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Chapter 4: Precedents to the present research

Introduction

This chapter provides an overview of the two precedent systems PREMIS and AEDES that the author developed. This provides useful insights as to the approach that should be taken in the present research. It also highlights lessons learnt in the two critiques.

4.1 The PREMIS Facilities Management System

4.1.1 Introduction

Conradie (1996) developed the PREMIS (Professional Real Estate Management Information System) over the last 12 years. The core system currently has the following main components (Figure 1).

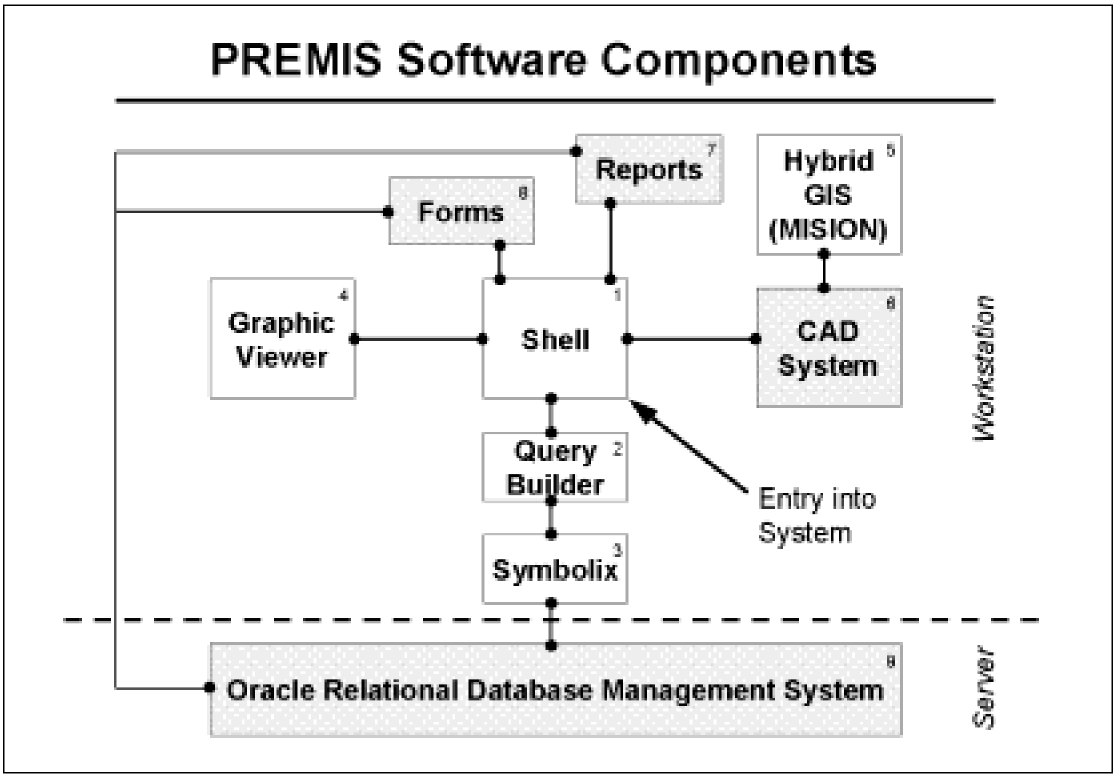

Figure 1: PREMIS Facilities Management Software Components (Author)

The PREMIS software system is based on industry standard components as far as possible. The system uses the Oracle database and AutoCAD as graphics editor. To these industry standard components were added a multi-purpose Ad-hoc query builder, Symbolix graphic visualisation language, viewer and MISION hybrid GIS system. These components are integrated together by means of a fully user configurable shell.

4.1.2 Intrinsic design principles

- The system core is generic and can act as a platform for a broad spectrum of facilities management application software.

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- Data are organised as information in raw format. No processed information is stored because it is impossible to unscramble scrambled information. The cost per m² will not be stored, rather the number of m² and the cost. The cost/m² is then calculated by means of a report. This enables users and application writers to customise the system easily to suit their specific environment. The system is designed in a generic way and is therefore very flexible and adaptable to changing needs.
- There is a clear distinction between data and reports and ultimately process. This is to ensure a long life system that can easily adapt to changes in the facilities management arena.
- Process is seen as something that sits on top of the data and uses the data. A good example of this is the difference between the way that different organisations might operate their space management systems. The author wrote two distinct systems for two different organisations. Although the reports and processes on top are vastly different they use exactly the same PREMIS/ Oracle database tables and forms. Company A might use the concept of calculated area to derive rent and company B operational cost apportioning.
- Software is designed for a high level of modularity to ensure the replacement of obsolete software components with more modern ones without affecting the stability of existing components (Open ended structure).
- The data backbone of the system is the Property category. This consists of a hierarchy starting from country right down to site, building, floor and space. Unless this structure is used it is impossible to handle the large range of different facility sizes. The property category incorporates the basic data required for asset registers and space management.
- The system is highly optimised for speed. Very high throughput is achieved even on moderate capability equipment due to the PREMIS systems architecture. The *Symbolix* language is a purpose made language that is compiled to achieve high speed. The index system in the MISION, hybrid GIS is highly optimised and shows no deterioration even with large file sizes over 2 Mb. Oracle PRO*C is used to ensure the highest possible communication speed with the database.
- The use of an implicit linking between alphanumeric data in the relational database and the graphic objects was pioneered in this system (Figure 2).

4.1.3 A typical application

A typical application such as the Building Maintenance Management System (BMMS) consists of 84 relational database tables and 60 Oracle forms of varying complexity. The main data table categories covered by the system is Property, Legal, People, Elements and Organisation Structure.

The system uses object-oriented principles to link graphic and alphanumeric data. This facilitates the integration of the graphic, alphanumeric and spreadsheet environments.

Implicit linking of graphic data to alphanumeric data is used. By using object-oriented principles the graphic data are linked to the alphanumeric data. This is done in such a way that although the items exist in totally separate environments relationships exist by virtue of the fact that the graphic object names are the same as the concatenated data key fields in Oracle. This has far reaching implications in the sense that one alphanumeric record may have multiple graphic representations. This also ensures a very high level of modularity and portability. Data may be independently added in the two environments. Relationships exist the moment that the graphic object name and the concatenated alphanumeric database record key are the same (Appendix A).

This particular application integrates strategic facilities planning with operational maintenance. This is achieved by means of a generic list of 352 construction elements that can

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be used for strategic planning. The very same list of elements can be used in an operational environment by means of maintenance action verbs like *Remove*, *Replace*, *Repair*, *Patch*, *Repaint*, *Refix/ Refit*, *Cut*, *Clean* and *Service*. These actions can then be combined to the elements to derive unlimited, but at the same time well-structured, combinations of actions.

The system can expand from a single user system to a large networked system. This ensures an unlimited growth path. The Oracle database performs particularly well with a large amount of data without significant deterioration in speed.

The PREMIS, Oracle forms can be deployed over the web by means of the Oracle web cartridge. Oracle offers a very high level of connectivity and openness to other systems. It is therefore relatively easy to interface Oracle to other systems.

The PREMIS graphic visualisation language SYMBOLIX offers superior graphic symbol processing capabilities. SYMBOLIX enables the programmer to design parametric symbols that vary their shape, colour and size according to parameters or values retrieved from the ORACLE database. SYMBOLIX enables graphic visualisation of issues. This is more advanced than business graphics, because the results can be geographically placed as well.

ORACLE FORMS 4.5 (one of the products in the Oracle Developer/2000 suite of software) is being used as the user interface to enter data into the database. FORMS 4.5 is a generic forms front end that supports ODBC (Open Database Connectivity), Custom Interfaces, User Exits, Visual Basic and OLE (Object Linking and Embedding)

Due to the fact that ORACLE is used as the database a user can start with a single user workstation with Personal Oracle 7 for Windows and expand to a virtually unlimited multi-user size. PREMIS is therefore able to offer a low cost entry point but with no upper limit on the size of the estate. In fact an estate can be anything from a single building to a complete estate consisting of many buildings.

PREMIS is designed in such a way that it facilitates very flexible combinations of multi-user access. It is possible in a multi-user system to install PREMIS on say ten workstations. If the user has only bought a 3-user concurrent license any combination of three out the ten users can used simultaneously. The access control will impose a limit of three concurrent users at any time.

4.1.4 Critique of PREMIS

PREMIS was developed over many years and significant experience was gained in the display of large volume data in way that makes it comprehensible for the strategic planner especially in health related facilities. The PREMIS method has become an established way of life in South Africa and numerous strategic condition and suitability audits have been undertaken subsequent to the large scale original National Health Facilities Audit. The processing speed of the parametric language SYMBOLIX (a recursive descent parser implemented as a stack machine) designed by the author is still very fast in comparison to what is offered by modern languages such as Visual Basic.

However the world changed significantly since the first version. PREMIS is currently being rewritten to utilise the capabilities of the Internet (PREMIS 2000i). The implicit linking technique pioneered in this system still works well (see Appendix A) except that it takes significant manpower to cross-link the alphanumeric RDBMS records with the graphic information.

The ad-hoc query builder enabled users to formulate complex (multi table joined) user defined queries to produce alphanumeric, spread sheet and graphical reports. Due to the

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complexity of the system very few users could unfortunately use the query builder without assistance.

The hierarchical ontology required for facilities highlighted the difficulty of creating hierarchical structures in a RDBMS.

4.2 The AEDES prototype system

Research undertaken over the last year at the CSIR resulted in providing a rudimentary framework for a holistic total life cycle methodology. The author wrote a prototype software system called AEDES (Architectural Evaluation and Design System). The results of this research were presented at the Eleventh Symposium on Quality Function Deployment in Detroit (Conradie & Küsel 1999).

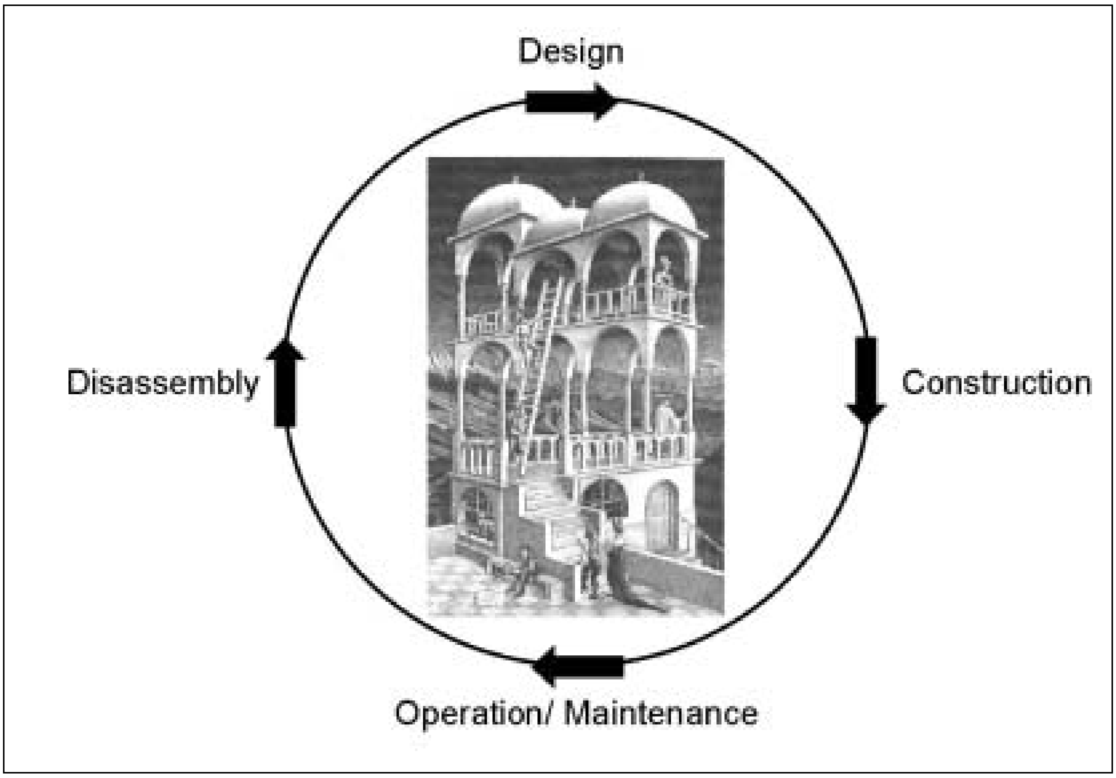

Figure 2: The life cycle phases of a building (Author)

The AEDES Prototype System offers an integrated, concurrent project environment for building designers, tailor-made for architects. It offers the following capabilities:

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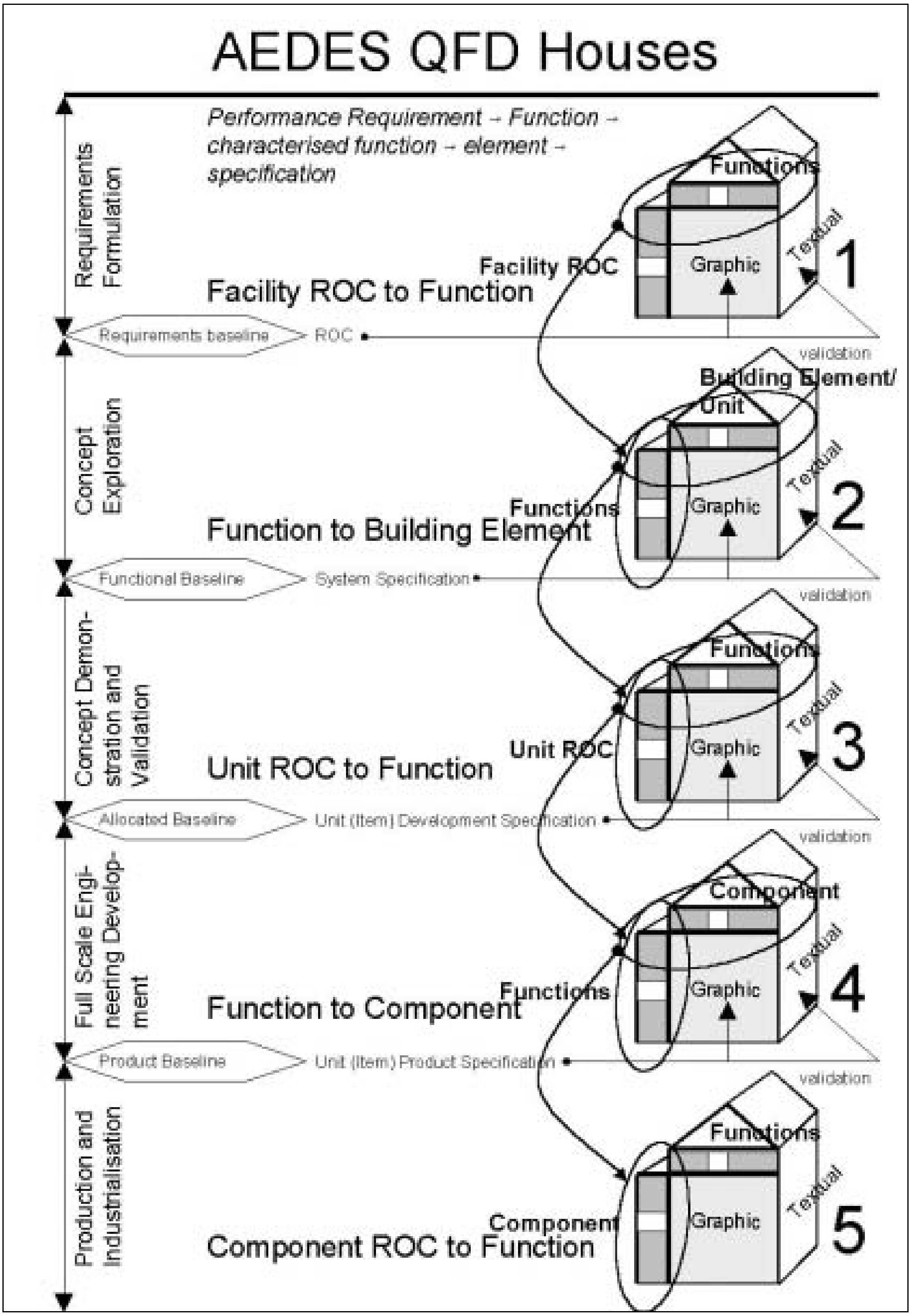

Figure 3: AEDES QFD Process (Conradie and Küsel 1999:24)

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4.2.1 Integrated life cycle process

4.2.1.1 The characteristics

In AEDES a building is designed by an interdisciplinary collaborative approach, in order to derive, evolve and validate a life cycle balanced building solution. This is done to achieve optimal architecture with regards responsible, economic and quality driven design. All decisions across the life cycle of the building development process are structured, traceable and time based.

4.2.1.2 Evaluation during the process

AEDES supports a measuring system to facilitate structured decisions. The AEDES mission is **"To measure is to know, to quantity is to master."**

Architecture is characterised by many different fashions, trends and major movements. Various quantified indicators are required to implement a life cycle development process. For example presently there is a need to achieve sustainable development. The pillars of sustainable development are social, economic, biophysical and technical sustainability (Hill *et al.* 1998:11) To achieve sustainable development or any other technical requirement such as an energy efficient design, appropriate quantified measurements or indicators needs to be devised. These need to be quantified for the total life cycle of the building. Systems like the Building Environmental Assessment and Rating System for South Africa (BEARS) have been devised to measure certain aspects of the building operation and design (Grobler *et al.* 1997). BEARS offer a "rating" system that can be used to rate existing buildings according to a list of indicators. This list includes heating, ventilation and air-conditioning, building and furnishing materials, lighting and solar control, noise, layout, operation and maintenance issues. The South African industry offers electronic web based product databases of specific construction products. However these services do not offer any quantified material attributes that is required to base technical design analyses on.

The AEDES measuring system assists with the measurement of technical sustainability. To this end a structured generic materials library was created. A prototype materials library containing 395 materials and 760 quantified attributes were therefore constructed. Typical generic but well quantified attributes for wood are for example bending and tension parallel to grain, compression parallel to grain, compression perpendicular to grain, density, durability, modulus of elasticity and shear parallel to grain. On the basis of this the materials and components used in a proposed design solution can be technically analysed with regards factors such as life cycle cost, sustainability, condition, suitability and utilisation of the facility (Conradie 1997).

4.2.2 Concurrent multimedia environment

4.2.2.1 The need for multimedia in the architectural profession

Traditionally architects are trained to think in terms of shape, texture, colour and space. This is an analogue way of thinking, with an emphasis on the visual aspects. Therefore, design supported by multimedia would be more acceptable.

4.2.2.2 Multimedia in AEDES

In AEDES information is structured according to how the building will be built. This automatically ensures that design information is produced in a concurrent environment and available in the order that it is required. This information is the golden thread that enables life

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cycle decisions. It is envisaged that different users with multi-variant requirements will manipulate the information with software tools.

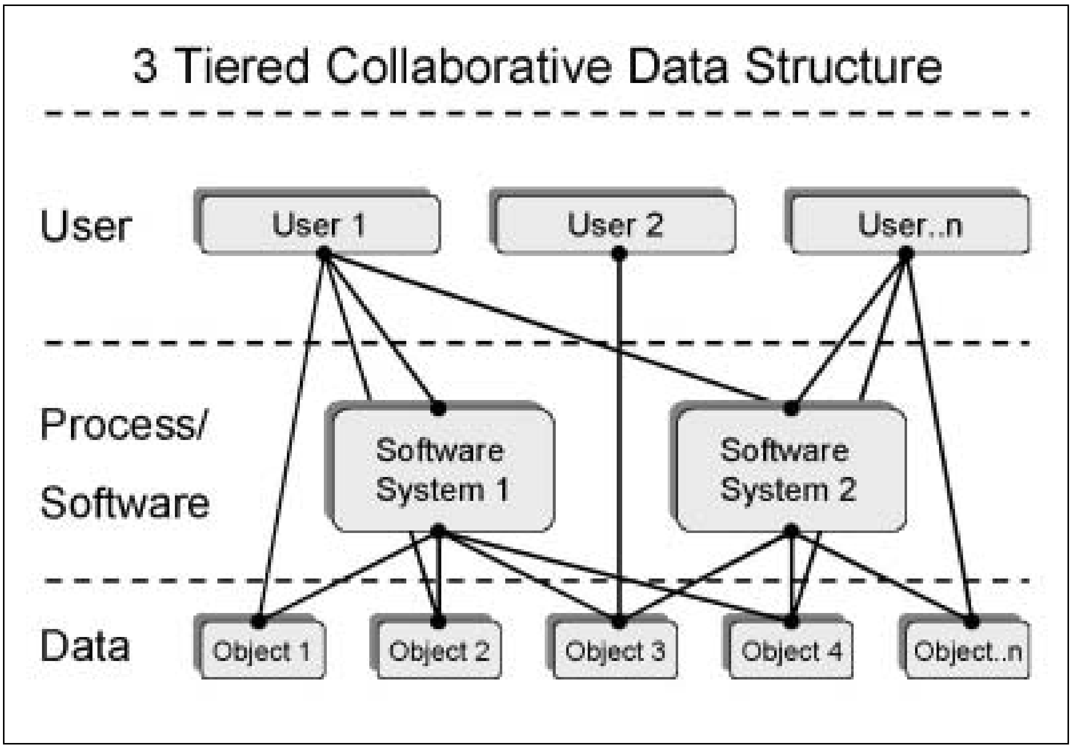

Figure 4: Three tiered collaborative data structure (Conradie and Küsel 1999:26)

Users are allocated specific information profiles to achieve certain tasks. A profile defines user rights as well as the visibility of information for that particular user and the relevant events that can occur. If the content of the task changes, then only the task profiles need to be changed without affecting the underlying information object structure. For example the maintainer responsible for replacing the light bulbs needs to access task applicable information.

The life cycle continuity of design information ensures that downstream decisions are taken within the life cycle context of the building, informed by the history of upstream actions. In this regard, it is virtually impossible to devise a suitable classification that will work across the different life cycle phases. Different life cycle phases have different information sets. For example in the operational phase, a software tool such as a Facilities Management System is used. During this phase there is a need for outsourcing, which requires an accurate specification of the task. This requires an appropriate subset of the total life cycle information set.

To accommodate different user profiles information containers were devised. All relevant project information is structured in 156 main categories implemented in a relational database.

4.2.3 Life cycle requirement validation

4.2.3.1 Multi-media QFD

In AEDES a five-matrix House of Quality (HOQ) system is used. A System Engineering design methodology is superimposed on these matrices. This determines the structuring of data in the matrices. An architect is able to design a building starting with a raw client

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requirement down to component level. All design information is directly available to the development team in a concurrent multimedia project environment.

Multimedia-QFD enables the development team to validate design baselines throughout the development process (Figure 3). It offers dual validation:

Graphic:
Due to the analogue design approach of the traditional architectural design process, provision is made to capture diagrams and sketches in electronic QFD forms. When the most appropriate technical solution is sought, the standard QFD relationship matrix or context sensitive drawings, sketches and photographs back up the designer decision.

Textual:
Textual (alphanumeric) information facilitates the validation of design baselines and progressive design development through status reports. This implies that designer decisions are validated by substantiated documentation accumulated throughout the development process.

In AEDES the use of a generic set of client requirements (WHATs) and technical solutions (HOWs) proved to be more suitable, rather than generating a set by the Affinity Diagram method (Cohen 1995:47). 156 main categories (containers) cover performance requirements and constraints across the life cycle. Careful attention was given to ensure that data containers were correctly levelled at more or less the same level of grain. Furthermore, the system design makes it possible to theoretically create any number of matrices, vertically, as well as horizontally for any container, at any level of detail. This is perhaps a new type of matrix of matrices, albeit in a far simpler form than the Akao version (Cohen 1995:310).

When a new project is started the QFD software generates templates for WHATs and HOWs. The WHATS categories are always numbered A and the HOWS categories with a B. The HOQ1 is called the **Facility Required Operational Capability**. In this house one of the 156 containers is the Space container. This container is numbered **A1**.2.2.3 on the WHATs side and **B1**.2.2.3 on the HOWs side of the matrix. The number is indicative of the grain that originated from the data levelling exercise. The HOQ1 is rotated to the second level **Facility Specification** (HOQ2). In this process the Space container number is automatically changed to **A2**.2.2.3 on the WHATs side and **B2**.2.2.3 on the HOWs side.

The system offers a total system subsystem type analysis starting with system-level specifications down to component level of design. The following QFD system-levels are used:

House of Quality 1	Facility Required Operational Capability
House of Quality 2	Facility Specification
House of Quality 3	Unit Required Operational Capability
House of Quality 4	Unit Specification
House of Quality 5	Component Required Operational Capability

These five matrices handle eight classes of architectural design objects:

- Complex (Hospital complex: Group of buildings)
- Facility (Hospital building and site)
- Department (Administration department)
- Unit (Bathroom)
- Zone (Wet area)

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- Building Element (Door)
- Component (Door lock set)
- Sub-Component (Screw)

A typical AEDES computer screen (written with the ORACLE Developer 2000 Forms System) that supports multi-media is included in Figure 37.

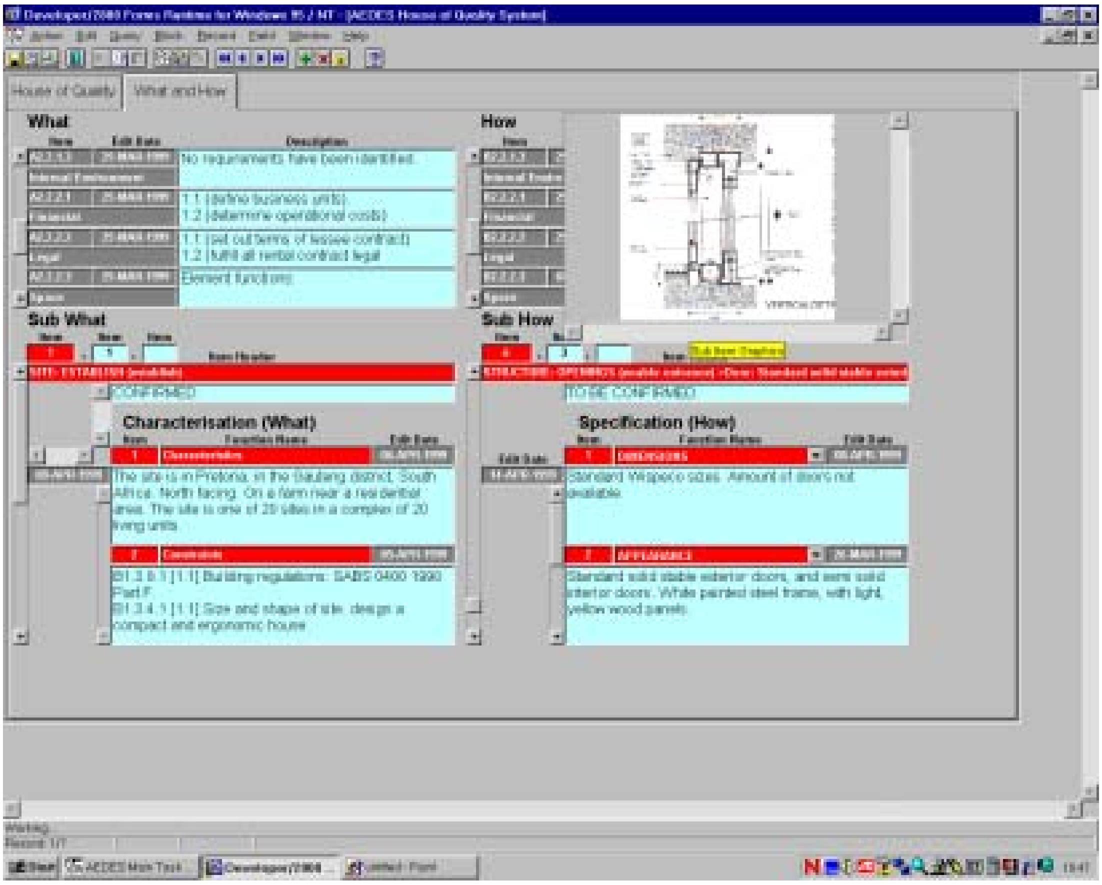

Figure 5: A typical AEDES screen with multi-media information (Author)

4.2.3.2 Break-out tools

A new concept called breakout has been pioneered. Matrices are linked to either supporting generic data forms or industry standard software analysis tools.

Generic data breakout forms enables more detailed analysis to be undertaken in order to reach a conclusion on the WHAT (characterisation) and HOW (specification) side.

A software analysis tool is linked to the QFD roof. The AEDES QFD roof is used in a slightly different way to textbook QFD. In an architectural environment it is useful to express affinity between different design objects such as units mentioned above. The relationship values have been modified to 9, 3, 0, -3, and -9. For example a value of 9 would imply that it is highly desirable to have the kitchen close to the dining room. A -9 implies that a bathroom should not be close to the living area. In complex buildings such as hospitals the correct circulation of activities and hence affinity between design units are crucial for a successful design. If the affinity decision is very complex, a standard software package such as Arena by the Systems Modelling Corporation can be used to model the proposed solution.

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4.2.4 Ad-hoc queries and reports

4.2.4.1 Electronic traceability

Structured methodology

As discussed a System Engineering methodology is superimposed on the QFD matrices. All information accumulated during the design process is hierarchically structured and captured within a relational database (**Error! Reference source not found.**).

A building is developed following a logical sequence of steps, starting at the HOQ1 (requirement) and ending at the HOQ5 (component). The process starts with the identification of a performance requirement (For example: **SERVICES: PLUMBING**) and developed to component level. Requirements and functions fall into two main groups i.e. passive and active. Passive requirements are physical elements such as structure, services, finishes, fittings, furniture and equipment. Active requirements are activities such as enable ablutions. A set of functions required to successfully enable the operational capability of the requirement is then identified. For example a requirement for **SERVICES: PLUMBING** would have as typical functions **(supply water), (distribute water), (store water), (heat water), (control pressure), (drain waste), (drain sewerage) and (process sewerage).** These functions are individually characterised according to functional and physical characteristics and constraints. A characterised function is then allocated to a physical element, for example **SERVICES: PLUMBING (supply water) >Supply pipe.** The physical element is then specified according to 9 indicators. Firstly to physical indicators (dimensions, appearance, construction) and secondly to operational support indicators (maintenance, personnel, data, equipment, supplies and facilities).

Starter Kits

*"QFD is time-consuming. Worse than that, it is explicitly time-consuming, in the sense that QFD makes obvious and visible the several long meetings, attended by quite a few people. For groups that have never used QFD before, this appears as time added to their already crowded schedules. What's not as explicit or visible is the time that QFD saves." (*Cohen 1995:31).

If quality time is devoted in systematically engineering a design solution, knowledge should be saved for subsequent use. If a completed design proves useful then it can be permanently packaged as a complete generic design object. AEDES uses an object-oriented approach to this effect. In future the designer can call on these packaged objects to speed up his design process.

Over the years the Division of Building Technology of the CSIR designed and packaged architectural design starter kits, which contributed towards an accelerated and more efficient design process. The intention was to assist hospital designers with complex designs. These starter kits are available in CAD format and contain "empirical ideal" total facility layouts.

In AEDES architectural design objects are introduced in order to address the diverse and hierarchical nature of construction industry data. An object is a non-specific term synonymous with the System Engineering item for any graphic (drawing) or alphanumeric (database) data in the system. Each object belongs to a specific class and each occurrence is an instance of one of the eight object classes it belongs to. The packaged object contains 2 or 3 dimensional CAD graphic objects, full specification, characteristics and a comprehensive family of functions. The CAD object names have been carefully chosen to be compatible with the main function libraries. For example: **Class:** House and **Instance:** Residential house. It is

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possible to package any number of functions and main indicators for any level of architectural design object.

4.2.4.2 Object manipulation

When a packaged object is subsequently retrieved, it will automatically go to the appropriate level in the QFD matrices. Each of these packaged units exists as an encapsulated world on its own. If it is brought into a specific project environment, it acquires or inherits specific localised qualities specific to the environment where it is used. At all stages full electronic traceability is maintained.

In AEDES electronic traceability can be defined as: *"The degree to which a relationship can be established between two or more products of the development process, especially products having predecessor-successor or master-subordinate relationship to one another; for example, the degree to which the requirements and design of a given system element match."* (IEEE 1996:3). Electronic traceability ensures that the history of all actions, messages and changes are kept.

To this requirement were added event triggers that would transfer documents in the concurrent environment. All of these events are traceable as to time of occurrence and parties involved. An example is the architect that changes a layout. The AEDES system automatically generates an e-mail message to the engineer. This informs him that a change has occurred in the layout of the building and that the architect requires him to check the stability of the concrete columns.

4.2.4.3 Flexible queries and reporting

The structured project data, information and knowledge facilitates flexible ad hoc queries and flexible reporting, for example:

- Report 1: Complete list of all What's at all QFD house levels.
- Report 2: Complete list of all How's at all QFD house levels.
- Report 3: Detailed characterisations of the solution required (QFD What side)
- Report 4: Complete specification of all items in the design (QFD How side)
- Report 5: Separate reports/customised design guides that can extract specifications for an element, according to any of the 9 indicator groups, for example a report on maintenance or equipment required.
- Query 1: Select a suitable pre-packaged unit

Report 5 is useful to assess operational requirements with regards to maintenance and to enable scientific operational comparisons to be made between different facilities of the same type.

Query 1 is used to select an appropriate pre-packaged solution. Pre-packaged units can be selected out of the data repository by any of the following means:

- Visual inspection of the characteristics.
- Structured query language based ad hoc query builders.
- Structured query language based query builders, enhanced by fuzzy set logic.
- Electronic Pugh concept selection.

Data repositories could be web-based and be provided by third party developers in a similar way that building product information is acquired. When a selection is made, the object is

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brought into the project environment and localised with regards the local material prices, maintainers and equipment required.

4.2.4.4 Implicit linking technique

It is a technique originally pioneered in the development of the CSIR Facilities Management system, PREMIS developed by the author. This technique creates relationships between diverse sources of alphanumeric and graphic data. This facilitates connection between existing commercially available information and new alphanumeric and graphical objects created (Conradie 1996). Appendix A describes this method in detail.

4.2.5 Major components

4.2.5.1 Relational database

In AEDES data relate to the life cycle of a building and is continuous and concurrent. They are accessible by appropriate software tools. All software components are well integrated with the underlying stratum of data, by means of specific AEDES diagramming and data manipulation tools.

AEDES incorporates a relational database management system, based on prior experience. It supports world-wide-web deployment. It is in the nature of structured methodologies that a significant amount of data is generated. The database structure is such that it is possible to cut the data horizontally or vertically. It is possible to extract all specifications for all indicator categories or only construction related items. If a specific data object is changed all dependant documentation will be synchronised. If a design is changed the impact with regards the main indicator categories can be assessed easily.

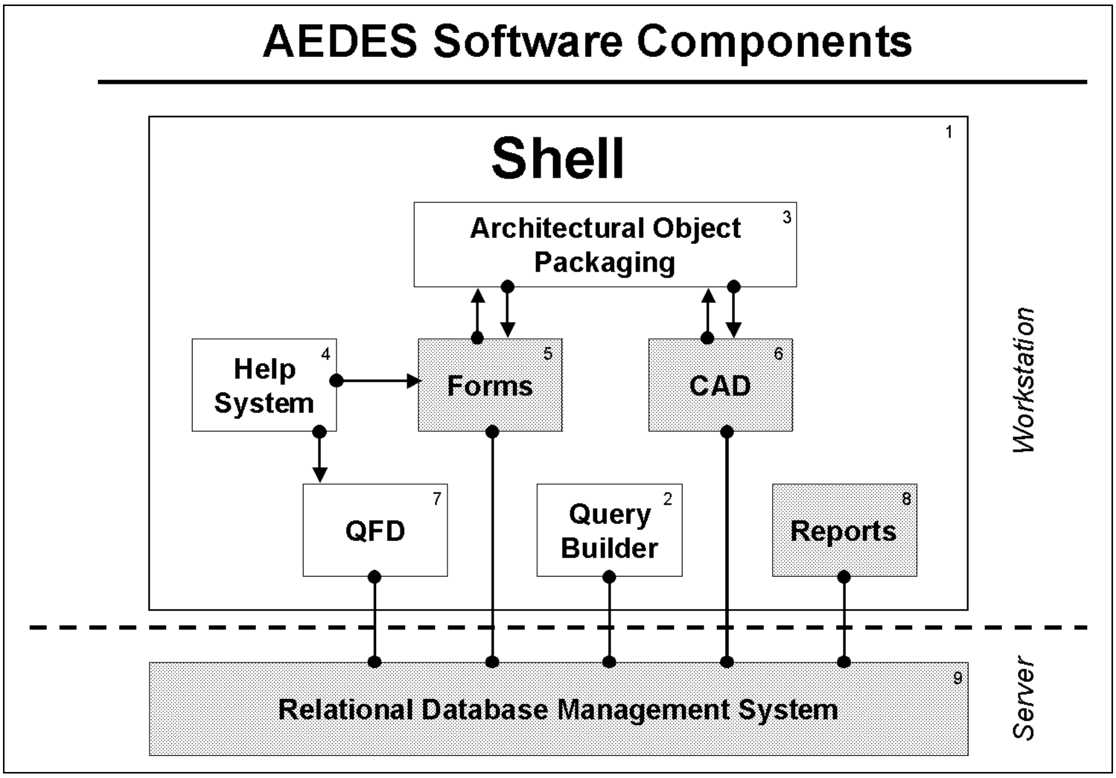

Figure 6: AEDES software components (Author)

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4.2.5.2 Software shell

The software shell provides an integrated environment for the development team. Users identify themselves by means of user names and passwords giving them certain access rights and user profiles. The ad hoc query builders as well as the standard reports are accessed from the shell.

4.2.5.3 Database forms

The database forms are designed in such a way as to give the user visual clues as to what is required. The intention is that the main QFD data capture forms will be used in conjunction with the help system. Users may cut and paste template examples from the help system to assist them to quickly populate the required form data fields.

The AEDES forms are completely generic. Any complexity of architectural design object can be conveniently handled. Any level can contain any number of sub-objects. The only restriction is that the description per text object or sub-text-object may not be more than 2 000 characters. The size of any graphic object may not be more than 2 Giga bytes. For practical purposes the system has virtually no limit.

4.2.5.4 Help system

A comprehensive context sensitive help system is provided, due to the fact that architectural practitioners are new to the field of structured briefing design. The help file provides a step by step description of the various actions that need to be taken in the briefing and design process. New definitions were invented for the intended environment to make it more acceptable.

4.2.5.5 QFD diagram software

Visio software proved useful to generate large pre-printed QFD charts for QFD sessions. Visio is electronic drawing sheet based with sufficient programming support to connect it to the central server-based database or even a portable personal database. The intention is that a scribe, familiar with the software, will be seated out of the way of the group's activities and quietly record data into the computer as the team reaches consensus. The decisions can then be copied onto large wall charts or even re-plotted from Visio. Decisions are captured in the main Oracle database forms that ensure full traceability and integrity. The Visio diagrams are used to capture the data required for matrices such as the relationships, technical matrix, planning matrix and technical correlation. Relationships can be defined across the container categories such as **A1.3.4.1 Landscape features** and **B1.2.2.3 Space**. At a finer grain items within the space container can be related such as a relationship between **A2.2.2.3**.*2.3* **Structure**: *Superstructure* and **B2.2.2.3**.*2.5* **Structure**: *Roofing*. At this stage the authors are of the opinion that due to the fact that the design is related to an architectural domain, the data will tend to cluster around physical containers and especially the space category **A1.2.2.3** through to **A4.2.2.3**

4.2.5.6 Starter kit packaging

A first attempt, albeit in very raw form, was made to package architectural design knowledge. The starter database kit form attempts to enable a designer to package an architectural object in a 2 or 3D CAD drawing, inclusive of main characteristics, specification and related materials. No attention was given to the tacit knowledge aspects or the intelligent interoperability of objects.

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4.2.5.7 Materials database

The materials database form makes provision for the main material description, a generic set of user definable attributes and a photograph or technical diagram depending on the type of material.

4.2.6 Conclusion

The AEDES Prototype System provides a new prototype structured design methodology, within an integrated concurrent multimedia project environment. An attempt is made to turn certain parts of the architectural briefing and design process into a science without compromising architecture or existing design ethics. According to Kolodner[1] the intention should not be to turn Architecture into a science but rather to create good tools that maximise the efforts of creative designers. This ensures the highest possible level of competitiveness, professionalism and use of scarce resources for architectural practitioners in a developing country.

In order to bring AEDES closer to commercial realisation and to protect the existing substantial investment in the FM system PREMIS (Professional Real Estate Management Information System) more focussed research is required. The two most pressing needs in South Africa are:

- The creation of a World Wide Web enabled continuous data infrastructure over the life cycle of a building.
- The ability to store and retrieve carefully engineered design knowledge in the form of electronic design starter kits.

In the present AEDES prototype system the abovementioned points are still poorly researched although the theoretical need can be clearly identified.

4.2.7 Critique of AEDES

AEDES was a first attempt to create an Integrated Project Environment that could span the entire life cycle of the facility. The system managed to use aspects of QFD, Systems Engineering and Concurrent Engineering. The research and development team (Conradie and Küsel 1999) succeeded in creating a system that enables the designer to start with a raw client requirement and go right down to the component level. Functional decomposition was used extensively.

The most significant shortcomings of the system were:

- An over emphasis of the functional decomposition (transformational approach) aspects led to a rigid system that is very prescriptive to the creative people that is supposed to use it.
- It was difficult to map multiple functions from different main container categories identified in AEDES to physical structural elements.
- The team never fully achieved the objective of creating starter kits[2] (cases at various levels of specificity) to expedite future designs. This was due to the fact that the benefits that AI could offer and specifically CBR was not known at the time.

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[1] Kolodner, J., Georgia Insitute of Technology, 2000 – personal communication

[2] A starter kit is a simple architectural CAD drawing that contains a complete ideal layout of for example a hospital ward and could be used to rapidly design a hospital. This is useful in South Africa with the shortage of skilled designers. The division of Building Technology of the CSIR developed an extensive set of these designs that are currently used to design significant hospitals and clinics. See 4.2.4.1 Starter Kits.

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- Adaptation of designs was very difficult due to the rigid structure.

AEDES highlighted the enormous complexity of creative design in an open world that is confirmed by numerous authors. The AEDES team failed to understand the implications of the fact that *design constraints are not constructive* and that the *design problem spaces are not enumerable* (Hinrichs 1991:15-16).

Summary

The long operational life of PREMIS can be attributed to the fact that it is modular (primitive object oriented structure) but also succeeded in separating data, process and application clearly. These facts made the system flexible. This provided useful insights into the design of applications that use the same data infrastructure yet serve totally different clients. The implicit linking technique is a useful way to link object oriented graphic and alphanumeric information together.

PREMIS provided useful insights into a deeper understanding of ontology in a Facilities Management environment. The development also highlighted the inadequacies of Relational Databases with regard hierarchical structures. Facility Managers are often confronted with the problem of maintaining construction structures that were badly designed. This emphasises the importance of the early phases of the building life cycle.

Although AEDES can be viewed as a failure in commercial terms it provided the first insights into the how user requirements might be extracted and structured to obtain a performance requirement. It was discovered that requirements and functions fall into two main groups i.e. active and passive. A set of functions to successfully enable the operational capability of the requirement could be identified. These functions could be individually characterised according to functional and physical characteristics and constraints. Finally a characterised function could be allocated to a physical element.