Final Report of Delphi Study

Project No. 2002-010-B

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1. Executive Summary

This is the final report of project 2002-010 Component Life – A Delphi Approach to Life Prediction of Building Material Components. A Delphi survey has been conducted to provide expert opinion on the life of components in buildings. Thirty different components were surveyed with a range of materials, coatings, environments and failure considered. These components were chosen to be representative of a wider range of components in the same building microclimate. The survey included both service life (with and without maintenance) and aesthetic life, and time to first maintenance. It included marine, industrial, and benign environments, and covered both commercial and residential buildings. In order to obtain answers to this wide range of question, but still have a survey that could be completed in a reasonable time, the survey was broken into five sections:

1 External metal components – residential buildings.
2. Internal metal components – residential buildings.
3. External metal components – commercial buildings.
4. Internal metal components – commercial buildings.
5. Metal connectors in buildings.

The survey was conducted in two stages. In the first stage, there were a total of 66 responses, with the number of the responses to each of the survey parts ranging from 9 to 18. The questions were placed in four classes depending on the degree of consensus in responses to the particular question. After the first stage, approximately 80% of questions had a consistent answer from the survey group. In Stage 2, 10% of questions were further investigated, with 75% of these remaining questions then having a consistent answer. The responses for each question were answered to give a mode (most frequent interval), a mean value and a standard deviation of the mean.

The final database was examined in three ways to determine its accuracy and reliability. These were analyses for internal consistency of the data, for consistency with expected trends based on knowledge of materials performance and environmental severity, and for correlation with existing databases on component performance. In all cases, the Delphi survey data appears reliable

The possible extensions of the approach are discussed in line with the technical 'success' of the method. However, the study was difficult to carry out owing to difficulties in obtaining answers from possible respondents. Thus, if a larger survey is to be undertaken including all building components, it is recommended that committed respondents be obtained before devising a survey.

2. Introduction to Delphi Surveys

2.1 General Background

A Delphi survey is a structured group interaction process that is directed in 'rounds' of opinion collection and feedback. Opinion collection is achieved by conducting a series of surveys using questionnaires. The result of each previous survey will be the basis of the formulation of the questionnaire used in the next round. The Delphi technique is an established method for obtaining consensus (Duffield 1993). It generally consists of a series of questionnaires that are developed or refined in sequential stages until consensus is achieved.

Since its development in the late 1960s, the procedure has been used in a variety of professional settings (Gilmore & Campbell 1996). It has been used to identify problems, define needs, establish priorities, plan curricula, and identify and evaluate related solutions (Jairath & Weinstein 1994; Ziglio 1996). The Delphi technique has a long history of use in health and medicine.

2.2 Application of Delphi Survey to Building Components

The theories on material durability derived from empirical data are few, and hence it will be useful to obtain subjective judgment and identify important issues in the field. Material degradation is also a complex process, and hence it may be beneficial to take advantage of the one of the strengths of Delphi method, i.e. the ability to gather opinions from experts from diverse backgrounds. By conducting a Delphi survey via a web server, participants from all over Australia can give their responses anywhere, at any time and at an affordable cost.

Professionals such as builders and architects were the primary respondents to this survey. They were selected on the basis of their practical experience and theoretical knowledge. Building material suppliers were also invited to participate in the survey for their intimate knowledge of their specific products. Academics and scientist were also included because it is believed that they understand scientific principles in areas that are related to material durability, and so their expertise will be relevant to the construction of a durability model.

2.3 Basic Approach

There were two rounds of questionnaires in this Delphi survey. The first round took about four months to complete, while the second and last round took less than a month. The registration period was devoted to inviting potential participants to indicate their willingness to participate. Participants were given a user ID and password so that they could complete the survey online. The results of the first round were tabulated and analysed. Questions where there was no obvious consensus, such as where there was a divergent opinion or a wide range of estimated service life, were identified. These selected questions were included in the second round.

3. Scope of the Survey

3.1 Metal Components in a Building

There are over 120 different components or component/material combinations within a building (as listed in Farnell Cost Codes). These are listed in Appendix A (Table A1). Clearly this is too large a number of components to survey.

3.2 Concept of Representative Components

To overcome the issue of the large number of classes, the concept of representative components was introduced. Groups of components similar in geometry (as far as factors promoting degradation is concerned), composed of the same material and exposed in the same environment were grouped together, and only one component was surveyed. In this manner, it was possible to reduce our components to be surveyed down to 30. These are listed in Appendix A (Table A-2).

3.3 Scope of Survey

For each of the 30 components, the survey needed to cover the most common materials and coatings used, the substrate of the material (in case of fasteners, bracing, building straps etc.), the effect of maintenance, and a range of environments and failure modes.

Within this survey it was not possible to investigate the type of maintenance applied, only the life of components with or without maintenance. Thus, a simple definition of maintenance is applied, as follows:

> *In terms of the survey, maintenance may extend from cleaning to repainting, but will not include replacement except for accidental damage (of not more than 1% of system). When assessing life of nails, bolts etc., maintenance refers to maintenance of the substrate (paint on timber etc.).*

Australia experiences a range of different climates and a range of different levels of exposures to degradation agents (primarily marine salts and industrial pollutants) However, the scope of this contract is restricted to ‘temperate’ zones and thus the effect of tropical/alpine/desert environments was not included in this survey. In fact, data suggest that climatic zone, while significant, is not nearly as important as pollutants in controlling the degradation of metals (Cole et al. 1999). As mentioned above, the main ‘pollutants’ in Australia are marine salts and industrial pollutants (NO_x, SO_x, ozone). Corrosion scientists will normally break environments up into four ranges for salinity and four for SO_x. In this survey, for simplification we limited the classification to three, which represent the extremes of exposure in Australia. These were ‘marine’, ‘industrial’ and ‘benign’, with the advice given to survey respondents being given below.

> ***Marine*** *– In order to ensure a consistent answer, a marine location should be treated as the first off-beach building from a surf beach. Again, in order to standardise responses, assume that the dwelling or commercial building is 200 m from the high tide level separated by a road, light vegetation and beach. For the corrosionists, airborne salinity will be 150 mg/m².day.*
>
> ***Industrial*** *– Again for consistency, an industrial location is 500 m from heavy industry (steel works or oil refinery) separated by a low vegetation buffer zone. For corrosionists, the airborne sulfate level will be category I2 from ISO 9225.*
>
> ***Benign*** *– A location not significantly affected by either marine aerosol or industrial pollutant. Typical location would be more than 10 km from a surf coast and not within 5 km of an industrial zone.*

The last issue to be addressed in defining the scope of the survey was the failure criteria to be used. It was decided to survey both life expectancy and aesthetic life of a component. Both of these concepts are somewhat subjective. Life expectancy would be when a component stops fulfilling its function and would appear to be an objective concept. However, different users will tolerate different degrees of loss of function.

4. Design of Survey

In designing the survey, a number of issues needed to be considered, including:

1. The number of questions to ask.
2. The complexity of each question.
3. The information to be gathered concerning respondents.
4. Delivery mode of questionnaire.
5. Layout of questions and survey.

As indicated above, the survey had been limited to 30 components. However, these components could be fabricated from three materials or coatings, they may or may not be maintained, and they could be placed in up to three environments, and could fail because of aesthetic or performance reasons. In addition, for fasteners, components may have different substrates. Thus, even with the limited number of components, the possible number of questions was in excess of 1000. Clearly this was too large for one questionnaire. Thus, it was decided to break the survey into five sections:

1. External metal components – residential buildings.
2. Internal metal components – residential buildings.
3. External metal components – commercial buildings.
4. Internal metal components – commercial buildings.
5. Metal connectors in buildings.

This would limit the number of questions to slightly more than 200 for each survey.

Given the length of the survey, it was desired to keep the questions as simple as possible. In line with this philosophy, the minimum level of information was supplied consistent with allowing the respondent to make a meaningful decision. For example, in questioning the perceived life of metal components in the roof spaces of buildings there are a range of design factors that may affect the component life, including the degree of ventilation and the nature of the insulation/sarking. In general, these variations were not explored and only variations in metal and/or coating type were explored. In addition to the requirement to keep the survey simple, it was considered that there would not be a sufficient level of knowledge and/or consensus in the community to justify this level of detail. For each component, the generic names of the most common materials and coatings were given and, where appropriate, common thicknesses. For fasteners and other connectors, the nature of the substrate was also given. On a number of occasions respondents requested additional information concerning design details. This information was then communicated on a case-by-case basis to the respondents.

Considerable discussion was held concerning the level of details to seek from each respondent. Proposals were put that the respondents should self-rate their expertise. However, it was decided to minimise the respondent details to name/email/company and job description. Job description could be used to assess probable level of expertise. This simplified request was further justified by the decision to split the survey into five. Each possible respondent was asked to complete the survey that they had the greatest expertise in.

There were a number of possible delivery modes including:

1. Direct meetings.
2. Phone Interviews.
3. Paper distribution.
4. Electronic distribution.
5. Web distribution.

Each delivery mode was considered and it was decided to undertake a web-distributed survey. This mode was considered to have the advantages that it was:

1. Easy to collate.
2. The respondent could complete the survey in his or her own time.
3. It could be automatically retrieved without any need for the respondent to give electronic or physical responses.
4. An attractive easy to complete form could be derived.

In fact, to encourage respondents to complete the survey all forms of distribution were offered and, with the exception of paper distribution, no interest was shown in other modes of survey completion by respondents.

The web capability was used to develop a simple but easy to use form. The form contained:

1. General information on the survey.
2. A section for respondent details.
3. Index to the form divided into main building spaces/categories.
4. Questions in each category.

The questions took the form of an illustration of the component in situ then a definition of the component, as well as material/coating/substrate, followed by questions on:

1. Service life with maintenance.
2. Service life without maintenance.
3. Time to first maintenance.
4. Aesthetic life.

This was repeated for the environments, namely marine, industrial and benign, and also for the variations in material type (i.e. for roof sheeting for pre-painted coated steel (Colorbond), aluminium-zinc coated steel (Zincalume) (AZ150) and galvanised steel (Z275). The respondents used drop-down menus, which had the following choices:

1. <5 years.
2. 5 – <10 years.
3. 10 – <15 years.
4. 15 – <20 years.
5. 20 – <30 years.
6. 30 – <50 years.
7. >50 years.

An example of the layout of a question is shown in Figure 1.

Wall Cladding

Galvanized (Z275)

Marine Locations

Service life with maintenance	
Service life without maintenance	
Time to first maintenance	
Aesthetic life	

Industrial Locations

Service life with maintenance	
Service life without maintenance	
Time to first maintenance	
Aesthetic life	

Benign Locations

Service life with maintenance	
Service life without maintenance	
Time to first maintenance	
Aesthetic life	

Prepainted Coated Steel (Colorbond Grade)

Marine Locations

Service life with maintenance	
Service life without maintenance	
Time to first maintenance	
Aesthetic life	

Industrial Locations

Service life with maintenance	
Service life without maintenance	
Time to first maintenance	
Aesthetic life	

Benign Locations

Service life with maintenance	
Service life without maintenance	
Time to first maintenance	
Aesthetic life	

Figure 1. Section of survey on external components for commercial buildings

4.1 Possible Respondents

The possible respondents were drawn from a number of sources:

1. CSIRO contacts predominately in material/component suppliers, corrosion consulting and research areas (approximately 300).
2. University of Newcastle contacts primarily amongst builders and designs (approximately 200).
3. Contacts from Queensland Department of Public Works and Brisbane City Council of their own officers (approximately 20).
4. CSIRO – general list which ranges from design, builders through to building owners and managers (approximately 2000).

4.2 Issues Concerning Obtaining Responses

Despite the large number on email lists, responses were very hard to obtain. In addition to email contact, phone contact was made, and the survey was advertised at two conferences and in a number of technical newsletters. In the end almost all respondents were known to members of the research team and were due to personnel contacts.

5. Stage 1 Data

5.1 Respondents

The number of respondents varied from 9 to 18 for each survey. While this number is low, it is acceptable for surveys of controlled groups such as Delphi surveys (Jairath & Weinstein 1994). In Table 1, the profession of the respondents has been determined. They are divided into:

1. Suppliers – working for material or component suppliers.
2. Construction – working for construction companies or builders.
3. Consultants – consultants on material durability and corrosion.
4. Government/maintainers – working for government bodies charged with maintaining buildings.
5. Researchers – researching into material durability.

Table 1. Number and nature of respondents

Survey*	**Total**	**Suppliers**	**Construction**	**Consultants**	**Government/ maintainers**	**Researchers**
Com-ext.	18	4	3	4	3	3
Com-int	16	4	5	1	3	2
Res-ext	9	—	2	1	3	3
Res-int	11	2	2	1	3	3
Connectors	12	4	3	0	2	3

* Where required 'Com' and 'Res' will be used for commercial and residential buildings respectively, and 'ext' and 'int' will be used for external and internal components respectively.

5.2 Responses

The responses to individual questions were classified into four classes based on a simple rule:

Class 1. One interval contained more than 50% of responses.
Class 2. Two adjacent intervals contained more than 50% of responses.
Class 3. Three adjacent intervals contained more than 50% of responses.
Class 4. None of the above or cases where there are two or more (non-adjacent) intervals with the same maximum number of occurrences.

The responses to questions were always put into the highest class possible. Examples of Class 1 to Class 4 responses are listed in Figures 2–5 respectively. Full data from the Stage 1 survey can be found in Report No. 3 – Results from Delphi Stage 1.

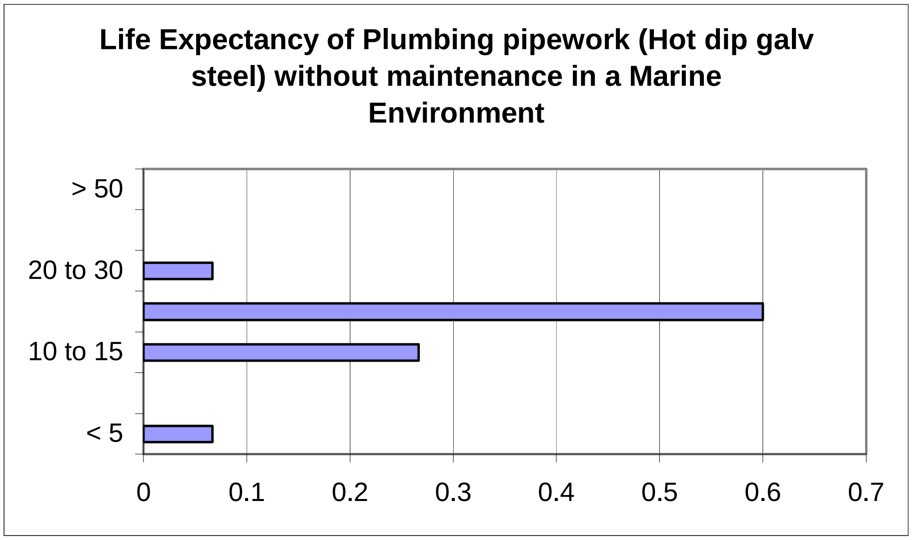

Figure 2. Example of Class 1 response

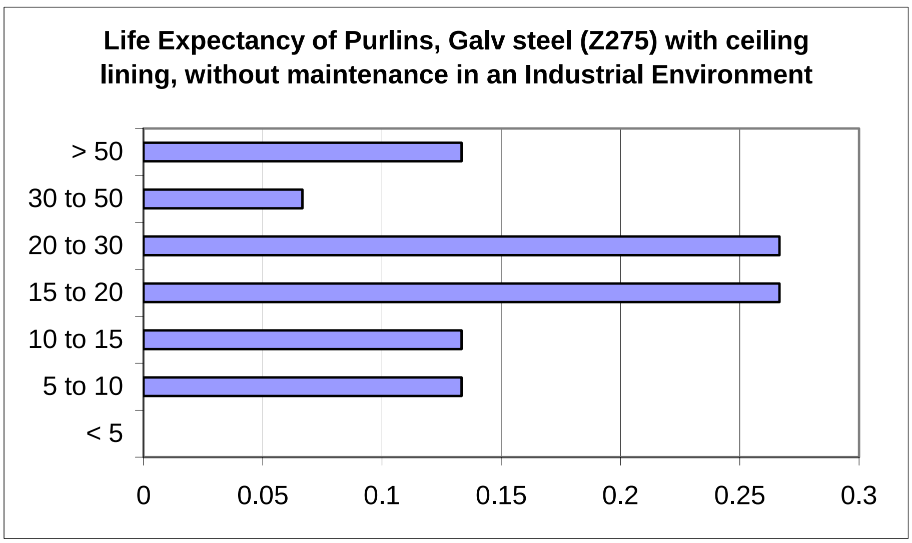

Figure 3. Example of Class 2 response

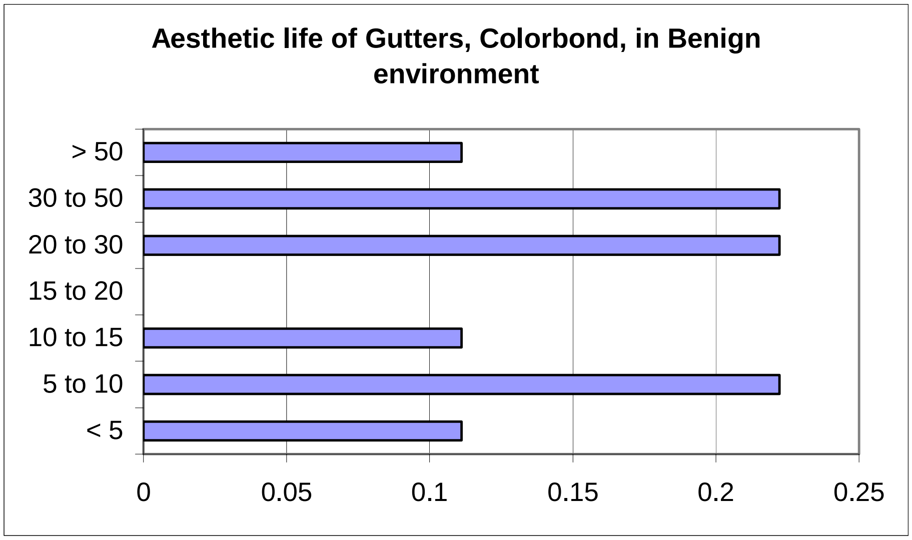

Figure 4. Example of Class 3 response

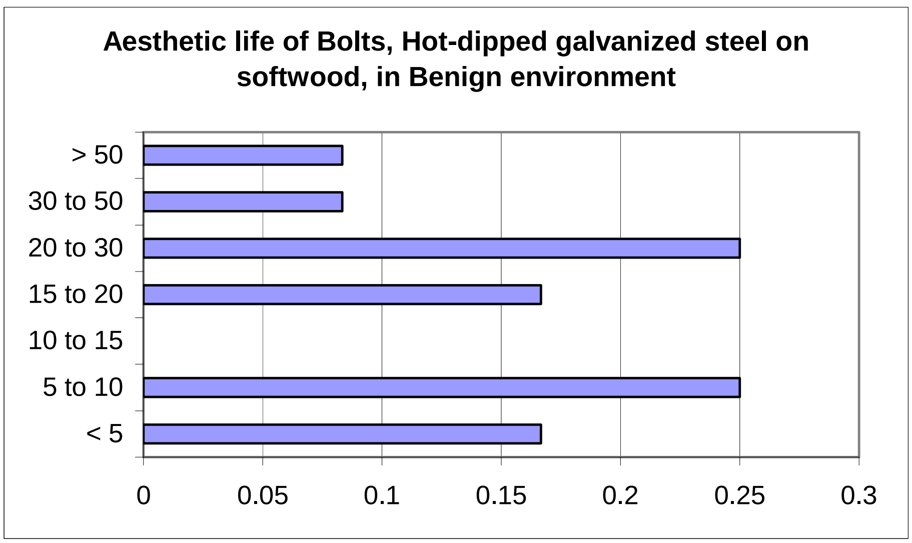

Figure 5. Example of Class 4 response

In stage 1, 671 questions were asked. Analysis indicated that 523 or 78% where Class 1 or 2 responses and 148 or 22% were Class 3 or 4 responses.

6. Stage 2 Survey – Methodology

The design of the Stage 2 survey was driven by two considerations:

1. The need to address the critical questions where Stage 1 responses did not show a significant consensus (Class 3 or 4 responses).
2. The need to limit the survey to a restricted number of questions to increase completion rate.

As with Stage 1, five surveys were conducted, and for each a limit of 20 questions was set. Initially it was desired to ask for a second response on all questions, which did not fall into Class 1 or Class 2. However, the number of re-asks would have significantly exceeded 20, so it was desired to exclude questions relating to industrial environments and time to first maintenance for Stage 2. Industrial environments are relatively benign in Australia and thus the life of components is not severely affected.

In Stage 2, the questions focussed on the divergence in opinion, and thus a simple question with only two or three responses was asked in order to check the original variation in data spread. For example, in the aesthetic life of gutters (Colorbond) in a benign environment, answers originally fell in two populations – one with life greater than 20 years and the other with life less than 20 years. Thus, in Stage 2 the question is asked:

Is the aesthetic life of gutters (Colorbond) in a benign environment:

1. *Life ≥20 years; or*
2. *Life <20 years.*

When the responses were received, the original data was revised to maintain the respective distribution of lives within each part of the population, but to balance the responses for the two sides of populations (i.e. ratio of lives in the categories >50, 30 to <50 and 20 to <30 stays the same with respect to each other, but changes with respect to group <5, 5 to <10, 10 to <15 and 15 to <20).

Only 90 questions were asked in stage 2 in order to guarantee a high level of response. Thus questions in the following categories were excluded:

1) Time to first maintenance
2) Industrial Environments

This decision was based on the fact that as far as inducing corrosion and thus limiting component life Industrial effects are relatively limited in Australia being restricted to one or two centres. The category "time to first maintenance" while providing useful information is not critical to the central aim of the project (providing data on component life). These exclusions reduce the number of Class 2 and 3 questions to just over 100. The number of questions in Stage 2 was marginally reduced from this number by not asking further questions on relatively unimportant components (shower rails etc).

6.1 Results of Stage 2 Survey

The effect of the Stage 2 survey was to increase the consensus as determined by the class of the responses in a large fraction of questions addressed. Table 2 sums the class of responses before and after the Stage 2 survey (only those questions surveyed in Stage 2 are given). It is apparent that of the 75 questions for which an acceptable consensus had not been reached (Class 3 or 4) after Stage 1, after Stage 2 there was an acceptable consensus in 56 cases (Stage 1 and 2).

For example, the data for aesthetic lives of gutters (Colorbond) in a benign environment is given in Figure 6, and the data for aesthetic life of bolts (hot dipped on softwood) in a benign environment is given in Figure 7. Both responses are now of Class 2.

In order to define the nature of each set of responses, three parameters are defined:
1. The mode of the distribution.
2. A pseudo mean.
3. A standard deviation about the pseudo mean.

The pseudo mean is defined by assuming that the values take the mid-point of the interval selected (i.e. a selection in the interval 10 – <15 years has a value of 12.5 years). In Appendix B the responses to questions before or after Stage 2 are given. Often after Stage 1 it was inappropriate to define a mode, as a number of intervals had the same value. It is apparent that in Stage 2, modes could be defined, the standard deviation of the responses had generally reduced and the class of answer had moved into Class 1 or Class 2.

Table 2. Number of responses in each class after Stage 1 and Stage 2

Stage	Class 1	Class 2	Class 3	Class 4
1	0	15	25	50
2	13	57	10	9

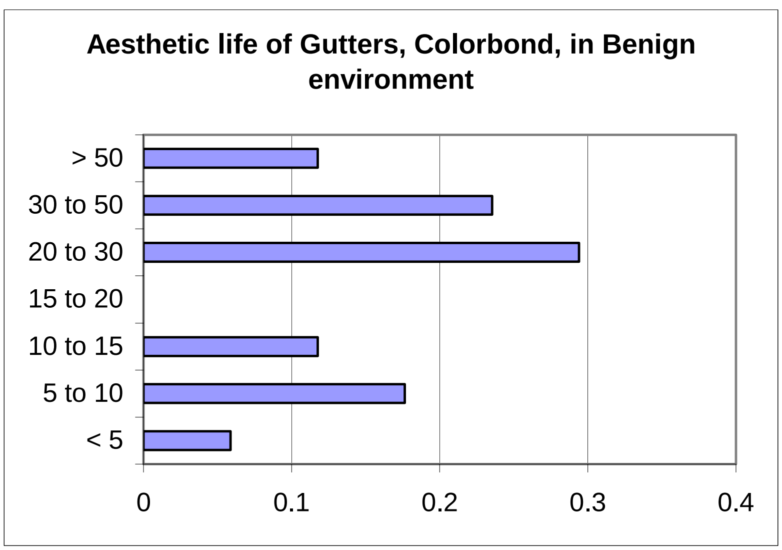

Figure 6. Stage 2 result for gutters (Colorbond) in a benign environment

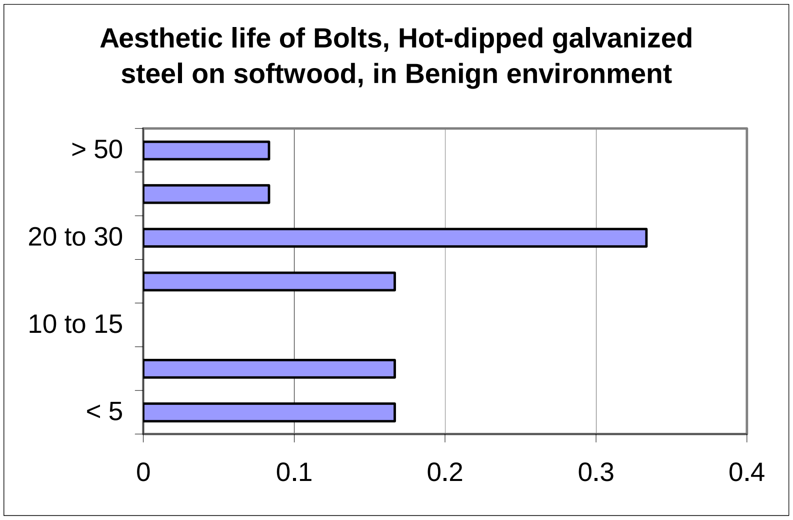

Figure 7. Stage 2 result for aesthetic life of bolts (hot-dipped galvanised on softwood) in a benign environment

7. Final Database

A final database of all responses consisting of Mode, Mean, standard deviation and class of responses has been constructed and is listed in Appendix C. Of the 671 questions, 86% have Class 1 or 2 responses. However of the remaining 92 or 14 % of questions which do not sufficient consensus, 29 or 4% related to question on “Time to first maintenance” and 17 or 3% on performance in Industrial zones. For reasons discussed above these are not considered critical to the database. Of the remaining 46 questions with class 3 or 4 responses, 19 related to questions where additional information was sought in a stage 2 of the Delphi study but a consensus was not reached and 27 related to relatively unimportant components which were not addressed in Stage 2.

8. Validation of Database

There are three means of testing the reliability of the data:

1. Reviewing the internal consistency of data.
2. Reviewing against expected trends.
3. Reviewing against existing experimental data.

8.1 Reviewing the Internal Consistency

If the database is to be reliable, opinions on closely related questions should be similar. One of the advantages of breaking the survey into five sections is that it permits cross-comparisons between the different surveys on closely related questions. The mean service lives with maintenance of gutters and roof sheeting in both residential and commercial buildings are listed in Table 3.

As indicated above the means are derived by using the mid-point of the selected intervals and the standard deviation about the means tends to be of the order of 10–20. Thus, differences in means of 2 or 3 should not be treated as significant. Comparing results for commercial buildings with those for residential buildings, it is apparent that the difference is greater than 3 for only three cases (marked in red), and in all case it is 4 years. In two out of three cases, the commercial life estimate is marginally shorter than the domestic. Indeed for a number of technical reasons (more exposed buildings, low level of pollutants) this may reflect reality.

8.2 Reviewing Against Expected Trends

Although only limited experimental studies have been undertaken defining component life (detailed in Section 7.3), physical sciences provide a reasonable understanding of the severity of microclimates around a building and the relative performance of buildings.

For example, with regard to gutters and roof sheeting, the following relationships would be expected:

1. The order of increasing durability would be galvanised steel, Zincalume and Colorbond (although Colorbond would not be that much better than Zincalume).
2. Gutters are in a more severe microclimate than roof sheeting, due to greater retention of water and debris in gutters, and to the fact that greater pollutant deposition is expected at the edges of buildings where gutters are situated.
3. Commercial buildings in an equivalent climatic/pollutant zone may be in a slightly more aggressive environment.

Table 3. Service life (years) of roof sheeting and gutters

Building type	**Component**	**Material**	**Marine**	**Industrial**	**Benign**
Commercial	Gutters	Galvanised	10	15	32
		Zincalume	21	24	42
		Colorbond	21	26	36
Residential	Gutters	Galvanised	11	14	33
		Zincalume	15	19	36
		Colorbond	18	24	40
Commercial	Roof sheet	Galvanised	19	23	43
		Zincalume	26	28	49
		Colorbond	26	29	46
Residential	Roof sheet	Galvanised	18	23	47
		Zincalume	22	26	49
		Colorbond	24	31	47

The data in Table 3 is, in general, consistent with these trends as:

1. Galvanised gutters have estimated lifetimes of from 4 to 11 years shorter than Zincalume or Colorbond gutters. Galvanised roof sheeting has estimated lifetimes for commercial applications of from 5 to 7 shorter than Zincalume or Colorbond sheering. Galvanised roof sheeting for domestic applications has an applicably shorter life than Zincalume in marine locations, but comparable in the other environments. Zincalume and Colorbond are comparable in life for both roof sheeting and gutters.
2. Gutters have an estimated shorter mean life (3–14 years) across all situations in comparison with roof sheeting.
3. As discussed above, the life of both types of components is similar in commercial and residential building, but where the differences exist, the life on commercial buildings tends to be shorter.

An alternative example is the service life of nails (steel and galvanised) and bolts (steel, hot-dipped galvanised and brass) in softwood. The following trends would be expected:

1. Galvanised nails should have a longer life than steel nails.
2. For bolts, the order of performance of the materials (best last) is steel, hot dipped galvanised and brass. Brass is expected to be significantly better.
3. Performance in benign conditions should be significantly longer than industrial or marine.

A comparison of nail performance is given in Table 4.

The Delphi survey results are in alignment with expected trends in that:

1. In marine and benign locations the estimated life of galvanised nails is significantly better than that of steel nails.
2. For bolts, performance increases dramatically from steel to galvanised to brass.
3. Performance of all types of nails and bolts is significantly better in benign conditions compared to marine.

8.3 Reviewing Against Experimental Data

Selected results from the Delphi study can be compared with those from CSIRO databases on component life. CSIRO data contains three forms of information:

1. Data derived from direct exposure of metal components for limited time periods (1–2 years), and then used as the basis for the estimate of life based on standard equations in the corrosion literature (labelled ‘experimental’ or ‘exp’).
2. Data derived from CSIRO’s holistic model. The CSIRO holistic model predicts life based on an understanding of the processes promoting corrosion. It has been validated against experimental data as outlined in ‘a’ (labelled ‘holistic’).
3. Data derived from the Queensland Department of Housing on time for significant replacement or repair of housing (labelled ‘maintenance).

Table 4. Estimated life of nails and bolts in softwood

Component	Material	Marine	Industrial	Benign
Nails	Steel	10	15	38
	Galvanised	19	17	46
Bolts	Brass	32	28	43
	Galvanised	19	21	38
	Steel	9	14	24

This information has been compared with the Delphi responses for life of roof sheeting without maintenance (galvanised) in marine and benign conditions (see Table 5), and life of roofing members without maintenance (galvanised and Zincalume coated) in marine and benign environments (see Table 6). Fuller analysis is reported in document No. 3 – Comparison of Life Estimates from Delphi Study with Data from CSIRO Data-Bases. However, the basic conclusions are that the mean of all forms of the data (including the Delphi study) are quite close for roof sheeting, although the survey data and the maintenance data are slightly lower in the benign environments. The mode of the survey data is slightly longer for the marine environment and slightly shorter for the benign environment than the experimental or holistic models.

In the case of roof members, the experimental data maintains a distinction between above and below sarking which is not included in the survey. The survey results in the marine environment are quite close to the above sarking experimental data particularly with regard to mean values. In the case of benign environments, both the survey and the experimental and survey data predict lives in excess of 50 years for modes and means.

Table 5. Comparison of database and survey predictions for roof sheeting

Data	**Environment**	**Mode**	**Mean**	**SD**
Survey	Marine	10–20	12	6
Exp	Marine	5–10	14	12
Holistic	Marine	5–10	9	5
Maintenance	Marine		16	
Survey	Benign	30–50	35	13
Exp	Benign	>50	>50	
Holistic	Benign	>50	>50	
Maintenance	Benign		41	4

Table 6. Comparison of database and survey predictions for roof members

Data	**Environment**	**Position**	**Material**	**Mode**	**Mean**	**SD**
Exp	Marine	Roof space – above sarking	Galvanised steel	20–30	32	17
Exp	Marine	Roof space – below sarking	Galvanised steel	30–50	50	10
Exp	Marine	Roof space – above sarking	Zincalume-coated steel		36	17
Exp	Marine	Roof space – below sarking	Zincalume-coated steel	30–50	54	10
Exp	Benign	Roof space – above sarking	Galvanised steel	>50	>50	
Exp	Benign	Roof space – below sarking	Galvanised steel	>50	>50	
Exp	Benign	Roof space – above sarking	Zincalume-coated steel	>50	>50	
Exp	Benign	Roof space – below sarking	Zincalume-coated steel	>50	>50	
Survey	Marine	Roof members	Galvanised steel	20–50	39	19
Survey	Marine	Roof members	Zincalume-coated steel	15–20	34	21
Survey	Benign	Roof members	Galvanised steel	>50	53	19
Survey	Benign	Roof members	Zincalume-coated steel	>50	57	19

In summary, there is quite reasonable agreement between the Delphi survey results and the measurements in the existing database. Some minor differences do occur, however these should not be regarded as errors in the Delphi survey. Experimental measures of life are based on extrapolation of life from limited term exposures and on simple failure criteria (loss of 75% coating mass), and thus it may be that these assumptions are not sufficiently robust.

9. Implication of Results

9.1 Discussion of Data Reliability

The survey has provided an extensive database of expert opinion of life over a wide range of metal components. This database is much wider than any previous Australian database and could be of great utility in lifecycle costing and environmental effects assessments. The crucial question is how reliable is the information. There are only three means of testing the reliability of the data:

1. Reviewing the internal consistency of data.
2. Reviewing against expected trends.
3. Reviewing against existing experimental data.

As discussed previously the data does appear internally consistent, and the relative magnitudes of performance that would be expected from knowledge of the severity of microclimates around a building and the relative performance of metals, are in general met. In a few cases where sufficient experimental data exists, the survey results do match our experimental evidence.

On balance then, it would appear appropriate to use the data prudently. That is, it could be used as a guide to probable life where there is a need for a wide database, but the consequences of errors are not dramatic (such as lifecycle assessment). It should not, however, be used where errors could result in structural failure or other significant losses. Lastly, it must be highlighted that this study does not account for faults in maintenance, workmanship or design that may lead to premature failure of building systems and components.

The data would be most suited where it is used as one possible input into life prediction and is balanced against other sources. In fact, the data will be used in such a way in the CBR Project 2002-059-B. It is recommended that only the data where the response was in Class 1 or 2 be used. Lastly, there is the question of which 'data' to use, the mode, or the mean or the mean minus some fraction/multiple of a standard deviation (to give a safe lower limit to life). The answer, of course, depends on the use made of the data. If the data were to be used as an input into the structural reliability of a dwelling (which is not recommended), then the life should be a lower limit, however for indicative values in lifecycle assessments, the mean value is probably most appropriate. It has the advantage that is more easily placed into computations than the mode interval. However, it must be reiterated that there is considerable uncertainty in these numbers and that the assignation of a unique integer value is an approximation.

9.2 Strategies for dealing with Unreliable Data.

As indicated in section 7, for 10% of the questions (excluding time to first maintenance) a sufficient consensus was not reached and thus the data relating to these questions cannot be regarded as reliable. In section 10 it is recommended that further work be carried out to address this issue. However if this is not undertaken prior to its completion the following conservative strategy is recommended to fill gaps in the databases.

- For unreliable data relating to service life with maintenance use data relating to service life without maintenance if available
- For unreliable data relating to performance in Industrial environments use equivalent data relating to performance in Marine environments
- For unreliable data relating to performance in commercial buildings use equivalent data in domestic buildings and vice-versa.

10. Recommendations for Future Work

10.1 Extension to a Wider Range of Building Components

Carrying out this study has been significantly more difficult than anticipated when the study was planned. The major difficultly has been in getting respondents to complete both Stage 1 and Stage 2. Initially it was intended that this be a pilot study that would then be extended to cover all building materials.

The results of this survey, in so much as the data appears internally consistent and consistent with experimental databases, would indicate that extension of the survey is a technically reasonable activity. It will, however, present significant practical difficulties and it is recommended that possible respondents be approached prior to formulating a survey, and ensure that these respondents have the required expertise in the materials under question. Thus, a minimum of 20 committed respondents would be required for each material (e.g. concrete, plastic, timber) of interest. If this could be arranged, then a wider survey would be possible.

Experience also indicates that long delays occur in obtaining responses from respondents. A future survey may wish to move to direct interview with respondents. This would decrease flexibility for the respondents and may prove a limitation, but it would guarantee a more timely response.

10.2 Extensions to Improve the Accuracy and Reliability of the Database

In addition to considering the application of a Delphi study to a larger range of components the following could increase the reliability and accuracy of the use of existing data:

1. As the reliability of the data can only be truly tested by validated against experimental or observational data, a targeted program of gathering field data may have merit in providing a greater understanding of the data’s reliability.
2. Targeted expansion of respondents for components in domestic buildings.

3. Carrying out a Stage 3 Delphi study for those components where a consensus has not been reached.

10.3 Extensions to Improve Ease of Use of Existing Data

The current data exists as Excel files and word attachments. This is appropriate if it is going to be recoded into another program, but is limiting if it is going to be used independently. Further, the environmental definitions 'marine', 'industrial' and 'benign', although standard, cannot be readily derived by the average user. A simple IT system could be built that establishes for a designer or builder their environment, and then retrieves the information for specified components.

11. Commercialisation and Dissemination

The study has generated an extensive database on component life. This is the only database of its kind and provides for the first time data that covers an extensive range of components rather than just a limited number. There are two possible strategies for commercialization and dissemination.

A) As a stand alone tool
B) As a data-base within a commercial product developed by another CRC project.

11.1 Commercialization and Dissemination as a stand-alone tool.

As indicated in 10.3 a stand-alone tool could be developed where the designer/building need only enter their position and component of interest and would be supplied with the estimated component life. However to be effective this would have to cover all materials in a building, not just the metallic components. This tool would be of significant use to CRC partners however it is questionable whether it is justifiable to develop it as a saleable product. The commercial opportunity would be relatively small while the legal risks of providing such "life" data are significant

11.2 Commercialization and Dissemination as an Embedded Database

The results of the study will be used in the CBR study as one of the inputs into estimating component life. It will also be provided to the LCA design team for their use both directly and through the output of the CBR study. The CBR study will integrate a number of means of estimating life (including the Delphi study) to provide potentially more accurate component life estimates. The Delphi data base will significantly expand the accuracy of the component life estimates within LCA adding to the potential of this product.. .

It is planned that the project results be exposed to the research community firstly through a paper at the 10th DBMC in May 2004 and secondly through a journal paper. The results will be presented to the Industrial sector through a series of seminars being planed for project 2002-059-B.

12. Conclusions

A Delphi survey has been conducted to provide expert opinion on the life of components in buildings. Thirty different components were surveyed with a range of materials, coatings, environments and failure considered. The survey was conducted in two stages. After the first stage, approximately 80% of questions had a consistent answer from the survey group. In Stage 2, 10% of questions were further investigated, with 75% of these remaining questions then having a consistent answer.

Examination of the data for internal consistency and comparisons with externally available data indicates that the Delphi study appears reliable. However, the study was difficult to carry out owing to difficulties in obtaining answers from possible respondents. Thus, if a larger survey is to be undertaken to include all building components, it is recommended that committed respondents be obtained before devising the survey.

13. References

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14. Project Sign Off

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