# THE ROLE OF META-ANALYSIS IN CONSTRUCTION MANAGEMENT RESEARCH

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Research into the building and property industry has been undertaken for more than 30 years. Over that time many studies have been repeated, either for verification, updating, or challenging previous work. As a research community, we now have the opportunity to analyse previous studies to provide a meta-analysis. Meta-analysis is a methodology designed in the last twenty years to cast new light through reinterpretation of previous results. However the structured nature of the methodology highlights shortcomings and gaps in the construction management research record.

This paper discusses meta-analysis and its role in construction management research. Two case studies are used to illustrate the value of the method, but also to expose some of the shortcomings in the available studies. It is concluded that meta-analysis should now form a critical component of the research effort. Greater emphasis needs to be placed on replication of studies, which in turn will require a deliberate shift in research strategic management.

Keywords: comparative analysis, meta-analysis, Monte-Carlo simulation, research.

## INTRODUCTION

We have been collectively researching construction management over thirty years. This still leaves our discipline at the relative start of the research experience. This allows a great deal yet to be explored, which makes this an exciting time for those of us fortunate enough to make a contribution to the research effort.

It is not surprising, therefore, that most researchers seek to make new contributions, to stamp their identity onto the research record. This after all is a commonly espoused purpose of research, and in particular the pre-eminent research training mechanism, the PhD. As an example, consider the published requirements of a PhD at the Australian National University, Canberra (ANU 1997):

> *To qualify for the degree a candidate is required:*
>
> - *to carry out independent research involving a comprehensive study of a scope and size which can normally be expected to be completed in the equivalent of three years full-time study; and*
> - *to make a substantial contribution to learning and to reveal a capacity to relate the research done by the candidate to the broader framework of the discipline or disciplines within which it falls, at the international standard recognised for the degree in the relevant discipline or disciplines.*

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The substantial contribution to knowledge leads most of us to explore new models, new ideas, new relationships, or more increasingly of late, to adopt existing approaches from other disciplines in a new way to construction management. This is necessary and valid, however it should not be the sole purpose or outcome of the research effort. Instructions to PhD students provided by University of Reading (Hughes 1997) provide a clue "*In an evolving field, like construction management, it would seem that there must come a point where the methodology becomes more predictable and settled. Perhaps there should be a gradual move from the exploratory, concept-building type of work to the more routine application of techniques*." This type of research builds upon the work of others.

As our research effort matures, there is going to be increasing need to test existing models. This can already be seen. Papers have been published which explore the validity, or compare the merit, of existing models. Thus the comparison or testing is the purpose of the research, rather than merely an analysis of the literature prior to establishing a new contribution.

One such composite of analysis familiar to the author is cash flow modelling. Over the years there have been a number of models for cash flows on construction projects which use different "engines". This has spawned research which explores the validity of the models, or compares accuracy (Kaka 1991, Skitmore 1992, Kaka and Price 1993, Kaka 1996), the testing being preparation for subsequent adoption of an engine in an expanded model (Boussabaine and Kaka 1998).

Such approaches use a model derived from existing literature. However, there are fewer examples of re-testing of parameters or relationships. This is an important field of research endeavour, as it involves validation, replication and identification of patterns. This form of activity, and the argument for deliberate replication studies leading to meta-analysis, forms the thrust of this paper.

## COMPARATIVE ANALYSIS

Comparative studies are used in many disciplines to further the knowledge of the discipline. It has long been realised that individual studies, which are most often necessarily small, may not directly lead to significant results, and yet they may contribute collectively to such an outcome. Analysis of collective studies is usually referred to as meta-analysis.

It is generally agreed in the literature that Glass (and colleagues) coined the term "meta-analysis" in 1976.

> *Meta-analysis refers to the analysis of analyses . . . the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings. It connotes a rigorous alternative to the casual, narrative discussions of research studies which our attempts to make sense of the rapidly expanding research literature.* (Glass 1976)

Since that time, meta-analysis has become a widely accepted research tool. A recent search of the Education Resources Information Centre (ERIC) database (Bangert-Drowns and Rudner 1991) identified over 800 articles written after 1980 that use or discuss meta-analysis. Lyons (1998) illustrated the growth in the use of the technique in the fifteen years to 1990 (Figure 1) and noted the growth was almost geometric.

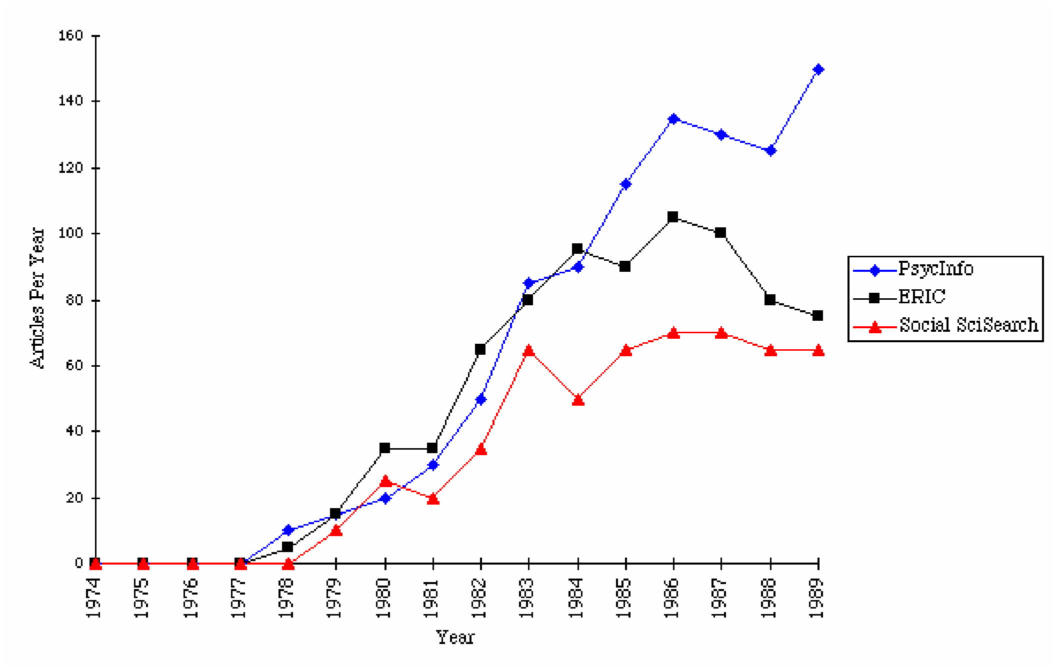


**Figure 1**: The first 15 years of meta-analysis (Lyons 1998)

As with any research method, meta-analysis possesses a number of potential weaknesses. Three of the most important are:

1. problems of comparing and aggregating studies that include different measuring techniques, definitions of variables, and subjects: that is, mixing 'apples and oranges';
2. uninterpretable results due to combining 'poorly' designed studies with 'good' studies; and,
3. bias in favour of significant findings as a consequence of published research having bias toward significant results; non-significant findings are rarely published (Wolf 1986).

Nowhere are potential weaknesses more heavily exploited, than in the most notorious use of meta-analysis: the meta-analysis of the many smoking and passive smoking studies conducted over many years. Meta-analysis techniques have allowed authorities to conclude that smoking and passive smoking are harmful, while at the same time it is generally conceded that individual studies do not support the claim (Abelson 1995). In response, meta-analysis as a methodology has the dubious distinction of having been extensively "flamed" on the internet. Amongst the pro-smoking propaganda, concern is expressed about the very mechanisms which make the technique powerful. "*In theory a statistically savvy researcher can take many small studies and carefully add up the findings to create the numerical power of a big study, but sometimes the studies are too different to add up*" (FORCES 1997).

Legitimate concern that meta-analysis studies are hampered by relying on published studies which may be biased, or may include garbage "garbage-in garbage-out" (FORCES 1997) should be considered seriously. However an impartial view would find this a fault of the data rather than the method.

Any researcher attempting meta-analysis in construction management, will immediately realise that there are genuine problems with adopting such complex and structured forms of literature analysis in a relatively immature research field. It is clear to the author, having been involved with two separate meta-analysis projects, that the rigour of existing studies can be challenged (poor design), or the studies have not published the results or statistics needed for comparison or different measures are recorded. These problems are consistent with Wolf's problems listed above.

The following two case studies illustrate some of the potential of meta analysis

## META-ANALYSIS OF WASTED TIME

In an analysis of wasted time studies, Horman and Kenley (1998) identified 24 studies with a total of 544 data points.

**Table 1**: Analysis of wasted time studies

| Author(s) of study | Sample size | Mean | Range | Standard deviation | Standard error |
|---|---|---|---|---|---|
| Alarcón | 22 | 54.5 | 47.5—61.4 | 4.0 | 1.7 |
| Baxendale | 20 | 49.0 | 29.0—63.0 | —[a] | — |
| Chan & Kumaraswamy—Plant utilisation | 4 | 38.4 | 37.7—39.6 | 1.0 | 1.0 |
| Chan & Kumaraswamy—Site productivity | 4 | 75.6 | 59.5—89.0 | 13.5 | 13.2 |
| Handa & Abdalla | 18 | 33.6 | 26.7—39.5 | 3.9 | 1.8 |
| Horner et al. | 14 | 21.6 | 13.9—28.6 | 5.1 | 2.7 |
| Liou & Borcherding | 45 | 67.0 | 46.5—82.0 | 7.7 | 2.3 |
| Logcher & Collins | 5 | 53.8 | 47.0—60.0 | 5.2 | 4.6 |
| Low & Chan—Public housing | 14 | 19.8 | 8.0—36.2 | 9.4 | 4.9 |
| Low & Chan—Private condominium | 18 | 59.1 | 16.5—83.7 | 22.0 | 10.2 |
| Oglesby et al.—Various trades | 16 | 63.9 | 54.0—73.0 | 6.9 | 3.4 |
| Oglesby et al.—Concrete placement | 12 | 49.2 | 30.0—75.0 | 15.6 | 8.8 |
| Olomolaiye et al. | 21 | 49.9 | 23.0—79.0 | 15.1 | 3.3 |
| Olomolaiye | 12 | 44.4 | 20.0—93.1 | 14.2 | 8.0 |
| Parker et al. | 10 | 39.4 | 5.0—81.1 | 20.0 | 12.4 |
| Peer & North—Labour time | 27 | 38.7 | 1.6—92.2 | 24.9 | 9.4 |
| Peer & North—Plant utilisation | 28 | 30.8 | 0.0—62.2 | 21.9 | 8.1 |
| Salim & Bernold | 4 | 62.3 | 45.5—75.2 | 14.1 | 13.8 |
| Serpell et al. | 17 | 52.6 | 45.0—65.0 | 4.3 | 2.0 |
| Stevens | 8 | 55.4 | 41.0—71.0 | 9.3 | 6.4 |
| Rogge & Tucker | 30 | 40.4 | 25.5—57.5 | 7.7 | 2.7 |
| Thomas—Three-project DB | 46 | 71.6 | 55.9—82.9 | 6.3 | 1.8 |
| Thomas—Grand Gulf DB | 22 | 58.8 | 44.5—69.2 | 7.4 | 3.1 |
| Thomas—Thirty-project DB | 127 | 67.7 | — | 5.9 | 1.0 |

In this study, the computation of standard error provided an indication of the quality of each study. None of the studies were omitted from the investigation on the basis of quality as all fell within tolerable limits. Each was weighted on the basis of sample size to ensure that the quality of study design did not unduly influence the final results. This enabled aggregated results that fell within desirable limits of quality.

This investigation found that the magnitude of wasted time in building operations is substantial at an average of 55%, although notably dispersed.

Horman's work, through applying meta-analysis to what might otherwise have been merely a thorough literature review, provides a more confident analysis of wasted time and a result suitable for inclusion in forecasting and simulation using Monte-Carlo techniques.

## ANALYSIS OF THE TIME-COST RELATIONSHIP

Since the late 1960s, many researchers have explored the apparent relationship between the cost of a project and the duration of the project. Bromilow in the late 1960s explored the relationship between time and cost and derived an equation which is still in use today. Since that time, many studies have tested the relationship and updated the constants. It is now possible to look back on studies conducted over twenty five years, and comment on the overall pattern and the usefulness of the model. This is a form of meta-analysis.

Bromilow (1969) first expressed time as a function of project value in 1969. The formula used for time as a function of cost was given by Bromilow and Henderson (1977) as:

$$T = K.C^{B} \qquad \textbf{Equation 1}$$

where T was the actual construction time in working days

C was the project value in millions (no base index was provided for these figures)

K was a constant characteristic of building time performance in Australia. Its value was given as 350 (it has subsequently been described as an efficiency variable),

and B was a constant indicative of the sensitivity of time performance to cost level. Its value was given as 0.30.

When C equals 1 ($1million) then T = K (350 days) so K represents the average working time for a $1million project.

The variable (K) is lower for projects that are more efficient and Bromilow and Henderson found it ranged between 173 (days) for a fast project and 407 (days) for a very slow project (at the 5% level of confidence). The average for K was found to be 313.

The values of the constants K and B have been studied over time, as researchers have sought to update the values of K and B over time. This allows collective analysis.

Bromilow's model required adjustment of the project value into September 1972 equivalent dollars. This adjustment was done by means of an index[5]. For work after 1976, Bromilow suggested the use of the Building Economist cost index (base 100 in 1962). While not expressed monthly in 1972, this index can be interpolated to have a value of 142 as at September. This index remains current today, although its value as at Jan 1997 was 797 (AIQS 1998) (Building Economist, June 1998).

It is possible to re-express Bromilow's equation to incorporate the cost index - effectively expressing the constants at base 100.

$$T = K.(r.C)^{B} = r^{B}.K.C^{B} \qquad \textbf{Equation 2}$$

where K is an efficiency variable,

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[5] Tucker & Tahilly (1985) suggested the use of a simple index based on a constant rate of adjustment. This is surprising considering the variability of the cost index.

C is the project value

r is the cost index ratio

and B is a constant describing how the performance is affected by project value

For six identified studies these are:

**Table 2**: Adjustment of K for currency index

| Analysis | *K* | *B* | *Cost index* | *Adjust K to index base 100* |
|---|---|---|---|---|
| Bromilow (1977) | 313 | 0.3 | 142 | 348 |
| Ireland (1983) | 274.4 | 0.47 | 211 | 311 |
| Tucker (1985) | 248 | 0.3 | 327.5 | 354 |
| Bromilow, Hinds et al. (1988) | 218 | 0.37 | 584 | 419 |
| Kaka (1991) | 391.22 | 0.287 | 584 | 472 |
| Yeong (1994) | 287 | 0.237 | 735 | 460 |

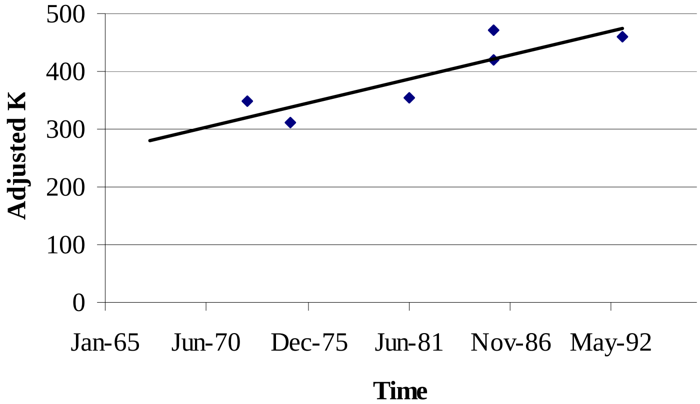


**Figure 2**: K adjusted for cost index

The value in this analysis is that collective analysis of data reveals patterns that would not otherwise be seen.

## CONCLUSIONS

The two case studies illustrate the value in repeat studies, although in different ways. As we now reflect on future research directions, we need to emulate our peers in other disciplines. They are increasingly producing meta-analysis, but this implies that they are also replicating studies. The meta-studies counted by Bangert-Drowns and Rudner (1991) and Lyons (1998) are from a diverse range of disciplines including social sciences, psychology and medical research, where they make a critical contribution to the knowledge.

There is a need for researchers to replicate studies, using rigorous and well-documented methodology, so that meta-analysis can take place in the future. This will lead to the potential to draw conclusions not supported by projects individually. It will also allow the identification of trends and new relationships, due to repeat observations. Furthermore the research may provide an international context.

This requires strategic planning of the research effort, with an additional test of replication being applied to experimental design. Replication studies in turn must be undertaken as a favoured form of research, so that the body of knowledge matures.

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