ANALYSIS OF THE COST PERFORMANCE OF STRUCTURAL BUILDING FRAMES IN AUSTRALIA

Dr Anthony Mills
Associate Professor, School of Property, Construction and Project Management, RMIT University, Melbourne, anthony.mills@rmit.edu.au

Abstract

The significance of this research is that it is the first comprehensive analysis of cost performance across Australia. It is well known that measuring cost performance is not an easy task; comparisons of building projects on a `like-for-like' basis are uncommon, and rarely occur in the real world. However, this paper analyses 120 different structural frame models that represent various; structural designs, construction methods, grid spans, and locations.

The research produced price models that were representative of structural frames used in medium-rise non-residential buildings. It is based on pricing a number of standard building frame designs in five Australian cities. The results represent the cost of producing the same building in different locations, using similar building construction techniques. By utilizing a standard model, project variables like building quality, ground conditions and access were eradicated, thereby facilitating an unbiased comparison of cost performance. I addition, the results are an indicator of building productivity based on costs per square metre of various construction types.

This research provides the Australian industry with robust data about the relative cost performance of various structural building frames. In addition, this research has wider implications because the models may also become useful data for the measuring relative cost performance in other countries.

Keywords: Structural building frames, building cost performance, medium-rise construction, Australia

INTRODUCTION

Measuring production performance and productivity in the construction industry is a complicated process. This is because quantifying output is not an easy task and because there are so many different products produced. Comparisons in construction performance are relatively uncommon because `like-for-like' building projects are rare. Despite this, a number of researchers have successfully carried out studies evaluating productivity levels on construction sites, utilizing various methodologies. (Price 1991; Proverbs & Faniran 2001; 1999)

The principal objective of the research is to indicate `best cost performance' and possible `best design practice' for structural frames in buildings in Australia. The research in this paper is based on pricing a number of standardised building frames designs in five Australian cities. The result produced show the cost of producing the same building in different locations, using similar building techniques. By utilizing a standard model, project variables like building quality, ground conditions and access were eradicated, thereby facilitating an unbiased comparison of national cost efficiency. Hence, results of this research is an indicator of building productivity based on costs per square metre of construction

The Australian construction industry is characterised by a long history of construction using concrete frames. At 13 per cent of the market, steel framing's share of Australian building construction significantly lags that of the UK (70 per cent) and US (50 per cent) (The Warren Centre 2007). This study attempts to provide some insight into the cost drivers that impact on the choice of structural frames in commercial buildings. The next section considers past research approaches that have been used to measure cost efficiency.

Past research using cost models

Methods previously employed to compare construction performance internationally have been categorized into one of three approaches, namely, pricing studies, macroeconomic studies and case studies (Edkins & Winch 1999). Each approach has its own advantages and limitations, mainly in terms of comparability and representativeness. These three approaches are now briefly described.

In *pricing studies*, experienced professionals in different locations are asked to price buildings on the basis of identical drawings, specifications and bills of quantities. This method involves experienced professionals in different places pricing identical buildings, so to some extent it solves the problem of comparability, but does not completely reflect the `real' situation (i.e. representativeness) of different locations. This is because it may be impossible, or at least uneconomic, to build identical buildings in different location without some accommodation for local conditions, architectural characteristics and so forth. According to (Meikle 1990), where identical projects are priced, results may not truly reflect the actual costs because of these (e.g. vernacular) differences. The results are also very sensitive to the economic cycles in different locations.

Macroeconomic studies utilize available statistical data such as national accounts, national construction industry statistics, labour market surveys and other macroeconomic data sources. According to proverbs and Faniran (2001), due to the wide variety of data sources and varying definitions, their reliability and comparability is suspect. Furthermore, such studies only reveal differences between construction industries at a macro level and may therefore be said to be lacking in detail to be of any real value (Xiao & Proverbs 2002).

In *case studies*, `comparable' construction projects in different countries are selected and studied. Actual performance levels are measured against a variety of project criteria. For example, Flanagan et al. (1986) selected nine pairs of `comparable' construction projects in the UK and US for comparing the performance of design and construction processes in the two countries. According to Proverbs & Faniran (2001) it is often difficult, if not impossible, to find truly `comparable' cases in different countries. That is, even where similar designs are considered, differences will remain in (for example) the consultants, ground conditions, climate and the like.

The approach adopted in this research study has been described as belonging to the category of *pricing studies* (Edkins & Winch 1999). The aim of this research was to provide a realistic appraisal of the cost of structural frames used in typical commercial buildings in Australia. Notwithstanding this, the authors acknowledge the difficulties in addressing the issues of comparability and representativeness of data completely, and acknowledge that there is some degree of trade-off between the two. The next sections describes the factors that impact on building costs across five Australian cities

This research uses a customized method to gauge the productivity at site level of five Australian cities. It is expected that the supply and demand situations will be different in each location resulting in each city being in a different stage of the cycle. It is beyond the scope of research to determine the actual stage of the cycle that each city was experiencing at the time the data was collected. Instead it may be more useful to analyse the ranking of each cost model in each location. The next section considers past research approaches that have been used to measure cost efficiency.

METHODOLOGY

The principle objective was to develop a methodology suitable for measuring the cost performance of structural frames in Australian capital cities. The price model was deemed to apply to a range of structures that represent the various types of construction used in non-residential buildings. The aim was to provide industry decision-makers with information on the cost for alternate structural designs including:

- Differences between alternative designs and layouts
- Differences between various locations
- Implications for design and construction

Past research by (Edkins & Winch 1999; Price 1991; Proverbs & Faniran 2001; Proverbs, Holt & Olomolaiye 1999) considered the impact of factors that impact on productivity in the construction of structural building frames. The results of the research showed that the main of impact on productivity was related to of formwork systems, reinforcement, and labour management.

One of the unique characteristics of this research was that the cost models chosen comprised used four matched pairs of frame designs. This was done so that the impact of various construction technologies could be compared. The first two pairs (Design 1 v 2, Design 3 v 4) were used to analyse the cost impact of reinforcement technology. The other two pairs (Design 1 v 3, Design 2 v 4) were used to analyse the cost impact of formwork techniques

The research used both a quantitative and qualitative approach to compare the cost of structural frames in commercial buildings. Past research by Proverbs and Faniran (2001) suggested that this pricing approach suffers from an inability to account for local characteristics and economic cycles that are unique to each building. As a result this research has attempted to account for this using a validation workshop in each of the cities studied. Hence, the research methodology comprised two phases, a pricing the model, and then a validation workshop in each city.

Phase 1- Pricing the cost model

The first stage comprised a cost model based on the design of six typical medium-rise structures. The designs were generated by a professional engineering consultancy firm. Their brief was to design a structure that was typical of commercial buildings in Australia. The design was supposed to represent an average building, without special characteristics like, the requirements of heavy floor loadings.

The resulting designs were a simple layout that excluded the following structural elements: site preparation and bulk earthworks, Ground slab / basements, Structural cores, stairs, lift wells, risers, other structural walls, roof, builders' preliminaries. The cost element contained in the report is limited to:

- Substructure
- Columns
- Upper Floors
- Fire Protection

The design (Table 1) was varied to encompass a range of different structural solutions that were considered to be typical of commercial buildings in Australia. The design comprised the following:

Table 1 – Structural building frame design characteristics

Design	1	2	3	4	5	6
Reinforced concrete columns	✓	✓	✓	✓		
Steel columns					✓	
Precast concrete columns						✓
Reinforced concrete slab	✓	✓			✓	✓
Post tensioned concrete slab			✓	✓		
Conventional formwork to slab soffit		✓		✓	✓	
Permanent metal formwork to slab	✓		✓			
Precast concrete planks						✓
Reinforced concrete beams	✓	✓				
Post tensioned concrete beams			✓	✓		
Steel beams					✓	
Precast concrete beams						✓

The cost model was based on a design of, a typical of medium rise (10 storeys) commercial building. In addition, there were four grid layouts of various sizes that each provided different levels of flexibility of the internal layout of the building. However, relative cost did not change when comparing each of the different grids so as a result only the 8.40m x 8.40 m grid was used as a comparison in this research paper. Each design model was compared using a dollar per square metre rates in each city. Costs in this analysis are research was based on the cost per square metre of suspended slab, which is measured over internal columns to the outside edge of the floor plate.

The cost model was initially priced by national firm of quantity surveyors. The firm contacted their in-house experts in each city and priced the cost model to represent tender prices in March 2007. This was later updated using published prices indices to represent the cost at September 2008. Prices were updated to represent tender prices for September 2008 which was essential so that the cost information was current at the time of the validations workshops in each city.

Phase 2- Validating the cost model: industry workshops

The second stage of the research comprised validating the cost model using expert opinion in a workshop environment. The results produced in the first stage were validated using two separate qualitative approaches. Firstly, prices used in the model were compared with published cost data from other sources, to check the overall correctness of the prices in the model. A recognised builder's price book (Rawlinson 2008) was used to check the order of magnitude of prices in the initial model. The source was considered to be a comprehensive guide to building prices and widely accepted as a legitimate source of industry cost data.

The next phase was to validate the prices using a group of experts who were invited to industry a workshop in each of five cites used in the research. The groups ranged from 10 to 30 building professionals, comprising; structural engineers, building estimators and quantity surveyors. The experts were chosen from contacts known to Cement Concrete and Aggregates Australia. The workshop participants were invited to comment on the prices used in the model, and to validate the final output of the cost comparison. The next section provides the result of the two phases of the research, including the implications for the design and construction of structural building frames.

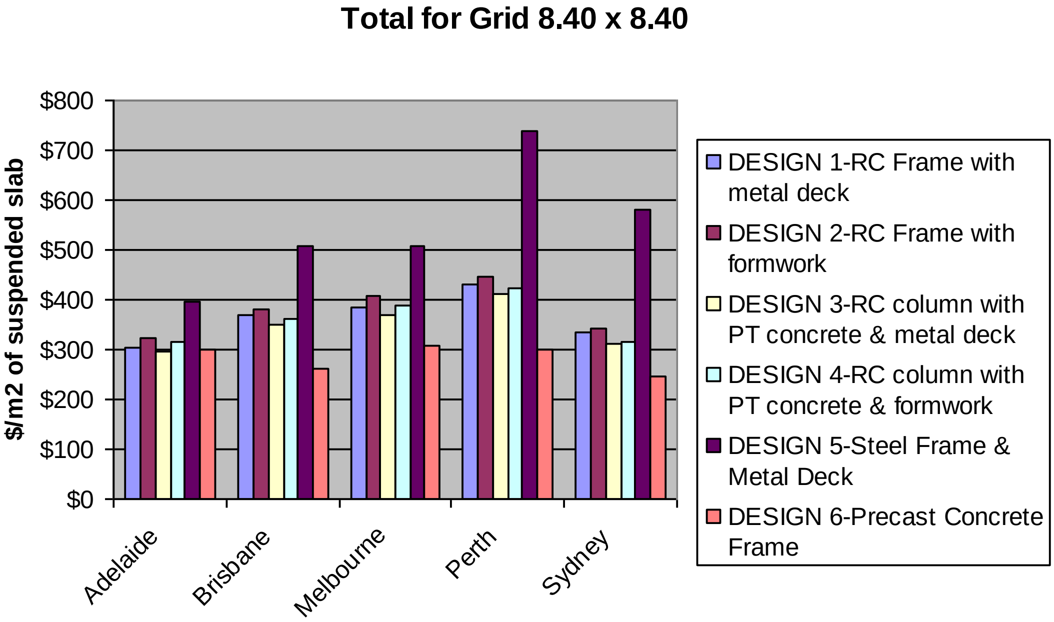
RESULTS

The aim of the report was to analyse a range of construction types that was applicable to typical commercial buildings. Prices used in the cost model included the cost of all work necessary to complete the construction work fixed in place in its final position. This is in accordance with normal industry practices used in the construction industry. The cost model comparison comprised five Australian cities:

- Adelaide
- Brisbane
- Melbourne
- Perth
- Sydney

The results indicate (Figure 1) that steel frame construction is more expensive than any of the concrete designs for all cites in the study. In addition, Perth appears to be the most expensive location in which to build for most designs, and Adelaide appears to be the cheapest.

Figure 1 Total cost of building structural frames by city



The results (table 2) show that when that average cost of each design is compared, precast concrete is the cheapest alternative. It also is the option that has the lowest Coefficient of Variation (CV) indicating that cost across the five cites in the study varies the least. The reverse occurs with Design 5 (Steel Frame construction). In this case steel frames are not only the most expensive but the cost varies the most between the cites (CV= 23%)

Table 2 Cost comparison between each design ($/m2 of floor area)

Total cost of Grid 8.40 x 8.40	Mean of five cities	Standard Deviation	Coefficient of Variation
DESIGN 1-RC Frame with metal deck	$365	49	13%
DESIGN 2-RC Frame with formwork	$379	49	13%

DESIGN 3-RC column with PT concrete & metal deck	$348	47	13%
DESIGN 4-RC column with PT concrete & formwork	$361	47	13%
DESIGN 5-Steel Frame & Metal Deck	$546	125	23%
DESIGN 6-Precast Concrete Frame	$283	28	10%

The cost were then broken down into building cost elements and compared. In addition, workshop participants were asked to comment on the cost outputs. The cost element contained in the report is limited to:

- Substructure
- Columns
- Upper Floors
- Fire Protection

Substructure

The substructure of the building comprises the, detailed excavation, concrete footings, reinforcement, and holding down bolt assemblies. The substructures estimate excludes; ground slab, bulk earthworks, and site preparation. This was because the model was not designed to be specific to any particular site. In addition, it was assumed that the model did not require; formwork, rock excavation, and planking and strutting. The results (Appendix) show that the steel frame design has the lightest structural weight and is therefore the cheapest design for all cost models. The results indicate that prices for steel structures are cheaper, and in all cities this represented $5/m2 of floor area.

Columns

The columns comprise the support structure between the floors. It includes only the vertical members and does not included beams or other structural members. The columns were designed specifically for each of the various structures, and a range of sizes and concrete strengths were detailed. All columns used in the reinforced concrete designs were rectangular in shape, and comprised formwork and bar reinforcement.

The results (Appendix) show that Design 3 and 4-Post-tensioned concrete was the most economical (eg Adelaide,$27/m2) This is due to the fact that the columns in these designs are smaller in size, due to the lighter construction of concrete frame. This occurred in all cities and is a function of the design. The precast concrete column design is slightly more expensive in some cites (eg Adelaide), but cheaper in others (eg Sydney). The variation is believed to be caused by local supply and demand factors, and is not the result of design.

The cost of steel columns is significantly more expensive than any other form of construction. The price of steel columns is in some cases (eg Brisbane, Perth, and Sydney) more than double the cost of concrete columns. The cost premium for the use of steel is very significant, and in the range of, $24.00 m2 (Adelaide) to $72.00 m2 (Sydney).

Upper Floors

The Upper Floors comprise the floor structure and includes associated supporting beams, but does not include Fire Protection to beams which was analysed separately. (See below). As previously mentioned, the structural designs do not comprise a ground supported floor slab.

The results (Appendix) show that Design 6 Precast Concrete was the most economical design for all locations except Melbourne. This is due to the fact that the simple grid designs contain no penetrations for stairs or lift shafts. It may be reasonable to suggest that the designs are almost optimised for the use of standard precast floor planks, which tend to favour the use of a standard modular solution.

The next best design was Design 3 Post Tensioned Concrete, which very economical in all locations, and has the advantage of being a versatile design that can be used in a range of site shapes. The cost of the steel design was the most expensive across all cites. Perth is the most expensive city in which to build upper floors, with the cost of steel being $332 m2 ($576-$244) more than the precast design.

Fire Rating

All the design models assume that the building will be provided with sprinklers for fire protection, which are assumed to be the same and have not been costed in the comparisons. Based on advice of the engineering designer, the steel design requires further passive fire protection to the external spandrel beams and transfer beams; the rating has been assumed to meet a two hour standard.

The results (Appendix) show that the fire protection adds from $24 m2 to $41m2 to the steel design. Due to the nature of the concrete designs which encases the steel reinforcement inside the structural member, no additional passive fire protection is necessary. As a result only the steel framed design requires passive fire protection, which adds to the cost that alternative.

The next section of the research report on the responses made during the workshops (Table 3). The results above were reported to participants and they were asked to respond on the accuracy of the cost models, and provide any feedback that on the implications for design and construction of the structural frames.

Phase 2 –Validation Workshop

The aim of the research was to consider the validity of the use of generic designs so that the cost efficiency of the various models can be tracked across five sites. The comments reported (Table 3) show that many factors contribute the choice of a particular design solution. Respondents were clear that most projects were unique and that that required a bespoke design.

Table 3 Typical comments on the validity of the cost models

Design	Cost Efficiency	Construction Implication
1-RC concrete + metal deck	Older design and generally more expensive than PT	Not preferred, unless PT is not possible
2-RC concrete + formed	Older design and generally more expensive than PT	Dependant on the availability of competent formwork contractors
3-PT concrete + metal deck	Generally the most cost effective in real-world projects	Most common form of frame which suits a wide range of applications
4-PT concrete + formed	Generally used in complicated projects, or where architectural finishes are required	Dependant on the availability of competent formwork contractors
5-Steel frame	Cheaper Non fire rated	Welding adds cost and time;

	structures are suitable in some applications	bolted connections are preferred
	Prefabrication offsite reduces preliminary costs,	Construction times can sometimes be achieved with prefabrication, but are not always critical
	Concrete columns can be used in combination with steel Upper Floor construction to reduce cost and building weight	A mix of steel and concrete can be suitable to many applications. For instance over atriums, or in existing buildings
6-Precast concrete	Cost effective in some product areas, but not others	Limited supply for some generic products and dependent on local supply and demand
	Purpose designed "Architectural" precast is more expensive than generic precast components	Architectural precast can be sourced from interstate and is cost effective on back-loaded transport; but requires more time and planning
	Builders cranage costs	Additional cranage may be required for precast

The next section of the research discusses the validity of the cost approach to model to economic effects of difference construction solution across the nation's five largest cities

DISCUSSION

There have been a number of studies that tried to compare the productivity of the construction industry by using the cost model approach (Edkins & Winch 1999; Meikle 1990; Proverbs, Holt & Olomolaiye 1999). This paper represents an extension of earlier work, which explored international contractor performance in France, Germany, UK and Australian contribution to the research (Proverbs & Faniran 2001).

The aim of the research was to explore the factors that impact on the selection of structural frames for medium-rise buildings in Australia. Past research has shown that steel framed structures represent small proportion of commercial buildings in Australia. According to research by The Warren Centre (2007)in 2003 steel held just 3 per cent of the market share in Australian construction, improving to 13 per cent of market share in 2006. This is in stark contrast with the use of steel in other countries. Steel framing's share of Australian building construction significantly lags that of the UK (70 per cent) and US (50 per cent). This research attempts compare the cost performance of typical buildings in order to explore the local supply and demand impacts.

When comparing designs it may be important to note that the cost model is based on a very simple design that was specially formulated for the study. The design was supposed to be typical of structural frames that exist for commercial buildings in each of cites under consideration. However, the nature of the design may advantage the precast option due to the fact that its simplicity optimises the use of standard components. The nature of the cost model provides a natural advantage to the precast design, and as a result precast is the cheapest option in all locations except Adelaide.

Results of the validation workshop indicated that most common form of construction for medium rise buildings is similar to Design 3, comprising reinforced concrete columns with post-tensioned band-beams, concrete slab formed with metal decking. According to participants this design is suitable for a wide variety of building shapes and applications in a real-world environment. Hence, Design 3 is the most versatile design and represents the "benchmark" for comparison of cost across cites.

Table 4 Cost premiums compared to the most commonly used benchmark design

Cost Premium compared to Design 3	Adelaide	Brisbane	Melbourne	Perth	Sydney	Average
DESIGN 1-RC Frame with metal deck	102%	125%	131%	146%	113%	123%
DESIGN 2-RC Frame with formwork	110%	129%	137%	150%	115%	128%
DESIGN 3-RC column with PT concrete & metal deck	**100%**	118%	125%	139%	105%	118%
DESIGN 4-RC column with PT concrete & formwork	106%	122%	132%	143%	107%	122%
DESIGN 5-Steel Frame & Metal Deck	134%	172%	172%	249%	196%	185%
DESIGN 6-Precast Concrete Frame	102%	88%	104%	101%	83%	96%

The results (Table 4) show the cost comparison between Design 3 in Adelaide. The cost of in all other cites is higher, with the most expensive location being Perth (+39%). The most expensive design is Steel (Design 5) and once again, Perth is the most expensive location which produces a cost premium of (+249%) compared to Design 3 in Adelaide.

Past research by Proverbs & Faniran (2001) indicated that French and Australian contractors achieve significantly faster construction times in situ concrete framed buildings compared with those from Germany and the UK. This somewhat positive outcome for Australian contractors overlooks the wide range of cost associated with each of the five cites in the study. In addition, there is a large variation between each of the various structural designs.

The next section of the paper provides some conclusions about the implications of this research for designers and contractors in the industry. This section considers the impact of technology and speed of construction.

Technology

Past research work (Price 1991; Proverbs & Faniran 2001) indicated that the use of various construction technologies impacts on productivity. The research reported in this paper considered two types of technology by using paired design models. Firstly, Design 1 and Design 2 are similar other than the use of different formwork systems, namely timber and metal deck. And secondly, Design 3 and 4 were the same other than different reinforcement technologies, namely bar reinforcement and post tensioning. Comparisons were made based on the average for the five Australian cites (Table 2)

It may be important to mention that all of the paired design comparisons were based on technologies that were in common use in the construction industry in Australia. The use of these technologies was not considered to be advanced or highly specialised and was not beyond the capacity of contractors. Instead, the comparison was included to indicate the level of cost efficiency that is possible using existing technology.

Formwork

Past research by Proverbs, Holt & Olomolaiye (1999) identified that formwork technology had an impact on productivity. The result of their work showed that French and German contractors were much more efficient than similar UK contractors. This was due mainly to the construction methods used by UK contractors. It was concluded therefore, that a best practice recommendation for UK contractors would be for them to avoid using traditional timber formwork methods to beams, and instead adopt more productive approaches afforded using either proprietary or prefabricated systems.

This research supports the work by Proverbs, Holt & Olomolaiye (1999), and results confirm that use of slightly more sophisticated metal deck formwork system was more cost efficient than traditional timber formwork. The results (Table 2) indicate than in both paired comparisons, (ie. Design 1 and 2, and Design 3 and 4) the traditional timber formworks systems were less cost efficient. On average Metal Deck formwork lowers the cost by $14 or 4% (Design 1 and 2) and $13 or 4% (Design 3 and 4) compared to timber formwork.

Reinforcement

The use of bar reinforcement was considered to be less sophisticated than the use of post tensioning (PT). In addition, the use of PT results in thinner suspended slab and beam design which contributes to a lighter weight structure. The results (Table 2) shows the cost of substructure for the PT structures $12/m2 (Design 3 and 4) were cheaper than RC structures $15 (Design 1 and 2).

Impact of the use of PT is evident in the paired comparison of Design 2 and Design 4, in that cases both the designs utilised the same formwork system, but have different reinforcement systems. The same issue is addressed by comparing Design 1 and 3, which both comprise metal deck formwork, but have different reinforcement. The results (Table 2) show that PT is more cost effective by $18 or 5% for timber formwork designs and $17 or 5% for metal formwork designs.

Construction Programme

The six design compared in the research have a range of different characteristics that impact on the speed of construction, and potentially the cost efficiency. Respondent in the workshops were asked to provide some indication of the impact of structural frame design and construction programme.

The results (Table 3) show that each design solution has advantages and disadvantages. Respondents indicated that prefabrication reduces the workforce on site, and has the potential to shorten construction times. The two prefabricated designs (Design 5-Steel and Design 6-Precast Concrete) were both perceived to be at an advantage for improving on-site construction speed. The discussion about construct speed was effected by a large range of issues like site access, cranage capacity, building complexity etc that were outside the scope of this study.

In the case of steel construction respondents indicated that bolted connection was preferred, and that welding should be avoided where possible. In addition, the high cost of full steel construction is a disincentive compared to the concrete designs investigated in this study. Respondents indicated that steel structures does have the advantage of lightness and may be useful for low-rise structures, and for buildings where fire protection is not required, for example low-rise car parks.

Precast concrete also has the potential to reduce construction times and appears to be economical in the study. The design used in this study (Design 6) used a very simple layout which did not contain any slab penetrations or interconnecting stairs or ducts. The design was optimised to suit generic precast concrete and beam products, and did not require any bespoke insitu construction. These characteristics tended to advantage the precast model, and respondents believed that this may have contributed to the higher levels of cost efficiency than would typically be evident in real world buildings.

Respondents indicated that the issue with precast is that some products are in short supply, and therefore not available “off-the-shelf” The respondents suggested that in some markets (like Perth) where supply capacity is limited precast concrete buildings are not necessarily quicker. In times of shortages precast products may need to be transported long distances (1000 kilometres or more) from other cites like Adelaide.

In all city respondents indicated the generic products like precast concrete planks and beams, were not serviced by a large number of suppliers. This lead to frequent shortages, forcing builders to use the higher priced “Architectural” quality precast products. While this can lead to faster construction times, it may also increase the cost.

CONCLUSION

Many past analysts have attempted to measure the relative efficiency of buildings by using cost of indicators nationally or internationally (Proverbs & Faniran 2001; Proverbs, Holt & Olomolaiye 1999). Most of the research has been largely aggregated, and would benefit form some finer grained analysis that could be utilised by real-world decision-makers. This research has attempted to provide such information on the relative cost efficiency of a broad range of project that was commonly considered in the building design and procurement process.

This report utilises a structural frame cost model to act as a proxy for the relative cost efficiency of various steel, concrete, and formwork systems which are typically used in commercial buildings. It is believed that this approach provides useful information about the capital cost of structural frames to decision-makers in the industry.

The research has attempted to provide a realistic approach to an age old question related to the most cost effective structural building design. The author recognised that the dynamic nature of the building industry make it impossible to be emphatic about the best cost solution for any particular site. However, it is obvious that that the steel frame solution is significantly more expensive than other options in this study. This may help to explain why only about **13** % (The Warren Centre 2007) of buildings is constructed in steel frames in Australia.

The cost premium is significant especially in the overheated Perth market. The efficiency of construction is affected by investment in technology, along with other factors like material supply. It is known that the Australian construction industry has had a long tradition of using concrete in preference to steel, and has probably invested time and technology in improving its cost performance. This does not mean that steel frames structure will neve be cost effective, and many industry commentator have suggest that there are a range of projects that benefit from the characteristics of steel frames.

This research has attempted to provide an insight into the drives of productivity that influence clients, designers, cost planners and contractors in Australia. It is clear that the cost of structural frames is impacted by both local market conditions and the design and construction process. The cost performance of buildings frames improves with the use of more advanced technology and also when local construction techniques are well understood by the industry.

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APPENDIX

Structural Farmed by cost element. ($/m2 of floor area)

Substructure $ /m2	Adelaide	Brisbane	Melbourne	Perth	Sydney
DESIGN 1-RC Frame with metal deck	$13	$14	$15	$16	$15
DESIGN 2-RC Frame with formwork	$13	$14	$15	$16	$15
DESIGN 3-RC column with PT concrete & metal deck	$11	$12	$12	$13	$12
DESIGN 4-RC column with PT concrete & formwork	$11	$12	$12	$13	$12
DESIGN 5-Steel Frame & Metal Deck	$8	$9	$10	$10	$10
DESIGN 6-Precast Concrete Frame	$10	$10	$11	$11	$11
Maximum Saving of the Steel Frame design	$5	$5	$5	$5	$5
Columns $ /m2	Adelaide	Brisbane	Melbourne	Perth	Sydney
DESIGN 1-RC Frame with metal deck	$28	$34	$45	$53	$36
DESIGN 2-RC Frame with formwork	$28	$34	$45	$53	$36
DESIGN 3-RC column with PT concrete & metal deck	$27	$33	$43	$51	$34
DESIGN 4-RC column with PT concrete & formwork	$27	$33	$43	$51	$34
DESIGN 5-Steel Frame & Metal Deck	$52	$69	$70	$111	$93
DESIGN 6-Precast Concrete Frame	$35	$30	$30	$44	$21
Upper Floors $ /m2	Adelaide	Brisbane	Melbourne	Perth	Sydney
DESIGN 1-RC Frame with metal deck	$262	$322	$327	$362	$283
DESIGN 2-RC Frame with formwork	$283	$334	$346	$376	$290
DESIGN 3-RC column with PT concrete & metal deck	$258	$306	$315	$348	$264
DESIGN 4-RC column with PT concrete & formwork	$277	$317	$334	$359	$270
DESIGN 5-Steel Frame & Metal Deck	$307	$406	$405	$576	$453
DESIGN 6-Precast Concrete Frame	$257	$221	$268	$244	$212
Fire Protection $ /m2	Adelaide	Brisbane	Melbourne	Perth	Sydney
DESIGN 1-RC Frame with metal deck	n/a	n/a	n/a	n/a	n/a
DESIGN 2-RC Frame with formwork	n/a	n/a	n/a	n/a	n/a
DESIGN 3-RC column with PT concrete & metal deck	n/a	n/a	n/a	n/a	n/a
DESIGN 4-RC column with PT concrete & formwork	n/a	n/a	n/a	n/a	n/a
DESIGN 5-Steel Frame & Metal Deck	$29	$24	$25	$41	$24
DESIGN 6-Precast Concrete Frame	n/a	n/a	n/a	n/a	n/a

n/a – Fire protection not applicable