Chapter 5: Aims of ARGOS

Introduction

Chapter 3 and 4 indicate that an opportunity exists to bridge the explicit and tacit aspects of design with an intelligent component. This chapter introduces the main aims of ARGOS and also discusses the important technique of concept selection (Pugh 1996; Ulrich *et al*. 1995:105-122). Concept selection takes place in the phases of design. The examples are used to develop possible conceptual solutions on the basis of the experience gained with the precedent systems discussed in Chapter 5 whilst at the same time describing the process. The concepts are specifically hand drawn to emphasise the creative and exploratory nature of what concept selection should be. On the basis of this a detailed prototype implementation for ARGOS will be developed in Chapter 6.

From the previous chapters it is clear that it is very difficult to improve the briefing and design processes successfully. Systems that attempt to improve these processes need to be very flexible. Designers work in many different equally valid ways. The design of the ARGOS intelligent component should be such that it can manipulate design information easily. Hinrichs (1991) and Simina (1999) provide useful insights as to the direction that should be taken specifically with regards creative design. It is clear that the creative human designer should remain in control and that systems should be designed in such a way as to assist the human designer. The following significant areas of assistance can be identified that could possibly be improved with ARGOS on the desktop:

- The ability to select the best concept for a project or part of project
- The availability of previous design experience at various levels of specificity to remind the designer of aspects he might have forgotten
- The ability to test shape and placement of design parts (relationships)
- To ability to judge the suitability of a design with regards function and performance (scenario planning)
- Long life and persistence of design fragments in a neutral environment
- Collaboration in a multi-disciplinary team on a global basis
- Support for modelling and simulation.

New branches of Artificial Intelligence (AI) such as Case-based Reasoning (CBR) brought realism as to the possible contribution AI could make in this environment. Current AI attempts to assist the human designer, not to simulate the capabilities or improve the human brain. To this end CBR has already contributed significantly to capture experiential knowledge. The study and also practical experience indicate that it is unlikely that all design knowledge could ever be concentrated in a single location or database. In the present world knowledge is added at such a tempo in general that attempts to gather it in a single database is unlikely to succeed, because of the diverse formats that exist in the world of design. Even after 20 years the world of CAD has not succeeded in formulating data exchange standards that can connect these diverse systems reliably beyond the pure exchange of graphical information. It must be admitted that although many different standards have seen the light, they only satisfy very specific needs. Due to the different ontological needs of design knowledge over the life cycle data standards such as the Industry Foundation Classes (IAI), IGES and DXF are not really suitable if CBR needs to be introduced in a neutral environment.

The World Wide Web has grown beyond recognition as the largest network the world has ever seen. Cheswick and Burch at Bell Laboratories (2 000) recently mapped the Internet by means of electronic tracers or packets. In the process at least 88 000 main routers were discovered. These routers are connected to millions of individual users. It became clear that an intelligent design component should both be object based and Internet enabled. Its knowledge must be structured and self-documenting. It should be able to operate in a wide variety of environments over a long period of time. It must be useful in small and large project teams using different design and construction processes. It cannot be predicted with certainty what the nature of these processes will be in future.

Due to these diverse requirements the author came to the conclusion that the optimal solution would be the introduction of an intelligent design components. These must be highly flexible and be able to operate in very diverse desktop container environments without being dependant on single technologies such as databases, CAD or other propriety programs for its success. Riesbeck (1996) stated that his theme for *post-modern* AI is the concept of intelligent components. The goal should be the improvement of how systems function through the development of intelligent parts to those systems. In *post-modern* AI, AI becomes an invisible part of the overall system. The goal is not smart appliances and cars that talk to the user. The goal is now street lamps that do not waste electricity on totally deserted sidewalks and traffic lights that do not turn green for streets closed for construction. Riesbeck (1996) indicates several research areas for CBR relevant to making CBR feasible for intelligent components in non-intelligent systems such as the indexing and adaptation aspects.

Concept selection is discussed under 5.1 for the following reasons:

- Concept selection is one of the most critical and difficult problems in design.
- The examples are used to develop possible conceptual solutions on the basis of the experience gained from Chapter 5 for the detailed implementation of ARGOS in Chapter 6 whilst at the same time describing the process.

5.1 Concept selection

5.1.1 Introduction

Concept selection is the emergence and selection of the best and strongest concepts with respect to customer needs and other criteria. Although creativity is essential throughout the entire product development process, concept selection reduces the number of alternatives under consideration. Concept selection is one of the most critical and difficult problems in design. It is the selection of the optimal concept with which to proceed to detail and ultimately manufacture or in the case of architecture construction. A lack of thoroughness in concept selection will bring conceptual vulnerability. Due to the nature of architecture it is easy to select the wrong concept and difficult to select the optimal one. In practice it is impossible to evaluate all possible solutions to a particular problem.

Concept selection is an integral part of the product development process. By using different methods the design team generates alternative concept solutions. According to Ulrich (1995:111) the use of a structured concept selection method offers the following main benefits:

- *A customer focused product*. Concepts are evaluated against customer-oriented criteria.
- *A competitive design*. The benchmarking of concepts with respect to existing designs push the designers to exceed their competitors' performance along key dimensions.
- *Better product-process co-ordination*. Explicit evaluation of the product with respect to manufacturing criteria improves the product's manufacturability and helps to match the product with the process capabilities of the firm.
- *Reduced time to product introduction*. A structured methodology becomes a common language among the design team members such as manufacturing and industrial engineers. This avoids ambiguity, improves communication and reduces false starts.

- *Effective group decision-making.* A structured methodology encourages decision-making based on objective criteria and minimises the likelihood that arbitrary or personal factors influence the product concept.
- *Documentation of the decision process.* A structured method results in a documented rationale behind concept decisions. This record is useful for integrating new team members. It is also useful to assess the impact of changes in the customer needs or in the available alternatives.
- *Traceability.* The commitment or "buy-in" of team members is recorded.
- *Structured decision.* Should it be necessary to backtrack on decisions it can be done in a structured way.

The following disadvantages can be identified:

- Concept selection could force the team to stick to the beaten track.
- It could inhibit lateral thinking.
- "Hard issues" and "hard people" could dominate the decisions taken.
- It is more work to analyse design problems in this structured way.

5.1.2 Conceptual vulnerability

Pugh (1996:169) states that conceptual weakness in design manifests itself in two ways:

- The final concept is weak due to lack of thoroughness in the conceptual approach. Thereafter no amount of attention to technical and detail requirements will save the situation.
- The final concept is good and the best within the constraints. Due to lack of thoroughness in conceptual approach and selection the reasons for its strength are not known or fully understood. It is also difficult to persuade or refute others on the basis of a sound technical argument.

5.1.3 Overview of the method

Concept selection is often performed in two stages to manage the complexity of evaluating dozens of product concepts. Screening is a quick evaluation aimed at producing a few viable alternatives. Scoring is a careful analysis of these concepts to choose a single concept that will lead to product success. Concept screening follows a seven-point process and scoring a six-point process that leads the team through the activity. If the design decisions are simple then concept screening is adequate. As an example four hand drawn alternative concepts are included in Figure 39 to Figure 42. This illustrates the design of a user interface for starter kits (intelligent case enabled components) that will be discussed in much more depth in chapter 6. The reference concept is the type of CAD drawings drawn in MicroGDS that is currently being made available on the Internet to architects designing hospitals (Figure 43). At the moment CAD is a mature technology and is widely used by most design professionals.

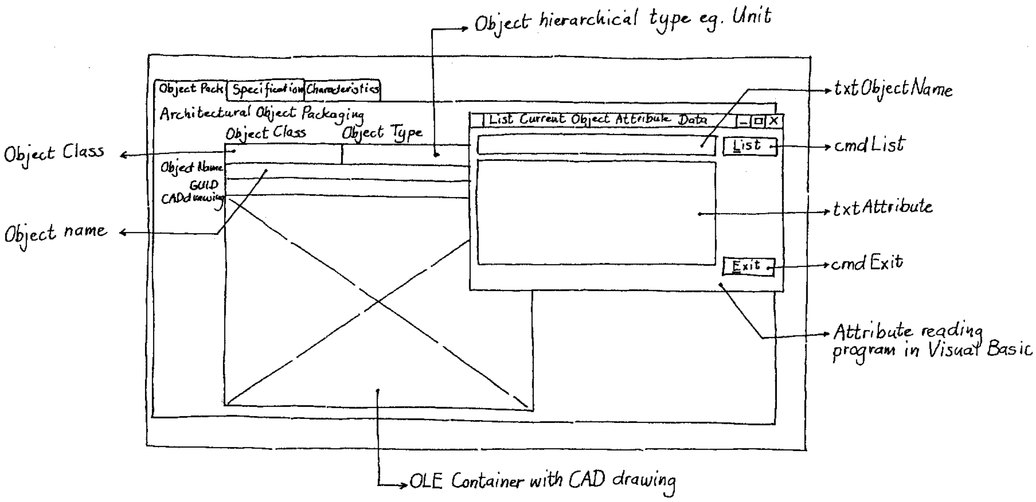

Figure 1: Concept A, Oracle form with CAD in OLE container and Visual Basic attribute reader (Author)

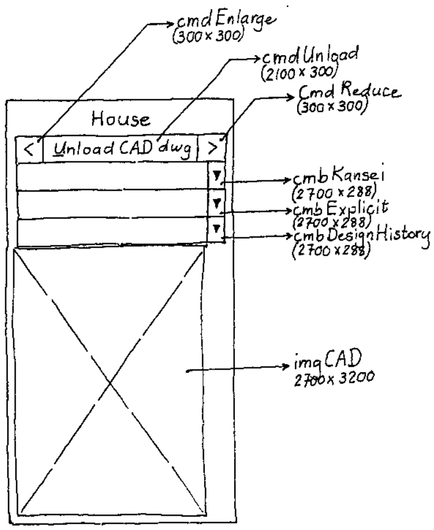

Figure 2: Concept B, ActiveX control based starter kit (Author)

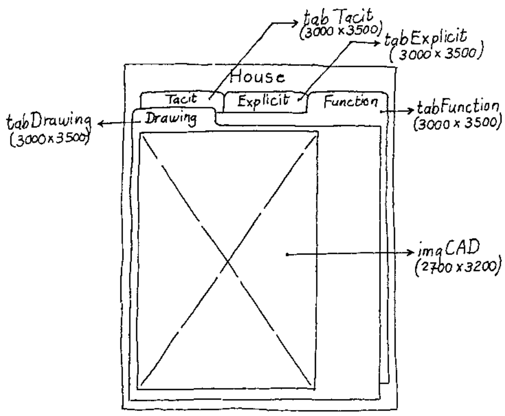

Figure 3: Concept C, ActiveX control based starter kit (Author)

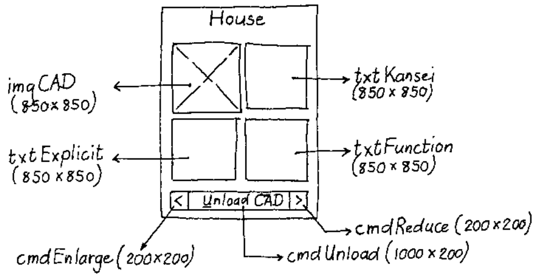

Figure 4: Concept D, ActiveX control based starter kit (Author)

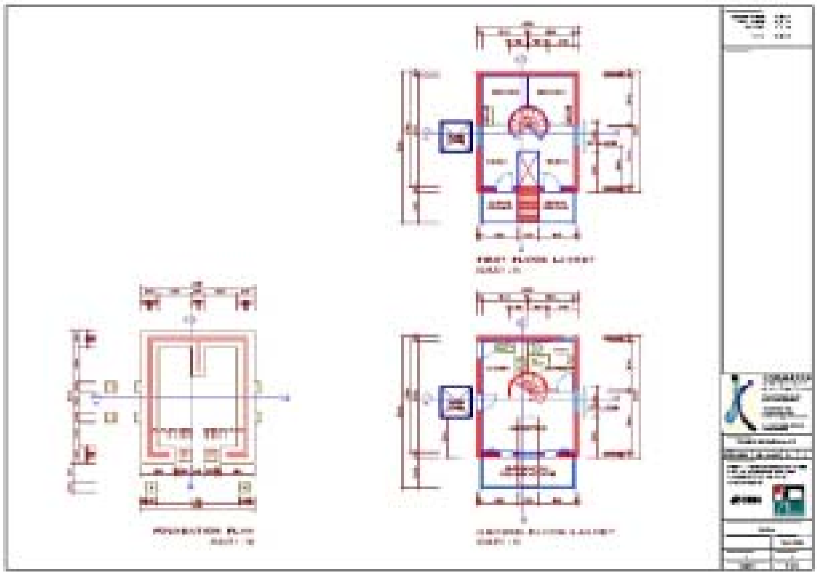

Figure 5: Typical starter kit drawing as used in the design of the AEDES prototype used as the starter kit reference concept (Author)

The following procedure could be used for concept screening:

1. Select possible solutions to the particular design problem.
2. Prepare the evaluation matrix.
3. Rate the concepts.
4. Rank the concepts.
5. Combine and improve the concepts.
6. Select one or more concepts.
7. Reflect on the results and the process.

If a *Case-Based Reasoning* (CBR) methodology were to be applied, then point 1 would be equivalent to a *case retrieval* process (Kolodner 1993:17). Concept scoring is identical to screening except that point 1 is not applicable.

5.1.4 Concept screening

5.1.4.1 Select possible solutions to the particular design problem

It is important that semantics are clarified and that the team members attach the same meaning to the criteria. The design team gathers all possible potential solutions for the design problem. Sketches are produced to the same level of detail in each case if it is a manual system.

5.1.4.2 Prepare the evaluation matrix

The selected concepts are entered on the matrix. The concepts are best displayed with a written as well as a graphic representation. If the team is considering more than 12 concepts, then voting should reduce them. The selection criteria are listed on the left-hand side of the screening matrix. The needs should be based on the needs of the customer as well as of the enterprise. At this stage the criteria should be at a reasonably high abstraction level and should contain about 5 to 10 metrics or criteria. It is important that the criteria should be selected in such a way that a distinction can be drawn between the different concepts. The team should also avoid to list too many unimportant criteria because during the screening phase each criterion is weighted equally. The criteria must be on the same basis and all to the same generic level.

Examples of initial screening criteria in an architectural environment could be *area and volume measurement, comfort indicators, acoustical qualities, physical shape and location, materials, energy and abstracted design metrics* (Conradie 1997). Due to the general complexity of criteria in an architectural environment the Saaty (1980) analytic hierarchy process might be more appropriate for comparing and evaluating different design solutions on a technical basis. Saaty (1980) describes advanced examples such as conflict analysis for health care management, energy examples such as optimum choice of coal plants and energy storage systems.

After careful consideration the team chooses the reference concept against which all the other concepts will be rated. If design or industry standards already exist for the product under consideration this should be included in the matrix to form a datum choice. The datum could be any of the following:

- A commercially available product.
- An earlier version of the product.
- Any of the concepts under consideration.
- Combination of subsystems combined to represent the best features of different products.

5.1.4.3 Rate the concepts

During this stage each concept is a general notion of the final product. Weighting of the ratings or detail is therefore not relevant at this stage. The spreadsheet was implenented in Excel and the command button used VBA to calculate the results (Figure 44).

Each concept’s criterium is rated against the chosen datum by means of the following legend:

- A plus sign (+) means *better than, less than, less prone to, easier than* relative to the datum.
- A minus sign (-) means *worse than, more expensive than, more difficult to develop than, more complex than, more prone to, harder than* relative to the datum.

- Where any doubt exists as to whether a concept is better or worse than the datum, use a (0) that means the same as the datum.

If objective metrics are available they should be used. In the design of a shopping centre *usable* and *rentable* area could give a very good indication of the commercial viability of a design. These metrics minimise the judgmental error that is inherent in the process. Objective metrics suitable for concept screening can also be derived from the establishment of target specifications of the product. At this stage it can also be established whether some criteria need further investigation.

5.1.4.4 Rank the concepts

After rating the concepts the team sums the ratings. The sum of +'s, -'s and 0's are first derived. The net score is then obtained (Figure 44). Once the summation has been calculated the concepts can be ranked. It is convenient at this stage to identify the differentiating criteria, which really make the biggest difference.

5.1.4.5 Combine and improve the concepts

After the concepts have been ranked the results should be verified to make sure that they make sense. After assessment of the individual scores the following possible phenomena could be observed:

- A certain concept exhibits exceptional strength. In this case the matrix should be rerun with the strengths removed. If, as a result of running the matrix several times, the initial high scores persist they are likely to be the best concepts with which to proceed.
- A strong pattern of concepts does not emerge and each concept appears to have a uniform strength. This is very unusual. In this case the datum should be changed and the pattern reassessed.
- A particular concept persists. The datum should be changed and the process repeated. If the result remains the same the emergent strong concept can assume the role of datum. The matrix should then be rerun and the results assessed.

Ways can now be considered to combine and improve certain concepts. Two possibilities are:

- Is there a good concept that is degraded by one single bad feature? Can a small modification improve the overall concept and maintain an edge over the other concepts?
- Can concepts be combined in such a way as to improve the good characteristics?

5.1.4.6 Select one or more concepts

At this stage it is clear what each concept is worth and a decision can be taken which concepts can be further analysed and refined. It must also be decided whether another round of concept screening will be performed or whether the team will proceed to concept scoring. If the screening did not provide sufficient clarity then the more detailed concept scoring can be used.

5.1.4.7 Reflect on the results and the process

All the team members should agree with the outcome. If somebody does not agree with the results it is possible that crucial criteria are missing from the matrix or a particular rating could be wrong. It is important that the team agrees with the results, because it increases the commitment to subsequent product development stages.

	Concept Screening			
	A	B	C	D
Selection Criteria	ORACLE CAD in OLE container and VISUAL BASIC	ActiveX control with pull-down lists	ActiveX control with tab controls	ActiveX control with quadrants
Portability	-1	1	1	1
Ease of development	-1	-1	-1	-1
Use in various life cycles	1	1	1	0
Encapsulation	1	1	1	1
Persistence of data	1	1	1	1
Ease of use	-1	1	1	-1
User interface	1	-1	0	-1
Third party development	-1	1	1	1
Sum of +'s	4	6	6	4
Sum of 0's	0	0	1	1
Sum of -'s	4	2	1	3
Net Score	0	4	5	1
Rank	4	2	1	3
Update				

Figure 6: The concept screening matrix for the concepts A to D (Author, based on Pugh 1996; Ulrich et al. 1995:114)

5.1.5 Concept scoring

Concept scoring is used when the previous concept screening could not provide sufficient differentiation. During scoring more detail is considered and the relative importance of the selection criteria is considered. The concept scores are determined by the sum of the different rating weights. In this case a six-stage process is followed. Point 1. Under concept screening is omitted this time.

The designers proceed to develop the strongest concepts emerging from the initial evaluation. The concepts are now engineered to a higher level of detail. The additional work results in a greater understanding of the problem and its solutions. Such understanding leads to a refinement and expansion of the criteria for evaluation. The matrix is reformed to incorporate the enhanced concepts and also the revised or expanded criteria. The general mechanism of the first phase is repeated. The outcome will confirm the earlier patterns or give rise to a reordered set of concepts. In each case the designer should have a critical review of the emergent pattern.

5.1.5.1 Prepare the selection matrix

The process is the same as previously with the screening stage. Due to the more complex calculations a computer spreadsheet is a convenient way to do calculate the results. The concepts are now more detailed than during the screening phase and therefore more detail is available. The concepts that have been selected are entered on the top of the matrix. More detail can be added to the selection criteria. A hierarchical approach can be followed where general terms such as “comfortable livingroom” could be broken down into “Internal

Temperature", "Lighting Levels" and "Ventilation". The level of detail depends on the needs of the designer.

After the criteria have been entered, the team adds importance ratings to the matrix. Several different schemes can be used to weigh the criteria, such as a scale of 5, 4, 3, 2, 1 or a distribution of 100 percentage points amongst the criteria. Refined marketing techniques exist that can be used to determine weights from customer data.

5.1.5.2 Rate the concepts

As in the screening stage the concepts are compared to the reference concept. However at this stage a finer scale is used to give finer resolution. A 1 to 5 five scale is normally used. It is generally best to have a scale that is symmetric around the reference concept score.

Relative Performance	**Rating**
Much worse than reference concept	1
Worse than reference concept	2
Same as reference concept	3
Better than reference concept	4
Much better than reference concept	5

Unless by coincidence the reference concept is of average performance with regards all criteria, the use of the reference concept for the evaluation of all criteria will lead to scale compression for some of the criteria. For example if the reference concept happens to be the easiest construction, then all remaining concepts will get 3, 2 or 1 scores. In a situation like this the team can choose different concepts as the reference points for different criteria.

5.1.5.3 Rank the concepts

Once the ratings are entered for each concept, weighted scores are calculated by multiplying the raw scores by the criteria weights. The total score for each concept is the sum of the different scores. Each concept is given a rank according to its total score. The following formula is used:

$$s_j = \sum_{i=1}^{n} r_{ij} w_i$$

where r_{ij} = raw rating of concept j for the i th criterion

w_i = weighting for the i th criterion

n = number of criteria

s_j = total score for concept j

5.1.5.4 Combine and improve the concepts

As in the screening stage, the team looks for changes that would improve the concepts reviewed. The team is now aware of the strengths and weaknesses of certain features of the product concepts.

5.1.5.5 Select one or more concepts

The final selection is not just to select the concept that achieves the highest ranking. The team should explore its initial evaluation by conducting a sensitivity analysis. As is the case in Figure 44 a spreadsheet can be used to vary weights and ratings to determine their effect on the ranking (Figure 45).

By careful analysis of how sensitive a ranking is to variation in a particular rating, it can be determined whether uncertainty about a particular rating has a large impact on the choice. Sometimes it is advisable to select a lower scoring concept that has less uncertainty than the high scoring one.

If the customer groups have different preferences then two different matrices can be prepared. It is possible that one concept is dominant in both cases. In the examples given it is clear from the data that Concept C is the most promising.

5.1.5.6 Reflect on the results and the process

		Concept Scoring					
		B		C		D	
Selection Criteria	Weight	Rating	ActiveX control with pull-down lists	Rating	ActiveX control with tab controls	Rating	ActiveX control with quadrants
Portability	10	4	0.4	4	0.4	4	0.4
Ease of development	5	2	0.1	2	0.1	2	0.1
Use in various life cycles	10	3	0.3	3	0.3	3	0.3
Encapsulation	20	5	1	5	1	5	1
Persistence of data	10	3	0.3	3	0.3	3	0.3
Ease of use	15	2	0.3	4	0.6	3	0.45
User interface	10	3	0.3	5	0.5	3	0.3
Third party development	20	5	1	5	1	5	1
	100						
Total Score			3.7		4.2		3.85
Rank							
Continue?			No		Develop		No

Figure 7: The concept scoring matrix for the concepts B, C and D (Author, based on Pugh 1996; Ulrich et al. 1995:117)

Finally the team reflects on the selected concept and on the concept selection process. This is an important point where the entire team should be convinced that all the relevant issues have been discussed and that the selected concept will satisfy customers and will be economically viable.

5.1.5.7 Some important factors

If the technique proposed is to be used in architectural design then the following points need to be considered carefully.

- *Decomposition of concept*. The idea of concept selection is that the selection criteria and therefore customer needs can be evaluated separately. It is also assumed that concept quality is the sum of the quality of each criterion. It is difficult to decompose certain products into a set of independent criteria. This is often the case in architecture due to the complex relationships among design criteria. Architectural design is a good example of multi-attribute decision making. Many of the relationships are non-linear. By means of QFD the customer preferences and the relative importance attached to certain criteria can be clearly established. This should be used in the concept selection process.

- *Subjective criteria.* Some selection criteria especially the ones related to aesthetics are highly subjective. In this case the team cannot decide on those issues on behalf of the customer. It is recommended that an accurate subjective voice of the customer be obtained by means of techniques such as Kansei Engineering discussed in chapter 3.

- *Where to include cost.* The selection criteria are mostly customer needs that could have originated from the use QFD techniques as suggested in the AEDES prototype. "Ease of manufacturing" and "manufacturing cost" are not customer needs. Depending on the type of construction project cost is an important factor in choosing a concept. To facilitate concept selection some measure of cost and life cycle cost should be included into the evaluation matrix.

- *Elements of complex concepts.* Some complex concepts are aggregations of simpler concepts. If all the concepts are aggregations of several simpler concepts, then the simple concepts can first be evaluated independently.

- *Ubiquitous use of concept selection.* Concept selection should be used throughout the product development process and not just in the beginning. The same is true of the numerous other techniques available such as QFD, Kansei, Theory of Constraints and TRIZ.

5.1.6 Enhanced QFD and concept selection

When QFD was first introduced into the U.S.A., the QFD model assumed that the selection of appropriate technology for a product was outside the scope of QFD (Cohen 1995:182). Don Clausing and Stuart Pugh realised that the process for selecting innovative concepts should interact with the translation of customer needs to prioritised technical responses. These ideas were embodied in a process called Enhanced QFD (EQFD). EQFD consists of five interrelated processes:

- Contextual analysis and static/ dynamic analysis.
- Structuring of product design specification.
- House of Quality.
- Concept selection.
- Total system/ subsystem analysis.

The concept selection process as described by Pugh is pivotal in EQFD. It is recommended that the EQFD be facilitated and managed by a person that is not directly involved in producing concepts to avoid suspicion of favouring a particular idea or interest.

Summary

An intelligent design component should be both object based and Internet enabled. Its knowledge should be structured and self-documenting. It must be able to operate in a wide variety of environments over a long period of time. It should serve small and large project teams using different design and construction processes. It cannot be predicted with certainty what the nature of these processes will be in future.

This chapter identified the significant areas of assistance that an autonomous intelligent component such as ARGOS could improve such as:

- Concept selection

- Retrieval of design experience
- Test of relationships
- Scenario planning
- Collaboration on a global basis
- Modelling and simulation