enable progress?

Roadmap 1

For Roadmap 1 Collaborative Prototyping to define and deliver client requirements the drivers remained valid, with the additions of improved productivity (of construction processes and assets) and improved whole life value of assets. The direction of travel for technology developments remained valid, however it was thought that more focus should be placed on business models and tools to demonstrate value as well as better training and communication across all elements of the supply chain.

Roadmap 1

DRIVERS

- Improved productivity (of construction processes & asset)
- Improved whole-life value of assets
- Increase in predictability
- Reduction in waste
- Reduction in defects
- Reduction in capital cost
- Reduction in O&M costs
- Reduction in accidents

PRODUCTS/SERVICES/TECHNOLOGY

	SHORT	MEDIUM	LONG
Intelligent Assets (Sensors, data acquisition and analysis, 'new technologies') **R1.1**	• ICT to determine **optimum facility** operating conditions and maintain operations within the performance envelope (i.e. energy efficient assets) • **Wireless and powerless sensors** that support interactive spaces—providing personalised, location and context-aware services.	• **Remote diagnostics** and control (real-time condition assessment, predicting problems before they arise, and enhancing performance of the asset). • **Automated (& integrated),** highly accurate capture of as-built data, to be fed into Asset Lifecycle Information System. • Embedded learning/user support, and feedback to designers and planners. • User-aware working/living/transport environments—access to information for optimising operations. • Personalised location and context aware services.	• **O&M decisions** and facilities management to be based on a fully integrated consideration of all lifecycle (e.g. environment cost) factors, supported by accurate, current, and complete date from ALIS. • **Self-maintaining,** self-repairing facilities and systems will enable safe, secure, continuously optimised operations with near-zero downtime. • **Adaptive systems** that learn from their own use and user behaviour, and are able to adapt to new situations without manual configuration, maintenance and support i.e. self-optimising systems. • **Accurate prediction of asset performance**/improved energy efficient design.
Client Engagement Tools (Involvement, end-user satisfaction, value) **R1.2**	• **Requirements management tools** (to help with identifying & capturing the client's needs and allow them to transparently see how their requirements are transformed to best-in-class solutions)	• **Compliance assessment tools** (to ensure the final asset meets the customer's aspirations) • **Streamlined client approvals**	• **Decision support tools** e.g. to demonstrate to clients the performance of their asset before they decide to construct ('Try before you buy'); or to test alternative courses of action ('What is?' analysis) • **Customer-orientated configuration design**
Whole-life Asset Management Tools (Cost, environment, society) **R1.3**	• **Building MOT's** (i.e. periodic independent inspections to check assets are performing above a minimum required standard). • **Socio-economic modelling** (to improve sustainable community development, predict effects of investment, and understand the system).	• **Whole-life value tools** to include all environmental costs (to provide a clear business case for addressing environmental issues). • **Comprehensive eco-efficiency evaluation tools** for all stages of the asset lifecycle (providing ready assessment of environmental performance against best practice).	• Total lifecycle is supported by **ICT tools/services for whole-life decision making,** management & appraisal, by users, owners and society.

Collaborative Prototyping to Define & Deliver Client Requirements

RESEARCH/ENABLERS

- Research & develop socio-economic models
- Requirements management—research ICT tools to capture the clients' requirements and transform them into technical solutions
- Research & develop use of active & passive wireless sensors & RFID
- Investigate how to (most easily and economically) retrofit intelligent sensors/systems into existing building stock
- Research the use of transaction monitors to automatically compliance check electronic information/documentation across collaborative platforms
- Research and publish more forward-looking building regulations/design standards (currently based on retrospective data, that is becoming rapidly out-of-date due to current trends in climate change)
- Better understand, & communicate, the relationship between long-term lifecycle costs and initial facility costs
- Research & develop embedded intelligence in products & components
- Legal and contractual governance and agreements on practical procedures for ICT based collaboration e.g. model contracts
- Identify and address organisational and personal barriers to the adoption of ICT based collaboration (i.e. culture)
- Develop standardised management processes for ICT collaboration between designers, suppliers, contractors, end-users and other stakeholders.
- Pilot new business models and market tools to show potential savings and benefits
- Communication with customers in clear, understandable language

- INTEROPERABILITY ENABLERS
- REMOTE WORKING & CONNECTIVITY TECHNOLOGIES ENABLERS
- Compliance assessment—Research ICT-based verification tools, where technical solutions can be (automatically) verified against the set performance requirements (e.g. client's brief, design standards) ensuring there are no defects in the final product
- Use of BIM for client approval
- Research & develop ICT and methods for post-occupancy reviews
- Develop model-based process/workflow management: intelligent workflow aid; combining product model (PLM) with scheduling, resource planning (ERP) and progress monitoring
- Research & develop common platforms, networks and protocols for all systems in buildings to share
- Develop ICT to calculate energy used, and compare against design forecasts (from data model)
- Research methods for use, monitoring, operation and maintenance with intelligent embedded systems; user and context aware control; and ambient user interfaces e.g. integration of computing into the built environment to facilitate information gathering, such as visible energy use 'metering' (allowing occupiers to measure carbon footprint)
- Refocus from the purely technical to include the human element/ attitude (i.e. technology is developing faster than human behaviour is changing)
- Facilitate a culture of co-operation and trust (e.g. partnering) between distributed teams, and encourage risk and reward sharing
- Create virtual communities using sophisticated applications based on WebDAV (Web-based Distributed Authoring and Versioning)
- Research & develop the design of workplaces for more efficient, collaborative and productive working
- Delivery of training to inform relevant parties on what construction products/services are available and how to access them.

- INTEROPERABILITY ENABLERS
- REMOTE WORKING & CONNECTIVITY TECHNOLOGIES ENABLERS
- ASSET LIFECYCLE INFORMATION SYSTEM ENABLERS (i.e. date model for lifecycle of asset, with single point data capture)
- Research & development of new visualisation, virtual reality and communication tools/techniques using shared integrated data models, enabling a 'value' & performance assessment of the asset to take place in many dimensions: e.g. energy consumption, visual impact, functionality, internal environment quality, safety, security, flexibility, operating costs and expected lifetime
- Develop optioneering capabilities e.g. climate change 'what if?' analysis (using model simulation, and based on rules and evidence)
- Research mass customised system concepts e.g. clients can order buildings like they now buy cars—selecting from a limited number of choices, creating widely different end results.

Roadmap 1 (2007)			
Title	Collaborative Prototyping to Define & Deliver Client Requirements		
Drivers	· Increase in predictability · Reduction in waste · Reduction in defects · Reduction in capital cost · Reduction in O&M costs · Reduction in accidents		
Products/Services/ Technologies	Short	Medium	Long
R1.1 Intelligent Assets	· ICT to determine optimum facility operating conditions and maintain operations within the performance envelope (i.e. energy efficient assets) · Wireless and powerless sensors that support interactive spaces—providing personalised, location and context-aware services.	· Remote diagnostics and control (real-time condition assessment, predicting problems before they arise, and enhancing performance of the asset). · Automated (& integrated), highly accurate capture of as-built data, to be fed into Asset Lifecycle Information System. · Embedded learning/user support, and feedback to designers and planners. · User-aware working/living/transport environments—access to information for optimising operations. · Personalised location and context aware services.	· O&M decisions and facilities management to be based on a fully integrated consideration of all lifecycle (e.g. environment cost) factors, supported by accurate, current, and complete date from ALIS. · Self-maintaining, self-repairing facilities and systems will enable safe, secure, continuously optimised operations with near-zero downtime. · Adaptive systems that learn from their own use and user behaviour, and are able to adapt to new situations without manual configuration, maintenance and support i.e. self-optimising systems. · Accurate prediction of asset performance/improved energy efficient design.

R1.2 Advanced 'Next Generation' ICT Collaboration Applications	· Transaction management for electronic exchange of information to ensure documents meet a pre-defined level of legal validity (e.g. within an ICT contract), security (e.g. digitally signed), and trust	· Fast access to latest (model-based) information, anytime, anywhere. · Robust team interaction e.g. information sharing and collaborative design.	· Seamless inter-enterprise integration
R1.3 Client Engagement Tools (Involvement, end-user satisfaction, value)	· Requirements management tools (to help with identifying & capturing the client's needs and allow them to transparently see how their requirements are transformed to best-in-class solutions)	· Compliance assessment tools (to ensure the final asset meets the customer's aspirations) · Streamlined client approvals	· Decision support tools e.g. to demonstrate to clients the performance of their asset before they decide to construct ('Try before you buy'); or to test alternative courses of action ('What is?' analysis) · Customer-orientated configuration design
R1.3 Whole-life Asset Management Tools (Cost, environment, society)	· Building MOT's (i.e. periodic independent inspections to check assets are performing above a minimum required standard). · Socio-economic modelling (to improve sustainable community development, predict effects of investment, and understand the system).	· Whole-life value tools to include all environmental costs (to provide a clear business case for addressing environmental issues). · Comprehensive eco-efficiency evaluation tools for all stages of the asset lifecycle (providing ready assessment of environmental performance against best practice).	· Total lifecycle is supported by ICT tools/services for whole-life decision making, management & appraisal, by users, owners and society.
Research/Enablers			
Short		Medium	Long
· Research & develop socio-economic models · Requirements management—research ICT tools to capture the clients' requirements and transform them into technical solutions · Research & develop use of active & passive wireless sensors & RFID · Investigate how to (most easily and economically) retrofit intelligent sensors/systems into existing building stock		· INTEROPERABILITY ENABLERS · REMOTE WORKING & CONNECTIVITY TECHNOLOGIES ENABLERS · Compliance assessment—Research ICT-based verification tools, where technical solutions can be (automatically) verified against the set performance requirements (e.g. client's brief, design standards) ensuring there are no defects in the final product · Use of BIM for client approval	· INTEROPERABILITY ENABLERS · REMOTE WORKING & CONNECTIVITY TECHNOLOGIES ENABLERS · ASSET LIFECYCLE INFORMATION SYSTEM ENABLERS (i.e. date model for lifecycle of asset, with single point data capture) · Research & development of new visualisation, virtual reality and communication tools/techniques using

· Research the use of transaction monitors to automatically compliance check electronic information/documentation across collaborative platforms · Research and publish more forward-looking building regulations/design standards (currently based on retrospective data, that is becoming rapidly out-of-date due to current trends in climate change) · Better understand, & communicate, the relationship between long-term lifecycle costs and initial facility costs · Research & develop embedded intelligence in products & components · Legal and contractual governance and agreements on practical procedures for ICT based collaboration e.g. model contracts · Identify and address organisational and personal barriers to the adoption of ICT based collaboration (i.e. culture) · Develop standardised management processes for ICT collaboration between designers, suppliers, contractors, end-users and other stakeholders.	· Research & develop ICT and methods for post-occupancy reviews · Develop model-based process/workflow management: intelligent workflow aid; combining product model (PLM) with scheduling, resource planning (ERP) and progress monitoring · Research & develop common platforms, networks and protocols for all systems in buildings to share · Develop ICT to calculate energy used, and compare against design forecasts (from data model) · Research methods for use, monitoring, operation and maintenance with intelligent embedded systems; user and context aware control; and ambient user interfaces e.g. integration of computing into the built environment to facilitate information gathering, such as visible energy use 'metering' (allowing occupiers to measure carbon footprint) · Refocus from the purely technical to include the human element/ attitude (i.e. technology is developing faster than human behaviour is changing) · Facilitate a culture of co-operation and trust (e.g. partnering) between distributed teams, and encourage risk and reward sharing · Create virtual communities using sophisticated applications based on WebDAV (Web-based Distributed Authoring and Versioning) · Research & develop the design of workplaces for more efficient, collaborative and productive working.	shared integrated data models, enabling a 'value' & performance assessment of the asset to take place in many dimensions: e.g. energy consumption, visual impact, functionality, internal environment quality, safety, security, flexibility, operating costs and expected lifetime · Develop optioneering capabilities e.g. climate change 'what if?' analysis (using model simulation, and based on rules and evidence) · Research mass customised system concepts e.g. clients can order buildings like they now buy cars—selecting from a limited number of choices, creating widely different end results.

Draft Roadmap 1 (2015)			
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Research/Enablers		
Short	Medium	Long
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Roadmap 2 + 3

The title Efficient, seamless sharing of information across the built environment stakeholders and ability to interact with Real-Time Information Regardless of Physical Location or Timezone no longer represented the vision of the industry and indeed the elements relating to real-time information have largely been dealt with by wider technological developments. The two roadmaps were renamed Efficient use of information to deliver optimised performance and customer experience across the built environment life cycle.

The products and services had changed significantly to focus on the importance of data in the built environment and the opportunities it opens up. The focus on data management, integrated processes and exploitation and added value of data.

Roadmap 2 + 3

The research and enablers were focussed in the short term on dealing with the issues around data, its ownership, its provenance, its security, governance etc. Once these fundamentals are dealt with the opportunities of innovating off the back of data to eventually deliver robotics and artificial intelligence. In the medium term a considerable amount of skills development will be required to enable the widespread understanding and implementation of the widespread use of data across the sector.

Roadmap 2

DRIVERS

- Construction 2025 drivers
- Reduction in waste
- Reduction in defects
- Increase in productivity
- Reduction in construction time
- Increase in predictability
- Business outcomes e.g. healthcare -> patients, schools -> education

PRODUCTS/SERVICES/TECHNOLOGY

	SHORT	MEDIUM	LONG
Data Management R2.1	• Structuring data that is currently difficult to capture, including text-based data.	• Prioritising data according to length, recognising that will change over time.	
Integrated Processes R2.2	• **Interoperability** • **Standard approach to BIM** over collaborative extranets (allowing distributed management of data model) • **Standards for data & metadata exchange and storage**, object definitions & integrated model servers • Knowledge Management	• **Compatibility and interoperability of software/**systems that are being used throughout all stages of projects (e.g. design, procurement, manufacturing, construction, operation) • **Ontologies & open ICT standards** for the semantic web-based communication throughout the supply chain • **Integrated procurement processes**	
Exploitation and Added Value of Data R2.3	• Design and construction improvements • O&M • Business ??? • End of life/refurbishment/reuse/repurpose	• **Fully automated (model-based) delivery, construction and operating system**—seamlessly integrated with all other project systems e.g. design, PM, finance, controls, etc. (i.e. 'cradle to grave' integrated processes, tools & standards) • **Integrated project management** • Use data to drive better standards and tools and practice	

- Data-based decisions through the asset's lifecycle.
- Full digital/automated asset lifecycle information model.
- Wider societal use and benefit of data for improved outcomes.
- **Asset Lifecycle Information System** (i.e. a fully integrated solution in which the standards, models, etc. are created and developed for a specific asset)
- **Virtual building and infrastructure model**, containing comprehensive as-built data of the building, delivered with building. FM is carried out using this model, e.g. automatic maintenance schedules

Efficient Use of Information Across the Built Environment Through Life Cycle

RESEARCH/ENABLERS

- Demonstrations and pilots of technology using real cases.
- Confidence in data
- Maintenance of data
- Provenance of data
- Security of data
- Controlled rights of access to data (retain ownership of critical data).
- Security of intelligent infrastructure assets e.g. wind farms
- Governance of data

- Benchmarking data against similar datasets
- Open data to a wider audience including uses and research and development
- Semantic data—capture data that may be useful in the future.
- Find ways to capture and process that data.
- Establish links between data and building/asset performance.

<u>Robots and artificial intelligence:</u>

- Role in delivery and operations
- Machine-based learning etc.
- Link to automated off-site manufacture

Roadmap 3

DRIVERS

- Construction 2025 targets
- Real-time progress/feedback
- TOTEX
- Whole-life assets

PRODUCTS/SERVICES/TECHNOLOGY

	SHORT	MEDIUM	LONG
Global Project Delivery Systems R3.1	• Cloud storage • Software integration • Resourcing/internal systems for BIM • Apps	• Data analytics for improvements and efficiency • IoT	• Machine 2 Machine • Robotics, automation • Full asset connection at 'city level'
Connectivity Technologies R3.2	• Sensor optimisation • Interoperability • BSI Smart Cities • Cyber security standards and connection conflicts	• Open source data satellite connection • Monitoring of systems (people, buildings, assets)	• Integrated sensing technologies/analysis • Self-healing/optimising systems

Improved Customer Service
Optimised Performance
Adaptability

RESEARCH/ENABLERS

• BIM demonstrations/research to inform and validate • Cyber security • CIC—data in infrastructure • Business models to drive change and release value of new technologies • Enable optimised solutions on-site to feedback into new assets and business improvement	• Modelling/simulation to validate automated data updates • Analysis skills (human and automation) • Inter-industry collaboration and connection of data and technology use • Local response to wider performance need • Machine learning • Optimised asset energy and resource use • Social/physical research on real benefits and acceptance	• Self-sacrifice • MEMS • Self ???

Roadmap 2+3 (2015)			
Title	Efficient use of information to deliver optimised performance and customer experience across the built environment life cycle		
Drivers	· Construction 2025 targets · Reduced waste, defects, construction time · Increased productivity, transparency and predictability · Whole life approach to asset management (Buildings & Infrastructure) · Focus on business outcomes for users e.g. schools to deliver better education outcomes		
Products/Services/ Technologies	Short	Medium	Long
R2.1 Data Management	· Structuring data that is currently difficult to capture, including text-based data · Cloud storage	· Prioritising data according to length, recognising that will change over time · Data analytics for improvements and efficiency	· Data-based decisions through the asset's lifecycle. · Full digital/automated asset lifecycle information model. · Wider societal use and benefit of data for improved outcomes. · Machine2Machine · Full asset connection at 'city level' · Integrated sensing technologies/analysis · Self-healing/optimising systems · Asset Lifecycle Information System (i.e. a fully integrated solution in which the standards, models, etc. are created and developed for a specific asset) · Virtual building and infrastructure model, containing comprehensive as-built data of the building, delivered with building. FM is carried out using
R2.2 Integrated Processes	· Interoperability · Software integration · Skills/Resources/Internal systems for BIM · Applications	· Integrated procurement processes · IoT · Open source data satellite connection · Monitoring of systems (people, buildings, assets)	

	· BSI Smart Cities · Cyber security standards · Standard approach to BIM over collaborative extranets (allowing distributed management of data model) · Standards for data & metadata exchange and storage, object definitions & integrated model servers · Knowledge Management	· Compatibility and interoperability of software/systems that are being used throughout all stages of projects (e.g. design, procurement, manufacturing, construction, operation) · Ontologies & open ICT standards for the semantic web-based communication throughout the supply chain	this model, e.g. automatic maintenance schedules
R2.3 Exploitation and Added Value of Data	· Design and construction improvements · Operation & Management processes · Business models to exploit data · End of life/refurbishment/reuse/repurpose	· Fully automated (model-based) delivery, construction and operating system—seamlessly integrated with all other project systems e.g. design, PM, finance, controls, etc. (i.e. 'cradle to grave' integrated processes, tools & standards) · Integrated project management · Use data to drive better standards and tools and practice	

Research/Enablers		
Short	Medium	Long
· Demonstrations and pilots of BIM using real cases to inform and validate tools · Confidence in data · Maintenance of data · Provenance of data · Security of data · Controlled rights of access to data (retain ownership of critical data). · Security of intelligent infrastructure assets e.g. wind farms · Governance of data · Business models to drive change and release value of new technologies	· Benchmarking data against similar datasets · Open data to a wider audience including uses and research and development · Semantic data—capture data that may be useful in the future. · Find ways to capture and process that data. · Establish links between data and building/asset performance · Modelling/simulation to validate automated data updates · Analysis skills (human and automation) · Inter-industry collaboration and connection of data and technology use · Local response to wider performance need	Robots and artificial intelligence: · Role in delivery and operations · Machine-based learning etc. · Link to automated off-site manufacture · Self-sacrifice · MEMS

· Enable optimised solutions on-site to feedback into new assets and business improvement	· Machine learning · Optimised asset energy and resource use · Social/physical research on real benefits and acceptance	

Roadmap 2 (2007)			
Title	Efficient, Seamless Sharing of Information Across the Built Environment Stakeholders		
Drivers	· Reduction in waste · Reduction in defects · Increase in productivity · Reduction in construction time · Increase in predictability · Reduction in O&M costs		
Products/Services/ Technologies	Short	Medium	Long
R2.1 Digital Models	· Integrated nD models (for use/development throughout the project lifecycle) · Design software based on digital modelling technologies (with visualisation and decision support tools)	· Virtualised/simulated built environments (incl. construction/manufacturing simulation) as standard service · Product and production optimisation tools · Model based services: new business opportunities enabled by model-based date e.g. design, analysis, estimation, visualisation, simulation etc. (computer-interpretable information allows highly specialised services using sophisticated software to become feasible)	· Asset Lifecycle Information System (i.e. a fully integrated solution in which the standards, models, etc. are created and developed for a specific asset) · Virtual building model, containing comprehensive as-built data of the building, delivered with building. FM is carried out using this model, e.g. automatic maintenance schedules
R2.2 Interoperability (Availability of existing	· Interoperability · Standard approach to BIM over collaborative extranets (allowing distributed management of data model)	· Compatibility and interoperability of software/systems that are being used throughout all stages of projects (e.g. design, procurement, manufacturing, construction, operation)	

information for new purposes without re-entering)	· Standards for data & metadata exchange and storage, object definitions & integrated model servers · Knowledge Management	· Migration from data/file exchange to data sharing · Ontologies & open ICT standards for the semantic web-based communication throughout the supply chain · Intelligent documents (codes, standards, legislation)	
R2.3 Integrated Processes (Design, procurement, construction, FM, PM, cost, risk, programme etc.)	· Model-based individual tools e.g. risk assessment, design etc.	· Fully automated (model-based) procurement system—seamlessly integrated with all other project systems e.g. design, PM, finance, controls, etc. (i.e. 'cradle to grave' integrated processes, tools & standards) · Integrated project management	
R2.4 Knowledge Management	· IPR protection of complex, shared data	· Develop and maintain a shared, industry-wide knowledge base of reference information	· ICT for capturing unstructured project data & experiences, and transforming them into sustainable corporate assets

Research/Enablers		
Short	Medium	Long
· Develop real-time technical and schedule management tools (instant visibility of progress and variances), including the hardware, software and communication links, to allow real-time transmission of site progress to the 4D model · Develop real-time cost management tools · Develop a simple Facilities Management (FM) navigation tool to source key information · Research & develop ICT for capturing unstructured project data · Specify and develop fully digitised, unique and personalised, universal electronic cards, which	· Create open standards as required for the data model and for business processes and best practices · Develop fully integrated, semantic web & web services technologies i.e. additions of intelligence & annotations to web content to facilitate retrieval & interpretation by different applications (both human & computer-driven) · Specify & develop infrastructures, model-based applications & Smart agents, which are based on open standards, grammar/syntax, ontologies & content · Develop open object-orientated ontologies & model servers	· Develop real-time technical and schedule management tools (instant visibility of progress and variances), including the hardware, software and communication links, to allow real-time transmission of site progress to the 4D model · Develop real-time cost management tools · Develop a simple Facilities Management (FM) navigation tool to source key information · Research & develop ICT for capturing unstructured project data

Research/Enablers		
Short	Medium	Long
will be shipped with the products, and manage the information structuring and integration for the product, and allow traceability of all parts of the final end product	· Develop 3D product definitions, and specifications (for automated procurement) · Research method for using output from design systems to link with suppliers' network, and identify need for restructuring of the supply chain · Research methods to integrate engineering, project controls, financial systems and procurement work processes and supporting tools · Research model-based applications, and interfaces for communication with other applications · Research & develop model checking tools—for validating model data against standards, regulations, design rules, contracts etc. with notification of identified conflicts and, when possible, suggesting corrective measures · Define and develop an 'Integrated Model server' (providing common access to databases with geometry, for sharing product model data) · Develop object databases e.g. product/component libraries (providing consistency and re-use of correct information) · Research how to use information on construction products & materials (in the form of standard coded data e.g. IFC—Industry Foundation Classes) better · Research whether DWF could be used as alternative to IFC · Need technology take-up and feedback along the whole supply chain	· Specify and develop fully digitised, unique and personalised, universal electronic cards, which will be shipped with the products, and manage the information structuring and integration for the product, and allow traceability of all parts of the final end product

Draft Roadmap 2 (2015)			
Title	Efficient Use of Information Across the Built Environment Through Life Cycle		
Drivers	· Construction 2025 drivers · Reduction in waste, defects and construction time · Increase in productivity and predictability · Focus on business outcomes for users e.g. schools to deliver better education outcomes		
Products/Services/ Technologies	Short	Medium	Long
R2.1 Data Management	· Structuring data that is currently difficult to capture, including text-based data	· Prioritising data according to length, recognising that will change over time	· Data-based decisions through the asset's lifecycle. · Full digital/automated asset lifecycle information model. · Wider societal use and benefit of data for improved outcomes. · Asset Lifecycle Information System (i.e. a fully integrated solution in which the standards, models, etc. are created and developed for a specific asset) · Virtual building and infrastructure model, containing comprehensive as-built data of the building, delivered with building. FM is carried out using this model, e.g. automatic maintenance schedules
R2.2 Integrated Processes	· Interoperability · Standard approach to BIM over collaborative extranets (allowing distributed management of data model)	· Compatibility and interoperability of software/systems that are being used throughout all stages of projects (e.g. design, procurement, manufacturing, construction, operation)	

	· Standards for data & metadata exchange and storage, object definitions & integrated model servers · Knowledge Management	· Ontologies & open ICT standards for the semantic web-based communication throughout the supply chain · Integrated procurement processes	
R2.3 Exploitation and Added Value of Data	· Design and construction improvements · Operation & Management processes · Business models to exploit data · End of life/refurbishment/reuse/repurpose	· Fully automated (model-based) delivery, construction and operating system—seamlessly integrated with all other project systems e.g. design, PM, finance, controls, etc. (i.e. 'cradle to grave' integrated processes, tools & standards) · Integrated project management · Use data to drive better standards and tools and practice	

Research/Enablers		
Short	Medium	Long
· Demonstrations and pilots of technology using real cases. · Confidence in data · Maintenance of data · Provenance of data · Security of data · Controlled rights of access to data (retain ownership of critical data). · Security of intelligent infrastructure assets e.g. wind farms · Governance of data	· Benchmarking data against similar datasets · Open data to a wider audience including uses and research and development · Semantic data—capture data that may be useful in the future. · Find ways to capture and process that data. · Establish links between data and building/asset performance.	Robots and artificial intelligence: · Role in delivery and operations · Machine-based learning etc. · Link to automated off-site manufacture

Roadmap 3 (2007)			
Title	Ability to Interact with Real-Time Information Regardless of Physical Location or Timezone		
Drivers	· Increase in productivity · Reduction in waste · Reduction in construction time · Reduction in capital cost		
Products/Services/ Technologies	Short	Medium	Long
R3.1 Remote Working Technologies	· Enhanced 'telepresence'/'virtual co-location'/'virtual site visits' technologies · Single comprehensive tool (light and robust, with multiple applications) for mobile work (possibly 'wearable' device), which delivers just-in-time information in an optimal format · Digital pens/paper	· Completely digitised sites, where intelligent terminals on machines and individuals give all site stakeholders ubiquitous context-based, geo-reference and permanent access to information	· Ambient access to all asset information (stored within an Asset Lifecycle Assessment System) is available to all stakeholders, anytime and anywhere
R3.2 Connectivity Technologies	· Improved mobile/site networks and systems for the efficient connection of mobile sites to corporate information networks · Developed WiMAX & Wide Area WiFi technologies	(To be determined at future roadmap reviews)	(To be determined at future roadmap reviews)
Research/Enablers			
Short		Medium	Long

· Investigate advanced possibilities offered by wireless or mobile communication technology (incl. potential WiMAX and wide area WiDi) · Research and develop enhanced 'telepresence' technologies, and implementing their wider use (both in the workplace and from home) - giving increased flexibility or working and reduced travelling · Embed & promote the use of existing 'virtual co-location' technologies (e.g. video conferencing technology, webinars, etc.) in the industry · Define & develop infrastructure requirements to support site working · Research & develop better viewing capabilities for PDAs etc. · Research & develop remote management of data/process via PDAs etc.	· INTELLIGENT ASSETS ENABLERS · Develop GPS (or similar) to deliver data to on-site staff · Research & develop a 'virtual site visits' capability (e.g. network of webcams linked to digital model of site, real-time BIM, etc.) · Identification & development of 'new' human interface technologies · Further research/enablers to be determined at future roadmap reviews	· ASSET LIFECYCLE INFORMATION SYSTEM ENABLERS · Further research/enablers to be determined at future roadmap reviews

Roadmap 3 (2015)			
Title	Improved Customer Service Optimised Performance Adaptability		
Drivers	· Construction 2025 targets · Real-time progress/feedback · TOTEX · Whole-life assets		
Products/Services/ Technologies	Short	Medium	Long
R3.1 Global Project Delivery Systems	· Cloud storage · Software integration · Skills/resourcing/internal systems for BIM · Applications	· Data analytics for improvements and efficiency · IoT	· Machine 2 Machine · Robotics, automation · Full asset connection at 'city level'
R3.2 Connectivity Technologies	· Sensor optimisation · Interoperability · BSI Smart Cities · Cyber security standards	· Open source data satellite connection · Monitoring of systems (people, buildings, assets)	· Integrated sensing technologies/analysis · Self-healing/optimising systems

Research/Enablers		
Short	Medium	Long
· BIM demonstrations/research to inform and validate · Cyber security · CIC—data in infrastructure · Business models to drive change and release value of new technologies · Enable optimised solutions on-site to feedback into new assets and business improvement	· Modelling/simulation to validate automated data updates · Analysis skills (human and automation) · Inter-industry collaboration and connection of data and technology use · Local response to wider performance need · Machine learning · Optimised asset energy and resource use · Social/physical research on real benefits and acceptance	· Self-sacrifice · MEMS

Roadmap 4

The drivers for Roadmap 4 Mass adoption and application of flexible, off-site manufacturing, automation and mechanisation processes and systems remained valid. To enable the effective uptake of off-site manufacturing the importance of configuration to meet customers requirements with the eventual introduction of fully flexible automation and design for manufacture and assembly to suit customer choice.

A digitally enabled workforce was critical for the long-term vision of flexible, digitally driven automated assembly sites. Greater visibility of components across the supply chain is seen as the first step towards integration of on and offsite delivery systems.

The importance of data was again recognised as was the potential role of advanced robotics and autonomous vehicles.

Roadmap 4

DRIVERS

- Reduction in waste
- Increase in productivity
- Reduction in accidents
- Reduction in construction time
- Increase in predictability

PRODUCTS/SERVICES/TECHNOLOGY

	SHORT	MEDIUM	LONG
Off-Site Manufacturing R4.1	• **Design for efficient manufacture**/off-site construction/pre-fabrication and pre-assembly , to be in common use. • Definable components and interfaces to allow configurations of customers' solutions.	• Standardised processes and partial introduction of automation to drive efficiency.	• Full flexible automation and design for manufacture and assembly to suit customer choice.
On-Site Automation R4.2	• Codifying construction activity and processes. • Simulating to drive predictability (4D BIM). • Digitally enabled workforce.	• Digitally connected plant, equipment and people for ??? automation of process to drive efficiency.	• Flexible, digitally driven automated assemble sites.
Intelligent Logistics R4.3	• Integrated view of component status across the supply chain.	• Simulated and optimise d component movements. • Automated processes, including condition monitoring.	• Integration of on and off-site delivery systems, including autonomous vehicles.

Mass Adoption & Application of Flexible, Off-Site Manufacturing, Automation & Mechanisation Processes & Systems

RESEARCH/ENABLERS

- INTELLIGENT ASSETS ENABLERS
- Adaptation of new concepts developed by other manufacturing industries (e.g. automotive & aerospace)
- Research materials to simplify, reduce cost, improve H&S, etc. for automated off-site fabrication an on-site erection
- Development & deployment of solutions (e.g. RFID) and services to identify & track on-site materials from delivery to in-situ. To include intelligent materials/products/smart coatings, capable of communicating location, orientation & condition for the lifecycle of the asset
- Define and document best practices for supply chain production, logistics, validation, and information flows to identify inefficiencies and bottlenecks and highlight improvement opportunities
- Produce construction automation guidelines
- Introduction of new services offered by satellites & GPS for site control (e.g. positioning construction equipment, and for monitoring works and their impact)
- Design new connection methods to enhance scope for automation
- Organising data aligned with components and production processes
- Standards for digital data exclusively for manufacturing and assembly processes.

- INTEROPERABILITY ENABLERS
- INTEGRATED PROCESSES ENABLERS
- Develop logistics and process monitoring/management tools (including tagging technology) to automate tracking of actual vs. planned progress
- Research use of GIS to manage site data and logistics
- Investigate rationalisation of construction processes, with focus on off-site assembly of large, fully-fitted components
- Research the automation of construction plant & equipment ('Intelligent site vehicles' & robotics), and mechanisation of site activities aided by new automation and guidance technologies, including advanced embedded electronics
- Research process orchestration e.g. flow of resources for optimal build efficiency
- Integrate and automate supply chain work processes and job site delivery and tracking of materials and labour
- Research & develop distributed production management
- New businesses models and supply chain relationships
- Opportunities for exporting high value construction IP.

- Research the transfer of Building Information Modelling (BIM) to manufacturing/virtual production
- Investigate the use of integrated data models (BIM) to facilitate modularisation
- Advanced robotics
- Autonomous vehicles

Roadmap 4 (2007)			
Title	Mass Adoption & Application of Flexible, Off-Site Manufacturing, Automation & Mechanisation Processes & Systems		
Drivers	· Reduction in waste · Increase in productivity · Reduction in accidents · Reduction in construction time · Increase in predictability		
Products/Services/ Technologies	Short	Medium	Long
R4.1 Off-Site Manufacturing	· Design for efficient manufacture/off-site construction/pre-fabrication and pre-assembly , to be in common use. · Definable components and interfaces to allow configurations of customers' solutions.	· Standardised processes and partial introduction of automation to drive efficiency.	· Full flexible automation and design for manufacture and assembly to suit customer choice.
R4.2 On-Site Automation	· Standardised construction processes and components e.g. modular provision of customised (prefabricated) constructions, logistics, assembly and services · Materials for automated manufacture and erection	· Completely digitised sites, where intelligent terminals on machines and individuals give all site stakeholders ubiquitous context-based, geo-referenced and permanent access to information	· On-site robotic assembly (especially for hazardous or monotonous work) - providing safer (more controlled) working environments, and improved site working conditions
R4.3 Intelligent Logistics	· Embedded ICT in products: Real-time traceability of materials & components on the construction site. Electronic 'how to build' information delivered with the product · Real-time tracking of construction plant & equipment to optimise site logistics.	· Integrated supply chain/improved supply chain management (to improve procurement efficiency and performance, allowing 'Just In Time' logistics)	(To be determined at future roadmap reviews)
Research/Enablers			
Short		Medium	Long

· INTELLIGENT ASSETS ENABLERS · Adaptation of new concepts developed by other manufacturing industries (e.g. automotive & aerospace) · Research materials to simplify, reduce cost, improve H&S, etc. for automated off-site fabrication an on-site erection · Development & deployment of solutions (e.g. RFID) and services to identify & track on-site materials from delivery to in-situ. To include intelligent materials/products/smart coatings, capable of communicating location, orientation & condition for the lifecycle of the asset · Define and document best practices for supply chain production, logistics, validation, and information flows to identify inefficiencies and bottlenecks and highlight improvement opportunities · Produce construction automation guidelines · Introduction of new services offered by satellites & GPS for site control (e.g. positioning construction equipment, and for monitoring works and their impact) · Design new connection methods to enhance scope for automation	· INTEROPERABILITY ENABLERS · INTEGRATED PROCESSES ENABLERS · Develop logistics and process monitoring/management tools (including tagging technology) to automate tracking of actual vs. planned progress · Research use of GIS to manage site data and logistics · Investigate rationalisation of construction processes, with focus on off-site assembly of large, fully-fitted components · Research the automation of construction plant & equipment ('Intelligent site vehicles' & robotics), and mechanisation of site activities aided by new automation and guidance technologies, including advanced embedded electronics · Research process orchestration e.g. flow of resources for optimal build efficiency · Integrate and automate supply chain work processes and job site delivery and tracking of materials and labour · Research & develop distributed production management	· Research the transfer of Building Information Modelling (BIM) to manufacturing/virtual production · Investigate the use of integrated data models (BIM) to facilitate modularisation

Roadmap 4 (2015)			
Title	Mass Adoption & Application of Flexible, Off-Site Manufacturing, Automation & Mechanisation Processes & Systems		
Drivers	· Reduction in waste · Increase in productivity · Reduction in accidents · Reduction in construction time · Increase in predictability		
Products/Services/ Technologies	Short	Medium	Long
R4.1 Off-Site Manufacturing	· Design for efficient manufacture/off-site construction/pre-fabrication and pre-assembly , to be in common use. · Definable components and interfaces to allow configurations of customers' solutions.	· Standardised processes and partial introduction of automation to drive efficiency.	· Full flexible automation and design for manufacture and assembly to suit customer choice.
R4.2 On-Site Automation	· Codifying construction activity and processes. · Simulating to drive predictability (4D BIM). · Digitally enabled workforce.	· Digitally connected plant, equipment and people for automation of process to drive efficiency.	· Flexible, digitally driven automated assembly sites.
R4.3 Intelligent Logistics	· Integrated view of component status across the supply chain.	· Simulated and optimise d component movements. · Automated processes, including condition monitoring.	· Integration of on and off-site delivery systems, including autonomous vehicles.
Research/Enablers			
Short		Medium	Long

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