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Briefing: Knowledge and information management for major projects

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This article identifies the issues facing the adoption of best practice on information management for major projects and the practical steps needed to address the knowledge gap. A number of projects were consulted by the authors in preparing the article.

1. A STANDARD AND CONSISTENT METHOD FOR PROJECT, DESIGN AND DATA MANAGEMENT FOR THE WHOLE LIFE CYCLE

Collaborative working in an integrated team environment has the ability to overcome the known problems associated with the construction industry.

(*a*) Lack of coordinated construction documentation.
(*b*) Increased resource to deal with problems at site level.
(*c*) Increased cost.
(*d*) Increased time to delivery.
(*e*) Constant rework and therefore reduced quality.
(*f*) Inability to capture design and construction data for reuse.
(*g*) Lack of quality and quantity in the data set for management and maintenance of the facility.
(*h*) Increased cost of the facility in its lifetime.
(*i*) Constant waste of energy/time in construction and project life cycle.

Even though the problems have been researched and well documented over the past decades not enough has been done in establishing a common industry approach to overcoming the problems on a regular basis.

On major capital facilities where project longevity is part of the development activity it is even more essential that past knowledge and guidance is introduced at the earliest possible time in the project's life cycle. This means introducing the needs for the delivery of the project information/knowledge as an asset for future use and development of the facility.

It must be procured at the outset of the project.

2. HISTORY—INDUSTRY STANDARDS AND STANDARD PROCEDURES

Over the past century the construction industry has accepted that all information used for construction purposes is inaccurate, ambiguous and incomplete; 'It is quite impossible for the surveyor to take out quantities from drawings such as sometimes come from the architect's offices, imperfectly finished and possibly incorrect'.[1]

This situation has not changed over the last century even with the introduction of infinitely accurate computer-aided design (CAD) systems that promise quality information.

More recently the UK Construction Project Information Committee (CPIC) and the Building Services Research and Information Association (BSRIA) have carried out research[2,3] that shows that nothing has changed and the Latham[4] and Egan[5] reports in the 1990s continued this theme with the statements that our industry is inefficient. The value placed on this is 20–25% of final project cost.

During 1987, CPIC published a procedure in an attempt to put some form of standardisation and integration into the delivery of a consistent construction data set. It republished this document in 2003 as *Production Information 'a Code of Procedure for the Construction Industry'*.[6] This has brought together the latest best practices, leaning heavily on research carried out on the BAA Lynton Endeavour House project, previously implemented on the Heathrow Express project and the 'DOME' and more recently on the successful information services/information technology (IS/IT) strategy at Terminal 5. All of these projects have been and will be delivered on time and on cost.

During the last three years these best practices have been further tested on the Department of Trade and Industry (DTI)-sponsored Avanti project[7] where the standard, method and procedure have returned significant savings to the whole supply chain and to the project delivery.

3. BACKGROUND TO INFORMATION NEEDS

This paper sets out the background to the needs for change to current working practices of knowledge and information management on major projects to support the whole life cycle from project inception to operations and maintenance and disposal/change of use of the facility.

To understand why some projects are successful in implementing information management strategies a group of

* This document constitutes the Institution of Civil Engineers ICT Panel Draft Guidelines, Version 2.1.

leading industry practising experts within the Institution of Civil Engineers (ICE) held a number of workshops where the knowledge from key UK major projects was captured together with input from Avanti, leading consultants' experience and academia. The objectives of the workshops were to capture best practice and provide a practical set of information management guidelines.

It is evident from this research that there have been a number of very successful projects that have shown how to successfully implement information management that promotes the reuse and spatial coordination of information throughout the whole design-and-build process. This approach creates a valuable asset on completion and handover for successful operations and maintenance without the need to go out and recapture the information. This can be best understood by considering Fig. 1.

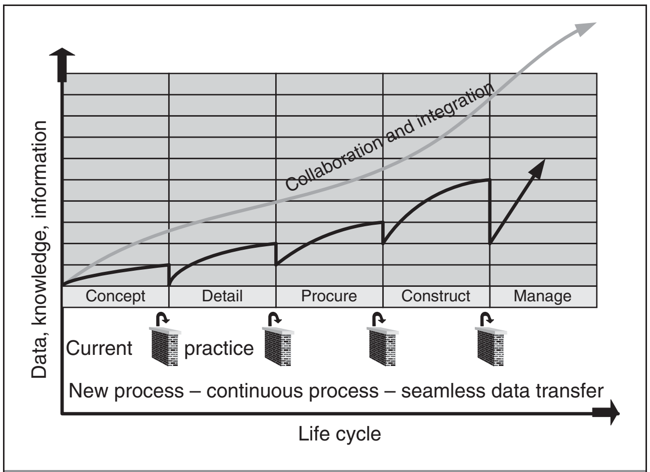

Fig. 1. Change from current business process to new business process

Current business processes on projects operate in silos the activities in the project life cycle. The design teams in particular work with a given fee base and continue to deliver the same package of work without understanding or delivering data and information that meets the needs of their client, the receiver of their information. Typically this is drawing not model based.

Individual standard forms of contracts in operation in the UK construction industry, based on Royal Institute of British Architects (RIBA), Association for Consultancy and Engineering (ACE) and BSRIA documents, specify that none of these disciplines are necessarily responsible for spatial coordination—the prime need of the contractor if the project is to be built first time. There is little need to collaborate except via the traditional methods of drawings which only capture a part of the overall information. Every time information is delivered something is lost, or thrown away, to the receiver and the project. This not only provides higher levels of risk throughout the project build process but also has been to shown to add costs to the overall project delivery and maintenance.

To change the industry and improve the flow of information new business processes are needed that remove the walls that exist between companies and adopt a collaborative approach within a revised overall contractual framework. The new business process requires that each part of the supply chain delivers a consistent set of data and information that can be reused by the recipients and enriched before passing on to the next. This new business process forms the basis of the work listed below and the benefits that have been achieved.

This process in its ultimate form requires a database for project information management. Fig. 2 lists the extracted benefits of a fully managed project information management system based on a data-centric process.

It is accepted by those companies involved in these projects that the combined benefits of a project information management solution with the adoption of an information management

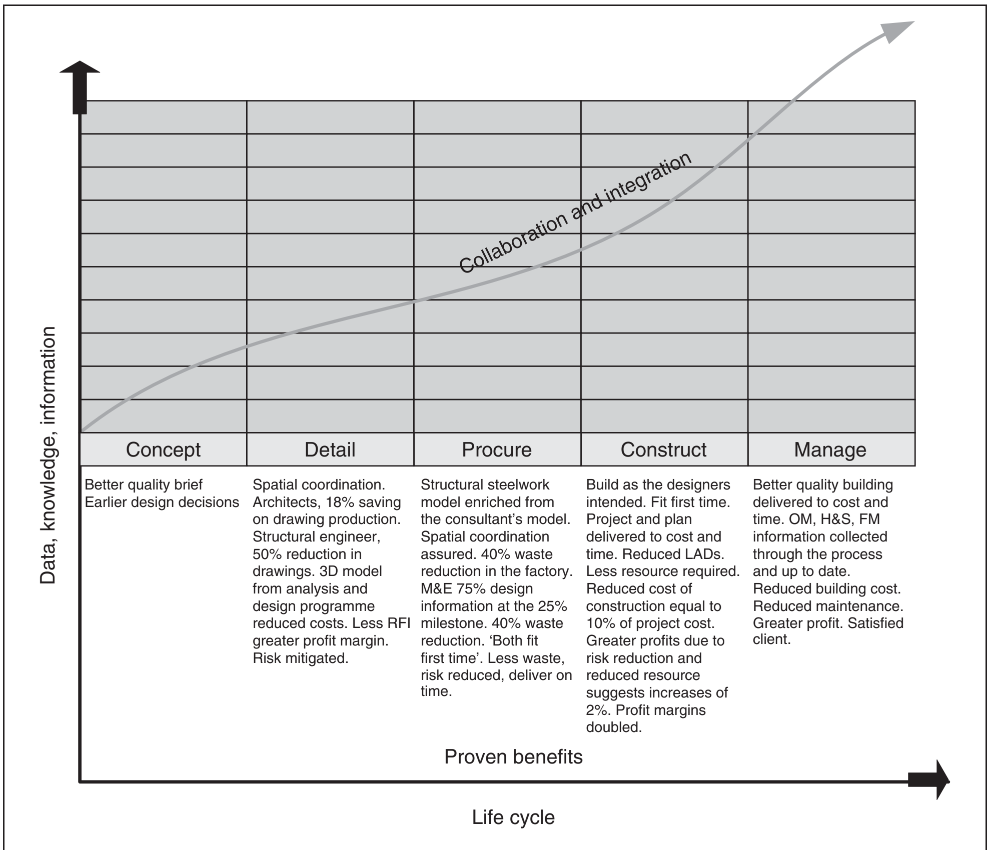

Fig. 2. The effects of changes to current business process when applying new collaborative processes (FM, facilities management; LAD, liquidated and ascertained damages; OM, operations manual; H&S, health and safety). © MR1 Consulting Ltd 2007, reproduced with permission

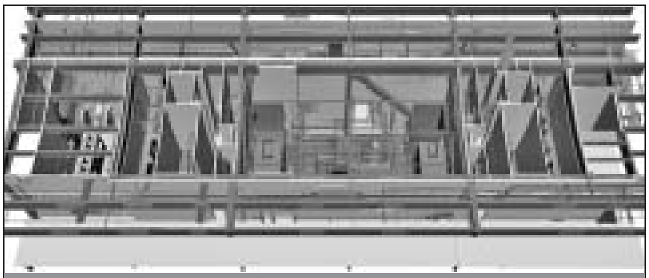

Fig. 3. Example of the model approach during the process from BAA—T5 (© BAA, reproduced with permission)

strategy will put 2–3% of final construction cost on the contractor's bottom line. For most that would be a 100% increase in margin.

4. PROJECTS CONSULTED

All of the examples listed below have been tested using new business processes. The new business process is based on the abilities of the supply chain to share data throughout the project rather than by continually rekeying information developed in a previous design and development stage. In traditional practices, data, knowledge and information are lost as each deliverable is met and the project moves into the next work stage. New business processes continually enhance and enrich the data throughout the project by sharing and through controlled data management. Some of the projects that have been used are

(*a*) Channel Tunnel Rail Link (now High Speed 1)
(*b*) BAA–Heathrow Express and Terminal 5
(*c*) Basingstoke Festival Place
(*d*) Festival City Dubai
(*e*) Taylor Woodrow St Helens (Avanti)
(*f*) Costains PalaceXchange (Avanti).

5. APPROACH

The paper provides a practical framework that set outs the considerations for ensuring that learning from major projects is used by the industry in the form of an overall information management strategy.

It was identified by the group that there needs to be one set of common industry-wide 'open' standards and procedures adopted on all major projects. This effectively should incorporate standards such as Uniclass[8] (see Section 6.2 below) that are already in place such as developed by CPIC, which built upon a number of live projects, and take into account the work being done on UK spatial frameworks (digital national framework: see Section 6.3 below).

There is a need for early adoption of and implementation of information management standards at the initial stage of a project to ensure that information is captured at the earliest possible opportunity. These need to be incorporated into organisations operating at all levels: industry/company/ individual.

5.1. Common data environment (single model environment)

Key to ensuring that information is collected through the project process is the adoption of a set of common standards, methods and protocol within a central environment. This has been one of the cornerstones of the successful project's delivery. To facilitate the reuse of information it is widely held that the best way forward is to put in place a common data environment (CDE) into which the building information models/data can be placed for coordination into the spatial model. This approach was pioneered through the early 1990s on some BAA projects and led to the creation of the single model environment for the Terminal 5 project (Figs 3 and 4).

(*a*) The CDE is a collaborative environment of developing, managing, exchanging and storing design and construction information.
(*b*) Data are enriched as they are developed and move through the different stages of the design process.
(*c*) The overall philosophy is to ensure there is no duplication throughout the project cycle.
(*d*) The CDE (single model environment (SME)) has been used to great effect in delivering the design for the Terminal 5 project through a single version of the truth (Fig. 5).

5.2. Building on the success of experience to deliver the benefits

Experience has shown that there are real benefits to be obtained by using a common data approach. The notes below summarise the advice built on the experience of setting up a CDE project to succeed. It is by no means comprehensive but covers the basics that will need to be explored and developed.

5.2.1. Essentials

(*a*) A clear set of business objectives.
(*b*) A client who understands the benefits throughout the life cycle and who wants these delivered.
(*c*) Management buy-in, support and championing.
(*d*) Project manager not CAD technician driven.
(*e*) Designers, constructors and asset managers who are committed to the process.
(*f*) A published and agreed project information management strategy.
(*g*) Universal standards driven by international requirements not individual supplier standards.
(*h*) Technical champions who understand the technology but are committed to delivering the project.

5.2.2. Shared common data environment

(*a*) A managed environment that holds project data including CAD.
(*b*) Built to a common standard as a model.
(*c*) Shared project information across all teams throughout the project life cycle.
(*d*) A cumulative data process throughout the life cycle avoiding reworking loss and wastage.
(*e*) An agreed process and protocols for production.
(*f*) Drawings and outputs published only as snapshots.

5.2.3. Standards

(*a*) Data classification.
    (i) Data classified to facilitate design, construction and operation/maintenance.
    (ii) Classified by asset type and component using a system such as that detailed below which is based on Uniclass (see Section 6.2 below) and the digital national framework (Section 6.3 below) for spatial data.

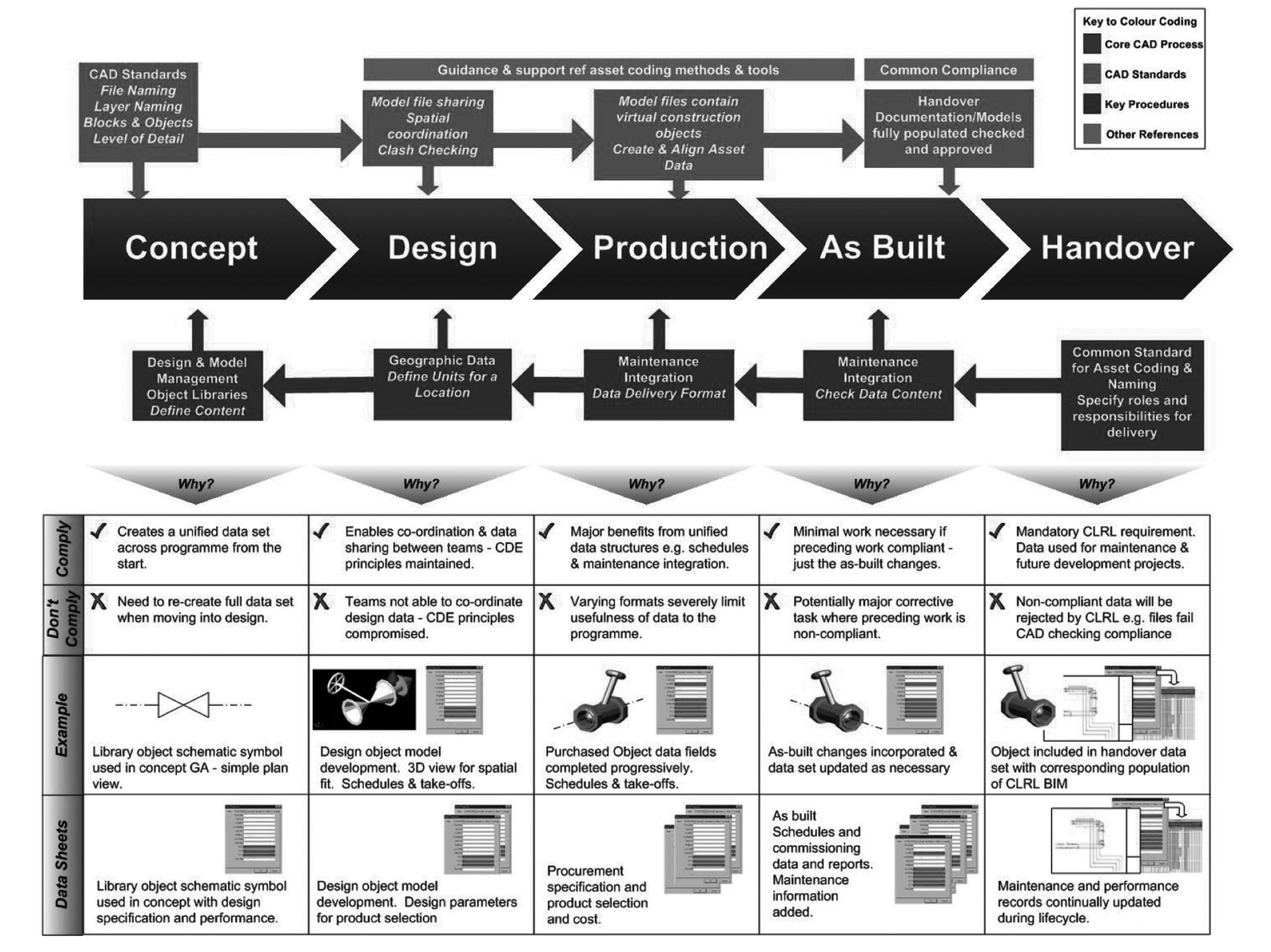

Fig. 4. Benefits of new collaborative processes as tested on the Avanti Programme (GA, general agreement; CLRL, Cross London Rail Links Ltd). © MR1 Consulting Ltd 2007, reproduced with permission

(*b*) Modelling standards.
- (i) Common origins and grids.
- (ii) Declared projections.
- (iii) Layered by classification NOT drawing requirements.
- (iv) Drawn 1:1 real world scale.
- (v) Associative dimensioning only.
- (vi) Two (2-D) and three-dimensional (3-D) modelling where appropriate.
- (vii) Common data format including version of formats.

(*c*) Publishing standards
- (i) Drawing standards based on drawing type as a publication from the CAD common data environment.
- (ii) Publications treated as snapshots of CAD common data environment.

5.2.4. *Information management strategy*

(*a*) Shared common base systems.
(*b*) Data formats.
(*c*) Software versions.
(*d*) Communications protocols.
- (i) File transfer protocol (FTP), disk, ZIP, etc.
- (ii) Data transmission and receipt.
- (iii) Data policing policies.

(*e*) Shared managed data environment.
- (i) A system designed to hold and manage the common data.
- (ii) A system to handle the agreed work processes.
- (iii) A policing system for receiving, checking, accepting, rejecting data from project participants.
- (iv) A system that can handle all the CAD components together with its provenance.
- (v) A system that addresses the needs of both models and drawings.

5.2.5. *Processes and protocols*

(*a*) An agreed set of protocols, workflows and processes.
(*b*) A clearly defined set of roles and responsibilities between the parties involved.

6. INFORMATION STANDARDS FOR CDE

Until now the construction industry has delivered projects based on a paper-based construction documentation practice. This means that what is printed on the paper copy is all the information that will be available to the extended design and construction teams. In an object-oriented, three-dimensional world all information/knowledge can be made available to the whole team at all times as reusable data. To achieve a data set that conforms to the best possible format for reuse, data will need to be consistent and appropriate.

The standard, method and procedure, used to produce the fully integrated 2-D or 3-D building information model and the CDE

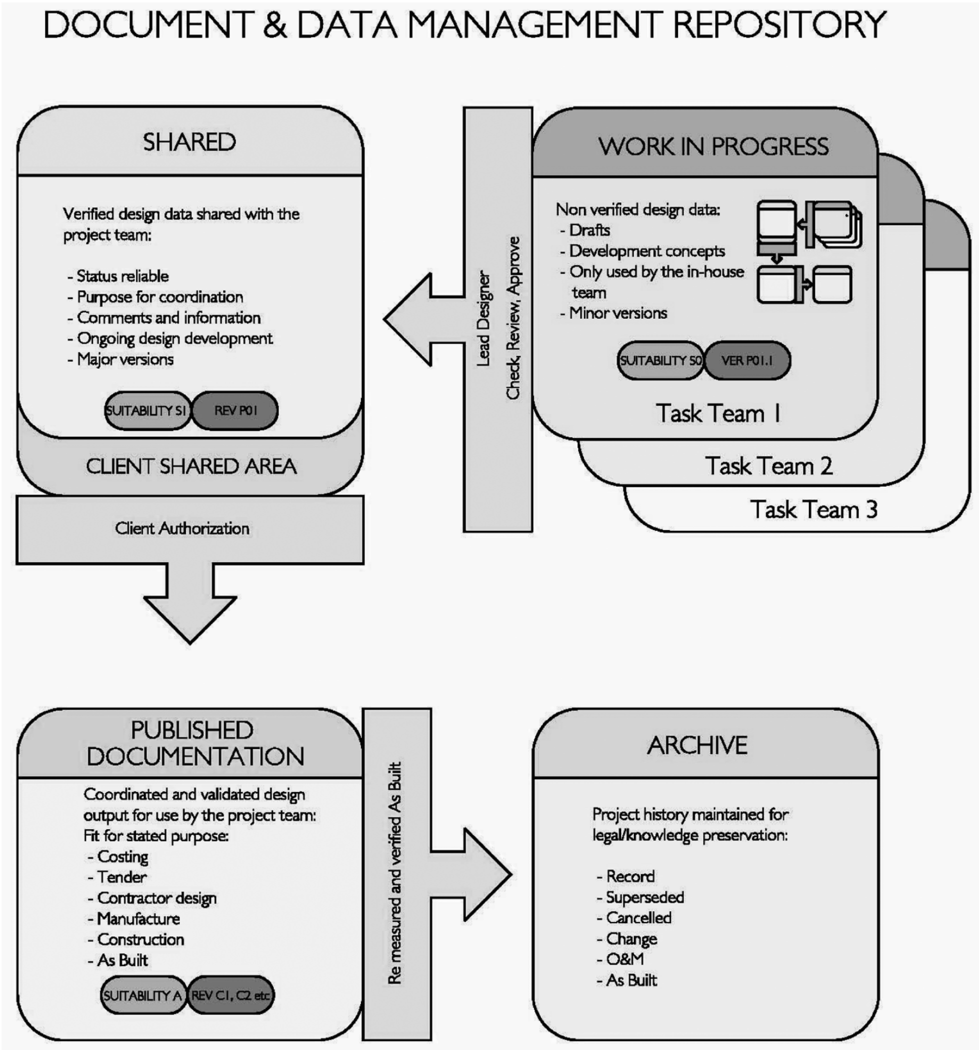

Fig. 5. The collaborative data environment for major projects (scalable for all projects; O & M, operations and maintenance). © MR1 Consulting Ltd 2007, reproduced with permission

will provide guidance on how to achieve this and that guidance relies on a number of key industry standards.

6.1. BS 1192 2007

The BS 1192 standard[9] has recently been revised. It has been brought up to date and supports the approach. It is a prescriptive rather than an informative document. This standard now defines how to name and manage CAD data through layer naming conventions. It provides conventions for file and document naming and eventually will be the source of an object naming convention.[9]

6.2. Uniclass[8]

This is a classification system for building elements and materials owned by CPIC and published by RIBA publications. Uniclass is based on a number of European standards and includes other important schemes.

(*a*) ISO 14177—classification of information in the construction industry.[10]
(*b*) CI/Sfb—construction industry indexing system.[11]
(*c*) Common arrangement for work sections for building works (CAWS).[12]
(*d*) Civil engineering standard method of measurement, third edition (CESMM3).[13]
(*e*) Electronic product information co-operation (EPIC).[14]

Uniclass provides a practical guide and approach to naming building and civil elements and products through an agreed classification as part of the BS 1192 document.[9] The classifications give a consistent method for elements and the ability to granulate those classifications for object reference and drawing methods. These elements can be easily identified and assembled into fully coordinated object models that can be reused for operational aspects. The classifications are currently under review and are being expanded and tested on major projects such as Crossrail Ltd.

The use of Uniclass allows data to be reused as part of a business process that is linked to the generation of building specification and costing.[8]

6.3. Digital national framework[15]

The UK digital national framework (DNF) is an industry standard for integrating and sharing business and geographic information from multiple sources. DNF employs existing ISO

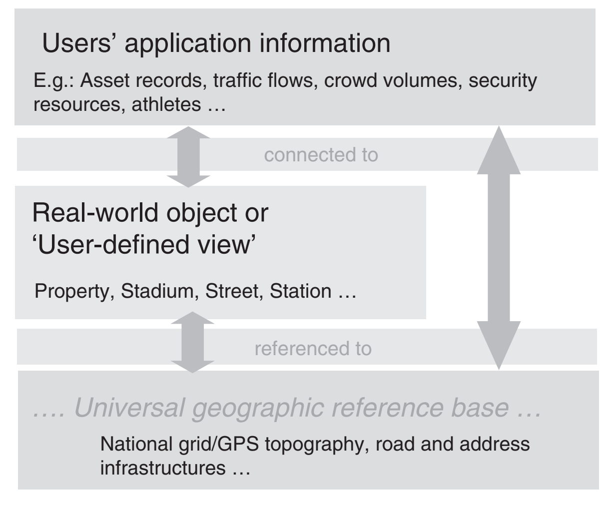

Fig. 6. Digital national framework approach for combining information

and Open Geospatial Consortium standards to support the wider development of a common interoperability spatial framework including the following components.[5]

(*a*) Defined data model components
  (i) basic principles
  (ii) reference model
  (iii) coordinate reference systems and transformations
  (iv) temporal reference models
  (v) object and information association models.

(*b*) Registry—operational components
  (i) unique object identifier management
  (ii) feature/object catalogue and classification schemes
  (iii) terminology
  (iv) information conformance parameters.

(*c*) Best practice components
  (i) metadata
  (ii) information quality
  (iii) information exchange
  (iv) maintenance.

The DNF model utilises the concept of a single data model, to which other 'user views' and user application information can be referenced and attached.

A fundamental goal of DNF is to capture information once and reuse it many times, avoiding costly duplication and maximising progress through the reuse of proven components. This promotes data sharing and improves data integrity in line with users' needs through a single, albeit distributed, data model.

DNF therefore provides a geospatial framework for the coordination and integration of information. This can be used as a platform to position the object data collected in the construction model (Fig. 6).

In the DNF information model, different application views and users' application information are all referenced against a common set of geographic objects such as buildings, roads, rivers, land parcels, and so on, which represent their real-world equivalents.

All of these standards provide a practical way of creating, managing and sharing information throughout the project life cycle to ensure that the value of information is realised.

7. SUGGESTED INFORMATION NEEDED AT END OF PROJECT

Two- and three-dimensional models of the buildings and the local infrastructure need to be fully coordinated within the overall surrounding built environment. Data should be provided according to the standards identified in Section 6 (above) and using the most appropriate technologies.

(*a*) All as-constructed and as-built drawings and model files delivered to an agreed format such as DWG/DXF.
(*b*) All asset information property data attached to the model where possible.
(*c*) Maintenance manuals records in electronic format uniquely identified against the asset identifier.
(*d*) Operational information in electronic format and held in a central database.
(*e*) Both 2-D and 3-D building information models – stadium, properties layered with all of the multi-services.
(*f*) Streets, pathways.
(*g*) Street furniture objects and function.
(*h*) Full 3-D digital terrain model with contoured height models.
(*i*) Infrastructure operations such as public transport (rail bus and underground) services.
(*j*) Location of hotels, restaurants, shops, and so on.
(*k*) Population statistics and demographics.

All these object classes can be accommodated in the DNF model as either base reference objects (such as buildings) or user views (e.g. a collection of buildings, land parcels, paths, streets that make up a stadium) and application information (usage, capacity, quantities, location of events, etc.).

8. INFORMATION MANAGEMENT LEADERSHIP

It is clear from major projects that have been successful in implementation that information management (IM) incorporates the management and stewardship of the project's intellectual property. Successful development and implementation of an IM strategy will deliver value through the whole project life cycle.

(*a*) Reducing risks (e.g. rework both during design and construction).
(*b*) Improving efficiency (e.g. reducing data re-entry).
(*c*) Improving decision support (e.g. progress reporting).

Information management is a combination of people, process and technology. It is central to project success and will involve all project stakeholders. Good IM ensures that the data are accessible when required, and provided at a cost and quality that meets the project's requirements. The following list presents the key points required for successful implementation.

(*a*) The IM strategy should be developed by a team representative of the project and owned by a high-level sponsor from the design team, such as the technical director.
(*b*) The IM team should be integrated with the project controls group and should not be separated out as an information technology team.

(*c*) The IM strategy should align with the overall project requirements, for example are the drivers cost, budget, quality, time?
(*d*) All IM systems should be justified by a compelling business case.
(*e*) All IM systems should be selected on the basis of the optimum team solution rather than on the basis of individual company preference.
(*f*) The IM team should provide clear and open communication lines for interaction with the end-users.
(*g*) The IM team should have clear roles and responsibilities.
(*h*) The benefits, at project, company and individual level, should be well communicated to the team, avoiding 'techie speak'.

9. KEY TO INFORMATION MANAGEMENT USE

(*a*) The IM team should form strong links with all stakeholders and be viewed as an integral part of the project.
(*b*) A whole life-cycle IM approach should be adopted allowing information to be reused at all stages of the project from feasibility through to operations and maintenance.
(*c*) All IM systems adopted should enable full collaboration on information by all members of the project team.
(*d*) All IM systems should be accessible through a single sign-on output/input interface where feasible.
(*e*) Education and training in best practice and policing compliance is critical to any successful major project's adoption of IM throughout the project.

10. COMMUNICATION

Understanding how the information strategy is important to the overall project deliverables is critical in ensuring successful roll-out. Therefore a communication strategy should be developed that sits alongside or is part of the IM strategy. Before this is implemented it may be necessary to conduct an audit of where the understanding currently sits. Key to delivery of the communications piece is to be able to articulate clearly the following requirements.

(*a*) Understanding of the objectives and benefits of the project.
(*b*) Understanding of the audiences that you need to buy in. (It will be necessary to ensure that the audience understanding is not diluted by others over time.) Make sure that it is carried forward through empowerment.
(*c*) Understanding of the message down the whole supply chain.

The communications strategy will need to consider and develop the following items.

(*a*) Channels of communication—website, poster campaign two-way.
(*b*) Timescales for delivery of the communications.
(*c*) Resources to communication strategy implementation.
(*d*) Branding that is readily identified with the project and effective marketing campaigns.
(*e*) Criteria that measure the success to ensure the benefits are realised.

11. PEOPLE, CULTURE AND BEHAVIOURS

There is a need to overcome the cultural, contractual and organisational barriers to adoption of new ways of working and implementing the change needed on major projects. Listed below are a range of issues and barriers that need to be overcome.

(*a*) The adversarial nature of the construction industry and its effects on major projects. Typically at the start of a project, the individual organisations tend to position themselves as thought leaders and also work to maximise each organisation's return from the project. To change this, the industry needs to develop a much greater level of team working around a set of shared goals. It is anticipated that this can only really be achieved through changing the contractual arrangements on a project, building in team working to the work packages, changing the culture of the individuals to ensure they focus on shared delivery rather than personal/organisation objectives.
(*b*) Changing the contractual relationships to address the adversarial nature. Change the current contract structures to be defined around the project that focus on shared delivery and reward with shared bonuses based on delivery within the overall budget(s).
(*c*) Break down the organisational barriers and company cultures. Remove individual organisation silos. Establish cross-business teams without the organisation individual branding. Build the team around specific units of delivery around the project programme.
(*d*) Define the roles and responsibilities separate from the organisations involved, and ensure that they are accountable. Establish job descriptions, deliverables and performance measurements within the context of the project rather than the company.
(*e*) Provide and encourage a project framework for the identification and implementation of change on projects (ideas box). Establish a continuous programme of re-enforcement of change and establish a reward scheme to improve the overall processes across the project.
(*f*) Ensure compliance with roles based around the rules. Once the framework is defined there is a need to put in place a team and technology to ensure that the processes and rules are adhered to. Establish a change request, versioning and update regime to the ways of working.
(*g*) It is often felt that the industry is too 'time' pressured to think! Therefore on major projects there is a need to build in time to do it right. Provide extra time to any task that uses technology as thinking time in the region of 25% of any task. The programme should take planning seriously. Time spent planning is not normally wasted. Failure to plan is planning to fail.
(*h*) Technology is becoming more complex, not simpler. Technology tends to be feature based rather than efficiency and task based. There is now a move to change the tools to make them more process focused. Therefore it is important on major projects to look to involve the key vendors in adopting process improvement technology rather than feature-based improvements. The construction industry needs to recognise that technology is a platform not a solution. How you use it as an organisation is part of the solution.
(*i*) The culture of the project fee base restricts process/ownership of information, particularly at the handover of the project. Establish a reward for data quality handed over at end of project. Use retention on sign-off/completion to ensure this is done in good time at stages throughout the project rather than at the end. Establish downstream operational requirements for asset management well *before*

the project starts to ensure information is captured and reused through the process. Multiple handovers at stages. Whoever owns the data at the end of the day needs to provide the resource and be authorised to reject information that does not meet the requirements. The owner of information is the project.

(*j*) The designers could create information upstream of handover that would improve the reuse of information downstream. The current contractual frameworks tend to restrict this happening. The issue here is payment for spending time upstream to help others downstream. This needs a fundamental shift away from seeing the deliverable as a set of drawings to a model/data/information that can be reused and measured against.

12. MEMBERS OF THE ICE ICT PANEL

This document was created by the people listed below who are members of the ICE ICT Panel and Working Group who have contributed to this paper and have helped develop the standards and working practices referred to in this document.

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Phil Jackson	Bentley Systems ICE IT.
Steve Jolley	Director Carillion and ICE ICT.
Mervyn Richards	Director MR1 Consulting Ltd, Avanti and CIPC.

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