LEXIS – AN AEC INDUSTRY LANGUAGE

Lexis – An AEC industry language

H.G. LESLIE
Commonwealth Scientific and Industry Research Organisation, Sydney, Australia

Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 2199-2213.

Abstract

In the context of a strategy for information management in the building and construction industry, this paper identifies and briefly examines the relationship between key industry stakeholders. Accepting the fundamental role of a project decision, it examines the flow of information between these decision-makers as a first step in developing an industry wider language. Finally, it discusses Lexis, a language being developed within CSIRO-BCE, and how it addresses these requirements.

Keywords: Language, project information exchange, project decision-making

1 Introduction

The building industry is under increasing pressure to improve the quality and value of its product, the efficiency and effectiveness of its processes and the accountability of its decision-makers. At the same time buildings are getting larger and more sophisticated[1], and building technology and material science becoming increasingly complex and subject to error in specification, installation, operation, and maintenance. These, in turn, are leading to larger and more specialised project teams whose members have increasingly narrower views of the project and of their respective responsibility towards it. The take-up of communication and computer technology is adding yet another dimension to the problem. While holding out the potential to address the above it does so by introducing yet more requirements. 'Data sharing' – entering data once and

[1] The Australian Procurement Construction Council suggests that up to twenty specialist skilled subcontractors may be employed on a residential housing project and up to 200 specialist skilled subcontractors may be employed on a major construction site (APPC, 1997).

having it accessible to all who require it – will save time, facilitate coordination, and reduce the potential conflict and confusion caused by the existence of multiple copies. However, doing so will introduce the need for all members of the project team to use an agreed way of identifying and describing the objects about which data is being shared. In fact, because projects do not occur as isolated events, such an agreement is likely to have to be industry wide.

Further, if the experiences in other industries is relevant, the effective use of IT will require the building industry to undergo fundamental structural change. In banking and finance, in the retail industry, in the introduction of credit card, traditional competitors found it necessary to come together to cooperatively establish the necessary infrastructure before returning to compete on new level. As The Financial Review notes, "fierce rivals such as Coles Myer Ltd, Woolworths Ltd and Franklins Ltd come together for the first time to discuss using high technology to improve the industry's structure and increase its competitive edge." (Carr, 1997)

Clearly, the problem facing the building industry is as much cultural as it is technical. And given its size and nature, change is likely to occur over an extended period of time – as individuals, and individual organisations, see direct, short term benefit. While responsibility for a significant proportion of this change can be left to individual self-interest, responsibility for overall integration, and developing and maintaining a common language, must be addressed by the wider industry.

This paper briefly examines the roles of key industry stakeholders as a basis for developing a strategic framework for managing information in the building and construction industry. It then considers the flow of information between these decision-makers and begins to draw out concept that a common language will have to address. Finally Lexis, a language being developed by CSIRO-BCE, is examined and a possible approach to the development of an internationally harmonised language is raised.

2 Stakeholders

There is insufficient room here to discuss the development of the proposed information management and decision support system. Suffice it to note that any initiatives in this regard must identify and respond to the need of:

- *Project decision-makers* - generalists (facility owners and financiers; designers, documenters, builders and demolishers; asset managers and maintainers) whose decisions and actions determine the quality and value of the end product.
  Focused on a project with its time and cost constraints, these stakeholders are unlikely to be in a position to keep abreast of changes to the industry knowledge base in more than a few areas of special interest. Being in a position of not knowing what they don’t know, these decision-makers will need proactive access to project and external reference data.
- *Industry reference library managers* – specialists (building regulators and researchers, through manufacturer’s technical and sales staff, to office

manager and librarian in consultant's offices) with an interest in and in-depth understanding of their respective domain(s).

(Industry reference library data is defined as any information residing outside of a particular project but intended for inclusion. This material ranges from building codes and standards, through research findings, manufacturers' literature, specification text and construction details, to performance bench marks and office procedure manuals.)

While dealing with different material and driven by different motives, these stakeholders have a common objective – having their material in front of the project decision-maker in a form and at a time that facilitates understanding and application. The fact is that each of these managers wants to 'speak' to the same project decision-maker – who is unlikely to have either the time or desire to learn a host of different protocols – argues strongly for the cooperative development of agreed communication conventions.

- *IT resource providers* - developers and marketeers of the communications, data access and decision support tools used by the other two stakeholder groups.

  The more precisely the first two groups can define their information needs, the easier it will be for the IT provider to provide cost efficient, application specific, resources. Unfortunately, to date, neither group has been a particularly good in this regard. Hopefully the proposed information framework and its common language will help to remedy this situation.

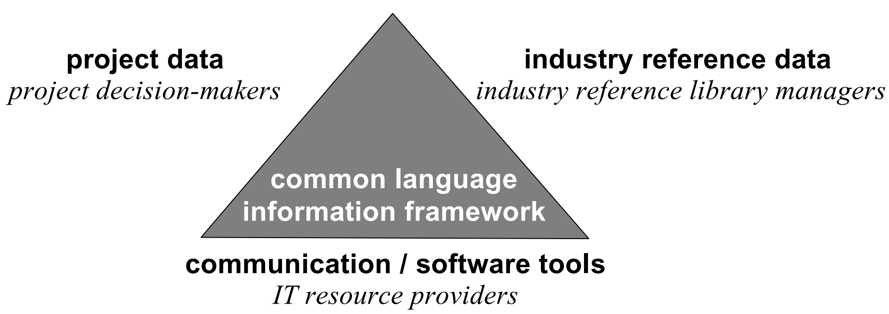

Fig. 1: Stakeholders and resources

3 Project decision-making

Regardless of the facility, its stage of development, contractual arrangements between the stakeholders or the technology used, to advance the work someone has to take a decision or action (DA). Who takes it and whether it is good, bad or indifferent, is project specific and of concern only to other members of the project team. In this context, the role of the proposed information and decision support system is limited to ensure that the decision-maker has efficient, effective access to relevant input (project and reference library data) and that the output is available for subsequent DAs.

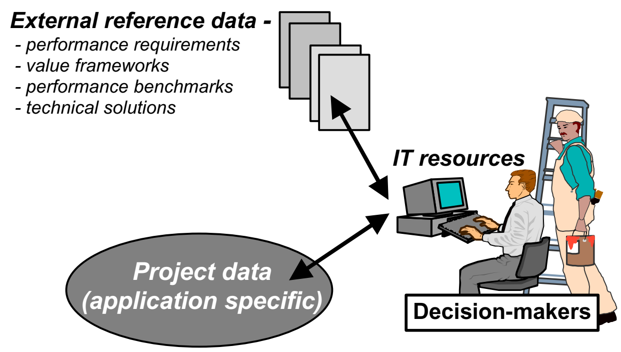

Fig. 2: Project decision/action set

As already noted, because the decision-maker is unlikely to be aware of what is available or of its relevance to the work at hand, such access must be proactive. That is, the project decision-maker who knows the project, it problems, issues, and priorities but lacks currency with regard to the industry knowledge bases, must be able to describe the circumstances of the project in such a way that the reference library managers, who have the necessary currency, can confidently respond with application specific information that is in a form that can be readily understood and applied with minimum reprocessing.

Project decisions, however, are rarely taken in isolation. The procurement and management of a facility involves hundreds of people taking thousands of DAs over extended periods. While each decision-maker understands the project and acts from a unique perspective, the fact is that he or she must communicate and coordinate their DAs with others. While there doesn't appear to be precise demarcation, this communication and coordination falls:

- *within a project phase* – where time and space allows one member of the project team to take a decision and to draw it to the attention of the others who can assess its implications for their respective areas of concern. Conflicts can be identified and mutually satisfactory solutions negotiated.

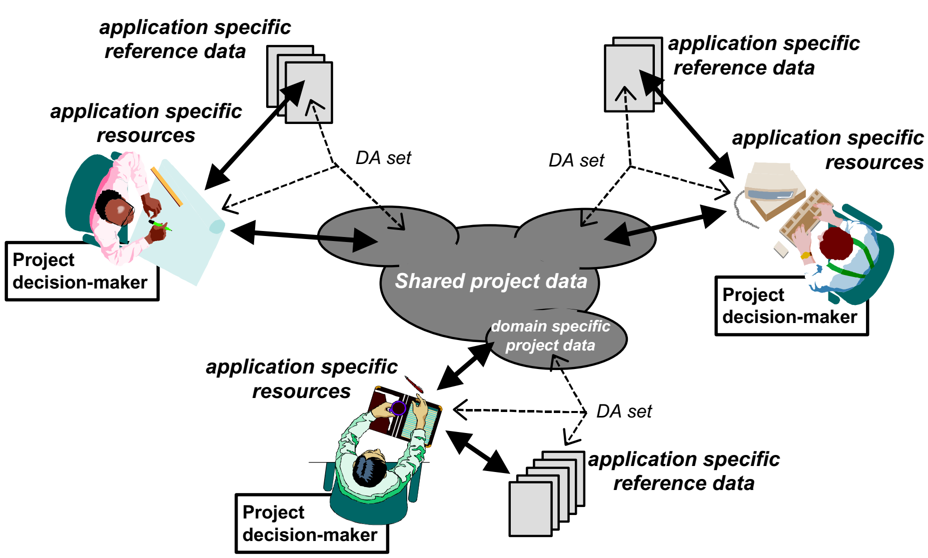

Fig. 3: Domain views and decision sets

For example, during the design phase, several decision-makers might seek to manipulate a wall according to their respective area of responsibility. The space planner might be concerned with its location and surface. The cost controller might be concerned with its impact on the capital cost budget. And, given the environmental and users conditions, they might wish to calculate its useful life in order to assess its impact on the recurring cost budget. The thermal engineer might be concerned with its location (as it determines the size of a space to be environmental conditioned), its thermal mass and thermal transmission. The structural designer, wishing to use part of it in the building's structure, might be concerned with its location and structural capacity.

As Fig.3 suggests, some data will be of concern to several decision-makers (eg wall identification, size, shape, location) and some will be of concern only to one individual (eg surface, colour, capital cost, recurring cost, thermal mass, thermal transmission, structural capacity). Whether data is to be shared or held exclusive to an individual will vary with the project and the responsibility of the project team to determine. Again, the role of the proposed information system is simply to facilitate the process – by providing a means of identifying specific units of data and associating them with one or more stakeholders.

- *between project phases* – where, due to time and space, decision-makers are unable to enter into direct negotiations. Under such a circumstance, one decision-maker will take a DA and inform another of the outcome (traditionally this has taken the form of a proposed solution). The need for the initial decision-maker to offer a solution remains, but this must be supported by an option to pass assumptions and/or performance requirements.

  Further, where the outcome of the latter decision-maker's DA is critical to the former, a method of compliance monitoring is required.

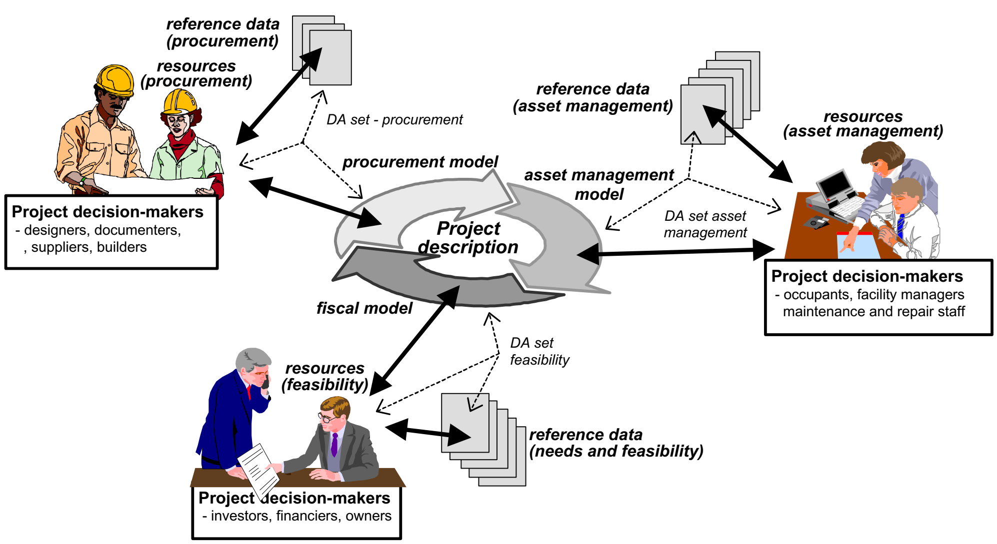

Fig. 4: Communication and compliance monitoring between phases

For example, during project feasibility studies, the financial planner will make assumptions about income and expenditure based on the facility being able to attract and retain a certain class of tenant. The Property Council of Australia (PCA) has formalised this in the form of their Office Quality Grade Matrix (PCA, 1997). Among other things, in relation to lifts, they identify the maximum waiting time, minimum capacity, and ride quality. Failure to meet this performance profile could jeopardise the financial viability of the project through the down grading of the facility and thereby its ability to attract the desired tenants. Rather than waiting until the project is finished and occupied, once the lift strategy has been established (numbers off, capacities, speeds, …) the financial planners should be provided with a compliance report setting out the 'projected performance' in each of the nominated areas. Once the lifts are installed and operating another compliance report, setting out the 'achieved performance' figures, should be issued. Further, once the facility is in operation, the 'achieved performance' figures should be checked against what was initially projected and a post-occupancy evaluation should be undertaken to ascertain the 'valued performance' (an assessment of the relative worth of various aspects the lift strategy in relation to other PCA performance objectives).

In addition to assuring the quality and value of end-product, such a compliance monitoring system will enable 'self-certification' of compliance with local building codes and regulations.

To facilitate the levels of communication discussed here, there is a need for a common framework within which information can be reliably accessed and processed by individuals, and passed between project stakeholders – within a project phase and over the project life cycle.

This framework, and its supporting language, must involve all sectors of the industry, cover both written and electronic information, and deal with subjective as well as objective issues.

4 Lexis - a common language

Language – any set or system of such symbols as used in a more or less uniform fashion by a number of people, who are thus enabled to communicate intelligibly with one another. (The Macquarie Dictionary, 1985)

While each decision-maker sees the project from a different perspective - has different objectives and contractual responsibilities – the fact is they must realise their respective goals through the manipulation of a common and relatively limited kit of parts. Lexis is intended to identify, describe, and attribute the objects in this 'kit'.

This section examines these objects, including how their data changes over the project life cycle, in order to determine what should or should not be included in the proposed system.

4.1 Object identification

Object – a functionally identifiable unit.

System – an *object*, composed of two or more *objects* (operational, spatial, physical), that together serve a characteristic function. Systems can contain other systems.

Component – an *object* with a characteristic function within a *system*. A *component* can belong to one or more *systems.*

View – an aggregation of objects and object attributes relevant to a particular process (decision or action).

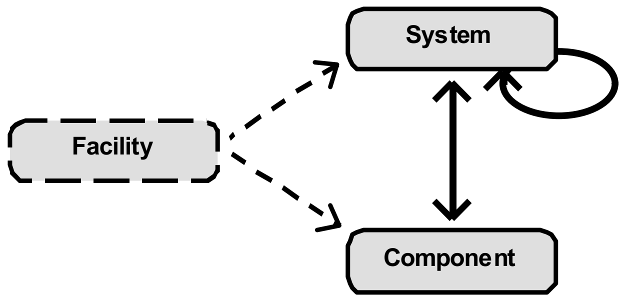

Fig. 5: Systems and components

Depending on the perspective of the decision-maker, a *system* can be a *component* and vice versa. To illustrate, an airport is a *facility*. So too are its terminal buildings, parking areas, runways, fuel dumps, and fire stations. Whether these facilities are seen as systems or components of systems will depend on the issue(s) under review. That is, to the regional planner the airport is a *component* of the city. To an airport manager it is a *system* in which the terminals, parking and rental car areas, runways, hangers, fuel dump, and fire stations are *components*.

This system/component relationship includes the building shell and services. To the designer, a wall is a *component* of the building. To the builder it is a *system* – composed, for example, of studs, plates, bridging, nails, plasterboard, edge beading, joint tape and plaster.

In other words, on a decision by decision basis, the project decision-maker will determine whether an object is a system or component. With reference back to Fig. 3 and 4, if these decision-makers use a common pool of objects to construct their respective views, they can each act from within their respective decision-sets confident that any value(s) they assign to an object attribute can be applied in a different domain. Where two stakeholders enter different values, any conflict will be immediately flagged and a mutually acceptable value negotiated.

This *object* (kit of parts) *view* (decision-maker) relationship is the basis upon which Lexis is being developed.

4.2 Lexis components

Lexis Core –an industry agreed set of *objects* (systems and components), including their associated attributes and relationships. The *Core* provides a pool of objects from which domain groups construct their respective *Views*. It is the 'kit of parts' referred to above.

Lexis View(s) – are aggregations of *objects*, *object attributes* and *object relationships* drawn from Lexis Core that model some aspect of a facility, eg capital cost, recurring cost, energy, construction management.

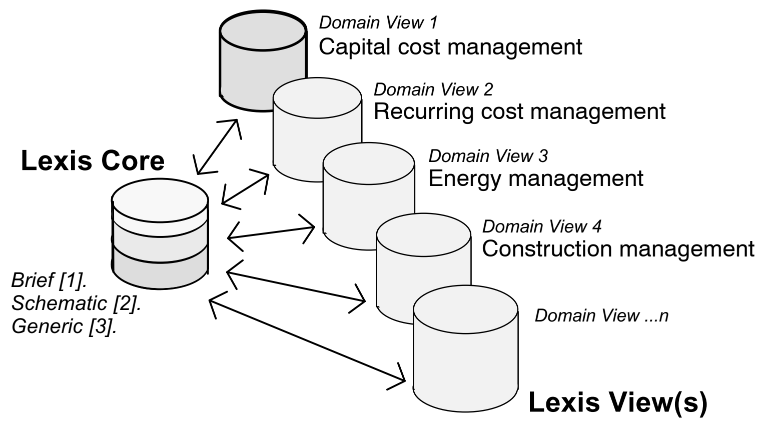

Fig. 6: Lexis components

4.3 Core objects

The objects identified here are indicative only. The final set will be determined in consultation with industry decision-makers – ensuring that the objects and object attributes are appropriate to their DAs.

4.3.1 Object classes

- **Operational objects:**

  Operational system - a set of goal-directed operational activities associated through a common objective and undertaken in support of the operational objectives of the organisation being accommodated in the facility.
  Operational component (setting) – a goal directed activity undertaken as part of an operational system.
  An operational setting might include –
  Actors – individuals, including their aids and/or appliances, involved in the activities of an *operational setting.*
  Furniture, equipment – objects, permanent fixed or brought in as required, that serve an identified function in the activities of an *operational setting*.

For example – the client might identify a school library as an *operational system* within which entering and leaving, checking out and returning books, searching the catalogue, periodical browsing, private and group study, are *operational settings.* Equally, the building regulator might identify the need for emergency egress as an *operational system* in which passing through doors, travelling corridors, and descending stairs are *operational settings*.

- **Spatial objects:**

  Spatial component – a notionally bounded three-dimensional volume.
  - *cell* - a notionally bounded three-dimensional envelope defining the extent of a micro-environment, eg shell (wall cavity), service (illumination ray diagram).
  - *activity space* - a notionally bounded three-dimensional envelope that defines the extent of an operational (*setting)* component.
  - *chamber* - a notionally bounded three-dimensional envelope, commonly defined by physical objects such as walls, within which one or more operational settings occur.
  - *zone* – a notionally bounded three-dimensional envelope, within which one or more spaces are aggregated through a common purpose.

- **Shell objects:**
  Shell system – a set of physical components associated through a common function of enclosing and sheltering facility occupants or activities.
  Shell component – a physical component or assembly of components that serves an identified function within a shell system.
- **Service objects:**
  Service system – a set of physical components associated through a common function of servicing a facility's occupants or activities.
  Service component – an object that serves an identified function within a service system. Service components include:
  - *nodes* – points in a services system or branch that processes a service substance. Node types include source, processor (monitor/control, treat, protect), and terminal.
  - *links* – a means of conducting a substance between nodes in a service system.

A service system may be *reticulated* (a service in which the substance is reticulated to the point of use) or *transported* (a service in which the substance is physically carried from one point (source) to another (terminal). Note, the terminal of a transported service can be the source of a reticulated service, eg. oxygen can be trucked to the site in cylinders and attached to a manifold where it is reticulated through the facility.

4.3.2 Object life cycle

With reference to Fig. 7, over the project life cycle, many of the objects identified above will undergo:

- ***attribute reassignment*** - A project brief [1] might identify an *operational system* 'a', containing two *operational settings 'b'* and *'c'*. One noise generating and the other noise sensitive. During schematic planning [2] the required noise reduction will be calculated and assigned to a notional shell object - *separator*. Once the physical relationship between the *operational settings* is established [3] – adjacent to one another and separated by a wall, or possibly across the corridor from one another and separated by two walls and a corridor – the sound reduction value of the separator can be reassigned to either the single wall and its finishes, or to the combination of two walls, their respective finishes and a 1200 mm air space.
- ***transformation*** - During design [3] other project decision-makers will identify and assign their performance requirements to the generic wall(s) identified above. This 'required performance profile' can then be used in a search engine to contact the relevant industry reference libraries for potential technical solutions. The candidate solution, offered by manufacturers and suppliers of walls or wall components, will have a 'projected performance profile' that each affected decision-makers will use to assess the implications it may have for their respective area of concern.

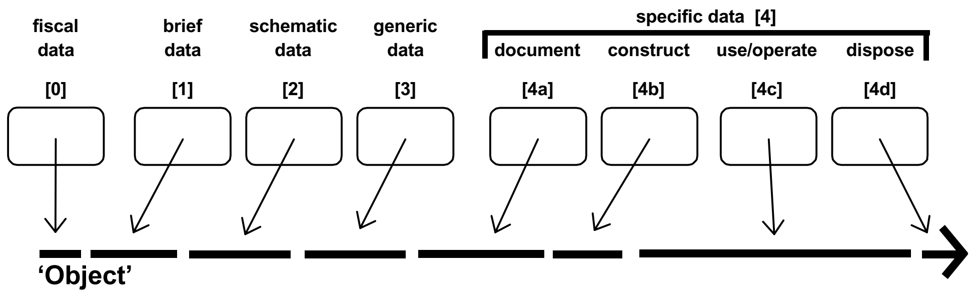

Fig. 7: Object data phases

Once the wall type has been selected the relevant manufacture/supplier, as part of its marketing strategy, might provide the:

- *documentation team* [4a] with a list of the materials and products out of which the nominated wall is constructed, construction details appropriate to the nominated performance requirements and units costs.
- *construction team* [4b] with delivery times and other data to enable electronic ordering, receiving, and payment for the nominated items.
- *asset management team* [4c], where appropriate, with data on how to operate, maintain, and repair the object.

In the same way, a manufactured product such as a water pump, moves from a generic object [3] with a required performance profile, to a specific one [4a] with an identified make, model and projected performance profile. Finally, during construction, it will become a specific object with make, model, serial/batch number, dates associated with its purchase, installation and commissioning, and an achieved performance profile.

The introduction of 'required/desired', 'projected' and 'achieved' performances provides the basis for quality control and compliance monitoring. Further, post-occupancy evaluation can tap the users' experience of the facility to establish a 'valued' performance of an object for use in preparing a brief for a subsequent project.

4.3.3 Object attributes

Cross-referencing the objects classes with their respective life cycles, establishes a matrix used to identify the objects and object attributes required to carry the concepts and/or data required by the various members of the project team.

This section offers a brief indication of the objects and their associated attribute sets.

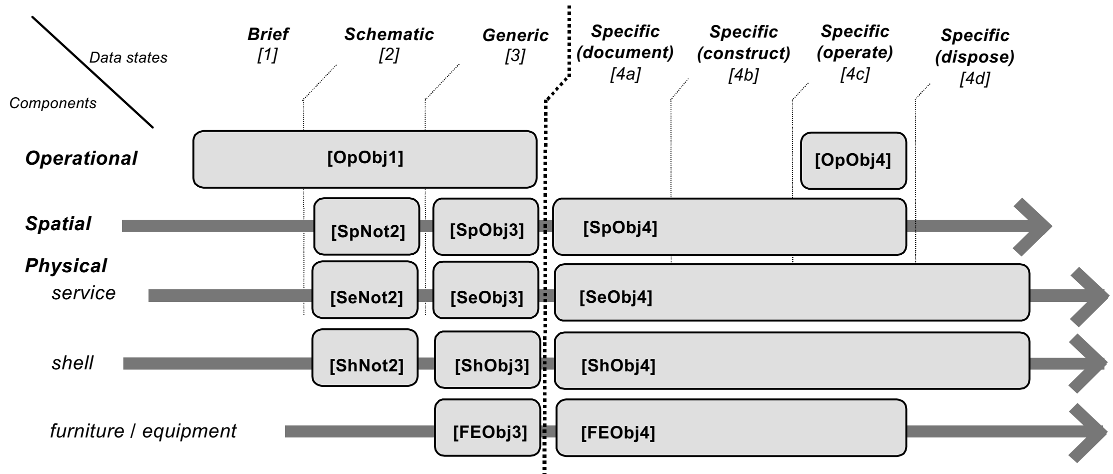

Fig. 8: Lexis data framework

Objects and object attributes *(indicative only)*

Operational (setting) objects:-

Primary school library	
Browsing system	
Periodical display	[OpObj1]
Casual seating	[OpObj1]
Book access system	
Using catalogue	[OpObj1]
Accessing books	[OpObj1]
Private study system	
Work station	[OpObj1]
Book checkout system	
Check out counter	[OpObj1]
Librarian work station	[OpObj1]
Book return area	[OpObj1]

Operational (setting) object attributes:-

Identification
- lexis id
- project id
- reference library id

Description
- definition
- geometry
- position (location, orientation)

Performance
- production rates

Need
- environmental (from Actor and F&E needs)
- shell
- service

Impact
- environmental (from Actor and F&E impacts)
- shell
- service

Spatial objects:-

Activity space	[SpNot2]
Chamber	[SpNot2]
Room	[SpObj3]
Corridor	[SpObj3]
Stairwell	[SpObj3]
Service riser	[SpObj3]
Zone	
HVAC zone	[SpObj3]
Fire zone	[SpObj3]

Spatial object attributes:-

Identification
- lexis id
- project id
- reference library id

Description
- definition
- geometry
- position (location, orientation)

Performance
- environmental (sum of Settings in space)

Need na

Impact na

Physical (shell) objects:-

Separator	[ShNot2]
Wall core	[ShObj3]
110mm brick wall	[ShObj4]
75mm frame wall	[ShObj4]
Wall finish	[ShObj3]
paint finish	[ShObj4]
wall paper	[ShObj4]
cement render	[ShObj4]
set plaster	[ShObj4]
ceramic tile	[ShObj4]
Door	[ShObj3]
Window	[ShObj3]

Physical (shell) object attributes:-

Identification
- lexis id
- project id
- reference library id

Description
- definition
- geometry (object, maintenance access)
- position (location, orientation)

Performance
- Separation (acoustic, physical, fire, …)
- Capacity (load bearing, …)
- Resistance (abrasion, water, fire, …)
- Cost (capital, recurrent)
- Embodied energy

Need
- environment
- shell (deflection, vibration, …)
- service (supply, removal)

Impact
- environmental emissions ()
- shell (loading, …)
- service ()

Physical (service) objects:-

Source	[SeNot2]
Existing service	[SeObj3]
Utility	[SeObj3]
Tank	[SeObj3]
Terminal	[SeNot2]
Tap	[SeObj3]
Fowler model AC632	[SeObj4]
Equipment	[SeObj3]
Plant	[SeObj3]
Processor	[SeNot2]
Link	[SpNot2]
Pipe	[SpObj3]

Physical (service) object attributes:-

Identification
- lexis id
- project id
- reference library id

Description
- definition
- geometry (object, service access)
- position (location, orientation)

Performance
- capacity (volume, flow rate, pressure, …)
- resistance (abrasion, water, fire, …)
- cost (capital, recurrent)
- embodied energy

Need
- environment
- shell (deflection, vibration, …)
- service (supply, removal)

Impact
- environmental (emissions, noise, heat, odour, …)
- shell (operating wt, shipping wt, …)
- service ()

Fig. 9: Objects and object attributes (indicative only)

5 Lexis application

With reference to Fig. 10, this section illustrates the practical application of Lexis objects.

5.1 Brief

The client brief identifies an *operational system 'a'* containing three *operational settings 'b', 'c', 'd'*. The people and equipment associated with each setting is also nominated. *Setting* 'b' is noise sensitive (need_noise level) and 'd' requires equipment that is noise generating (impact_noise level).

5.2 Schematic

During schematic planning *settings* 'b' and 'c' are located in *space 'e'* and *setting 'd'* in *space 'f'*. At this point the design is not be sufficiently developed to establish the spatial relationships between these *spaces (rooms)* so the required sound reduction (performance_separation_sound reduction) is assigned to the notional *separator* 'g'.

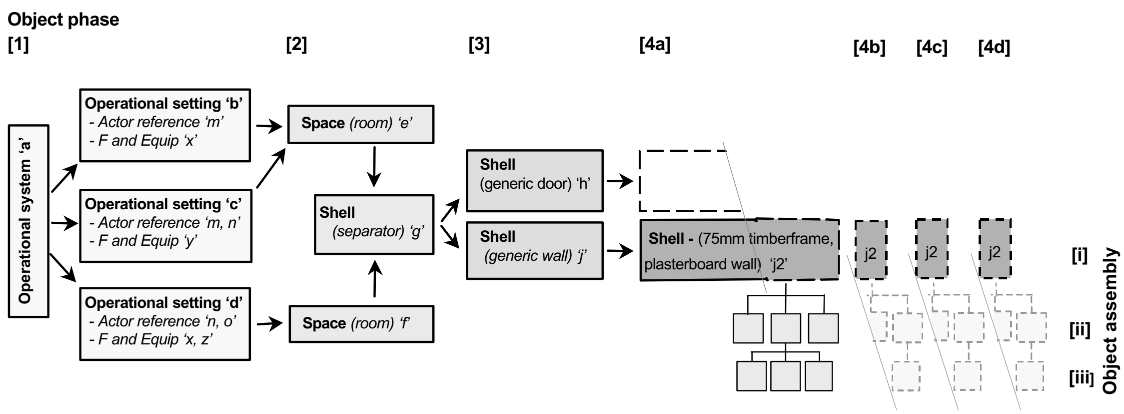

Fig. 10: Project data flow

5.3 Generic

As the design is resolved *rooms 'e' and 'f'* might be adjacent to one another (separated by a wall) or possibly across the corridor from one another (separated by two walls and corridor space). Respectively, the 'required' performance of the *separator* would be assigned to a *single wall 'j'*, or the combination of two walls and a corridor space.

This 'required' acoustic performance would be combined with other such requirements (eg. thermal insulation, fire rating, structural capacity, capital cost) to form the 'required performance profile' of the intervening walls and doors. This profile being used to search manufacture's reference libraries for potential solutions (this search tool is being developed by CSIRO under the name - Dynamic Data Directory). Each of the manufacturers' nominated solutions will have an associated 'projected performance profile' based on their product testing.

5.4 Specific

Once the particular wall type has been determined, the manufacturer might identify and specify the products and materials, and provide relevant construction details [4a]. To assist the builder, the manufacturer might supply costs and delivery details for the nominated materials and do so in a manner that, once the construction of the wall is scheduled, the ordering, shipping, and receiving of the materials and the subsequent invoices and payments can be managed automatically (electronic commerce). Any change to the schedule would automatically change the order/deliver dates [4b]. As appropriate, information might also be supplied to the facility manager to operate and maintain the components [4c] and to the demolisher to dismantle, transport, recycle and/or dispose of them [4d].

6 Conclusion

6.1 IAI - Industry foundation classes

While the Lexis object-set overlaps the Industry Foundation Classes (IFC), they serve parallel and complementary purposes. Lexis addresses the aforementioned decision-makers ability to access, understand, and apply information from relevant reference libraries. It is concerned with the flow of information and is intended to support clear, concise communication between stakeholders regardless of the type and level of IT used. This said, there is no question that most of this communication will be computer based and therefore Lexis and the IFCs must be fully harmonised.

6.2 Developing an international language

Lexis in its current state of development is best described as a skeleton. The next step is to test and develop it in direct association with industry. While this work is proceeding in Australia, it is timely to consider the possibility of using Lexis as a starting point for the development of an internationally agreed upon language.

Reflecting on the experience of ISO/TC59/SC13/WG2 those involved, including this author, sought an internationally agreed *View*. In terms of the ideas presented above, the need is for international agreement on the objects in the *Core*. That is, to develop and maintain an internationally agreed data directory and set of exchange protocols with which individual countries, industry associations, and project decision-makers can construct and manage their respective *Views*.

Further, because the content is likely to be too volatile to be effectively managed as an ISO standard, it is recommended that national research organisations such as NRC, VTT, BRE, TNO, CSTB, and CSIRO come together to jointly undertake this work. The outcome would be an internationally harmonised public document written in the local language and marketed through the relevant building research authority. A Memorandum of Understanding between these organisations could ensure that the proceeds from the sale of these documents are applied to the language's ongoing development.

7 References

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