STUDY REPORT

SR 219 (2010)

Construction Industry Productivity

I.C. Page

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Preface

This report discusses the various industry productivity metrics available and their uses. Factors affecting productivity are identified and recommendations for productivity improvement at various levels of the industry are made. A builders' survey of factors affecting productivity is reported.

Acknowledgments

This work was funded by the Building Research Levy.

Note

This report is intended for principals and managers of design and construction firms.

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Abstract

There are various definitions of productivity for the building industry and some confusion as to what is meant by the term. This study examines the various definitions and suggests two indexes to be used for monitoring the industry. Monitoring productivity is impeded by lack of timely data and currently in New Zealand a two-year wait is necessary before the more exact productivity metrics can be calculated. A quicker partial productivity measure is suggested for monitoring short-term trends. A limited breakdown of productivity by industry sector is provided.

Factors influencing a realistic productivity measurement are discussed, including how quality and an aging building stock are considered. Builders were surveyed on their opinion of influences on new housing costs, and some site and design specific characteristics (e.g. plan complexity and site slope) were found to be relevant. Another survey looked at building industry productivity and found it was affected by firm organisation, level of skills and the design details. The literature indicates the presence of quality control systems and benchmarking has net financial benefits, and quality-cost trade-offs are best considered at the firm or project level.

Contents

1. INTRODUCTION

Productivity growth is the basis for an increase in incomes and welfare in society and the building industry needs to be as efficient as possible in order to contribute to the overall economy. There have been many studies here and overseas which find that productivity performance in the building and construction industry compares poorly to other industries. This report examines existing research on productivity, including measurement and reasons for poor productivity, and identifies some actions that the industry can undertake to improve its performance.

2. SUMMARY

The main findings are:

A multi-factor productivity (MFP) index should be used for the construction industry. An index developed about work for the Department of Building and Housing (DBH) (Davis, 2007) is a suitable measure, but is subject to data delays.

A labour productivity index, which is more timely but less accurate, is suggested for monitoring trends every quarter. Two versions of this are suggested: value-added, and capital formation, divided by the number of persons employed. They represent within-industry trends and industry plus supplier (manufacturers, designers) trends, respectively.

In terms of value-added by the industry, workers in the civil engineering sector are the most 'productive' at about $69,000 per worker, followed by all buildings (residential and non-residential) at $58,000. The sub-contractors have $52,000 per worker.

The alternative measure of capital formation per worker gives $156,000 per worker for residential buildings, $82,000 per worker for non-residential buildings work, and $142,000 per worker for civil engineering. This measure includes the efficiency gains of suppliers outside the industry (e.g. manufacturers, designers).

Labour productivity in the whole industry has been declining by about 0.1% per year since 1988. MFP, which allows for labour and capital inputs, has declined by about 1% per year since 1988, although since the mid-1990s it has barely changed. MFP represents the effect of factors such as technology, management efficiency, regulation, workloads, changing work types etc. It is a measure of those factors that are hard to measure but have an influence on industry outputs.

The above productivity indexes do not directly consider the quality of work and hence may be a misleading measure of industry performance. It is suggested that quality effects are best considered at a project level and that designers and owners be encouraged to consider ongoing cost, as well as initial costs entailed by their decisions. In addition, quality management systems in design and construction firms are known to reap net benefits in overseas firms. The same effect is likely for New Zealand firms due to reduced call-backs and re-work.

3. LITERATURE REVIEW

A Treasury report (Black et al, 2003) calculated productivity for nine industry groups within New Zealand, including construction. The index was constructed from production-based GDP constant price series, the household labour force survey hours worked series, and the productive capital stock series, all from Statistics NZ. The report found that total-factor productivity in the construction industry had declined by about 1.5% pa between 1988 and 2002. Total-factor productivity (sometimes called multi-factor productivity or MFP) is the amount of output per unit input, the latter being a combination of inputs weighted by their relative cost shares.

A number of other Treasury reports (Fox, 2005; Mason, 2007 etc) have subsequently examined productivity for the overall economy and for particular sectors, including comparisons with other countries. They find change in total-factor productivity for construction in New Zealand is about 50% worse than in the UK.

Davis (2007, 2008) undertook studies for the DBH on productivity in the construction industry. The report briefly examines partial productivity measures, i.e. labour and capital productivity, but most of the focus was on industry structure and how government policy can improve productivity. He suggested an industry framework for productivity based on three levels. At the lowest level there is on-site productivity affected by labour supervision/organisation, scheduling, material procurement, off-site assembly and efficient design. The middle level is the firm where productivity is affected by how groups of projects are simultaneously managed, adoption of innovation, and general management practices. The highest level is the whole industry where skills, training, investment, research, competition, products, ease of entry, and regulation affect productivity.

Among the report's recommendations is the need to collect information at the firm level on skills, investment, business practices and performance data. There is also a recommendation for more economic analysis of industry performance. The report believes government policy can best affect the third level, and recommended government engagement with industry to identify factors that hinder productivity improvements and strategies to address these.

Partly in response to these reports the DBH set up two industry taskforces, one a Sector Productivity Taskforce and the other an Urban Taskforce. The first addresses issues identified in the DBH's work. The second taskforce arises in part from earlier work (e.g. Grimes et al, 2007) on the land cost issues affecting housing affordability and the mixed record in encouraging intensification in the major cities.

The first taskforce brief was to look at skills and procurement issues as they affect productivity. Their recommendations included:

- Central and local government develop, publish and maintain a 10-year rolling infrastructure programme. This work to be done by a National Infrastructure Unit within a government department. The aim is to mitigate boom-bust cycles and share information and dialogue with the industry.
- Government-funded projects are to have training obligations for non-residential work. These could be administered through a pre-qualification process whereby the skills development and management expertise of firms is assessed periodically.
- A government-private sector forum (e.g. a Built Infrastructure Leadership Group) meets at intervals to monitor infrastructure programming and training systems.

- Government consider the use of standard components on its new buildings (e.g. schools). This is expected to reduce costs and encourage wider industry adoption of standardisation.
- Government and private sector to extend the DBH 'starter' homes designs to other housing segments. The aim is to encourage more standardisation in housing.
- Construction industry training beyond secondary education Year 10 is unified so that consistent and clear career paths are open to new entrants.
- The continuing professional development and licensed building practioners regimes need to have more emphasis on management skills.
- There needs to be an analysis of the skills required in the long term.
- More government investment in infrastructure is required now to retain skills in the current downturn.

Although the taskforce brief believes government policy is best applied on industry-wide issues the recommendations affect productivity at all levels. More standardisation of design affects design at the lowest level, improved management training affects firms' performance at the middle level, and at the high level the programming and skills forecasting will cause an industry-wide productivity improvement.

The other taskforce on the urban environment has recommendations that are not directly related to construction industry productivity, but they do impinge on the housing sector via measures to encourage intensification and facilitate regulatory processes.

The Urban Taskforce recommendations included:

- Government identifies a lead department to provide strategic leadership to champion quality urban development and inter-agency coordination.
- A sector-led advisory group (designers, developers and financiers) provides advice to Ministers at regular intervals.
- Government establishes an urban development agency that facilitates the creation of partnerships for each project development. The government role is to facilitate land assembly, and ensure consents and infrastructure/amenity issues are resolved before calling for development proposals on a competitive basis.
- Central government works with local government and developers on partnering models for two or three high-density urban developments as soon as possible, to demonstrate the feasibility and impacts of the new model.
- Councils establish teams that 'account manage' intensive developments to facilitate the consent process and provision of infrastructure.
- The Building Code be reviewed to ensure it provides for noise abatement and other amenity needs in medium-high density housing.
- Some members of the taskforce also had recommendations related to council charges, long-term funding and the Resource Management Act 1991.

Overall the recommendations relate to urban intensification and will have cost impacts (e.g. extra structural and noise abatement costs) hopefully offset by savings with transport and other infrastructure.

There are many overseas studies on construction productivity, and a general overview includes Department of Trade and Industry (2004) that compared UK productivity to the US and some European countries. Productivity has been static in recent years, or at best it has had small growth for short periods and any growth is usually below other industry productivity growth rates. Factors influencing productivity between countries include the mix of work types, firm sizes, the size of the 'black' economy (unregistered workers), and what stage of the business cycle is measured. It finds that country comparisons are difficult and can be unreliable due to these factors.

In the US the National Research Council (NRC) has long been interested in the construction industry and developed a national strategy to improve productivity (NRC, 1980). They developed five main themes: 1) Managing the building process and the roles of the owner, designer and builder; 2) Financial planning with emphasis on managing debt in the boom-bust cycle; 3) Government regulation role, specifically less state requirements and more national standards; 4) Skills and workforce motivation; and 5) Innovation including sharing ideas, free-rider effects and technology transfer via industry institutions. A later publication from NRC (2009) has developed some of the earlier ideas on productivity. Their five 'breakthrough' improvements are: Electronic Building Information Modelling, On-site Management Processes, more Pre-fabrication/ Modularisation, Innovation Demonstrations, and better Performance Measures at project and industry level.

A Scandinavian summary (Alinaitwe et al, 2004) notes three themes commonly occur in productivity studies, namely innovation and knowledge transfer, benchmarking and industrialisation. Issues to be addressed to improve productivity are: design (complexity, changes, quality), manpower (skills of workers and supervisors, turnover, stoppages and absenteeism), management (supply chain, pre-fabrication, site congestion/layout/access, construction method, innovation), and environment (workloads, regulatory requirements, weather).

Many studies concentrate on particular aspects of productivity, such as measurement and data limitations (Crawford and Vogl, 2006; Bang and Bertelsen, 1999), improving labour skills (Williams, 2005), lessons from other industries (Veiseth et al, 2003), the role of innovation (Nam et al, 1995), labour productivity on social housing projects (Clark and Herrmann, 2004), and business cycle effects (Zhi et al, 2003).

In Australia Econtech and KPMG produced reports in 2003, 2007, 2008 and 2009 for various clients on productivity in the construction industry. The main focus of these reports was first defining and measuring productivity, and secondly to measure changes in productivity due to industry reform. The reports contain case studies of particular buildings and economy-wide impacts, but they do not examine in any detail the factors affecting productivity, apart from some regulatory impacts.

4. DEFINING PRODUCTIVITY

Productivity is normally defined as the volume of outputs from a process per unit of inputs. In the construction industry the outputs are buildings and civil structures and the inputs are labour, materials and capital employed in the industry.

Measures of productivity include:

- Work placed per person
- Value-added per person
- Value-added per combined unit of labour and capital inputs, expressed as an index
- Econometric measures using production functions.

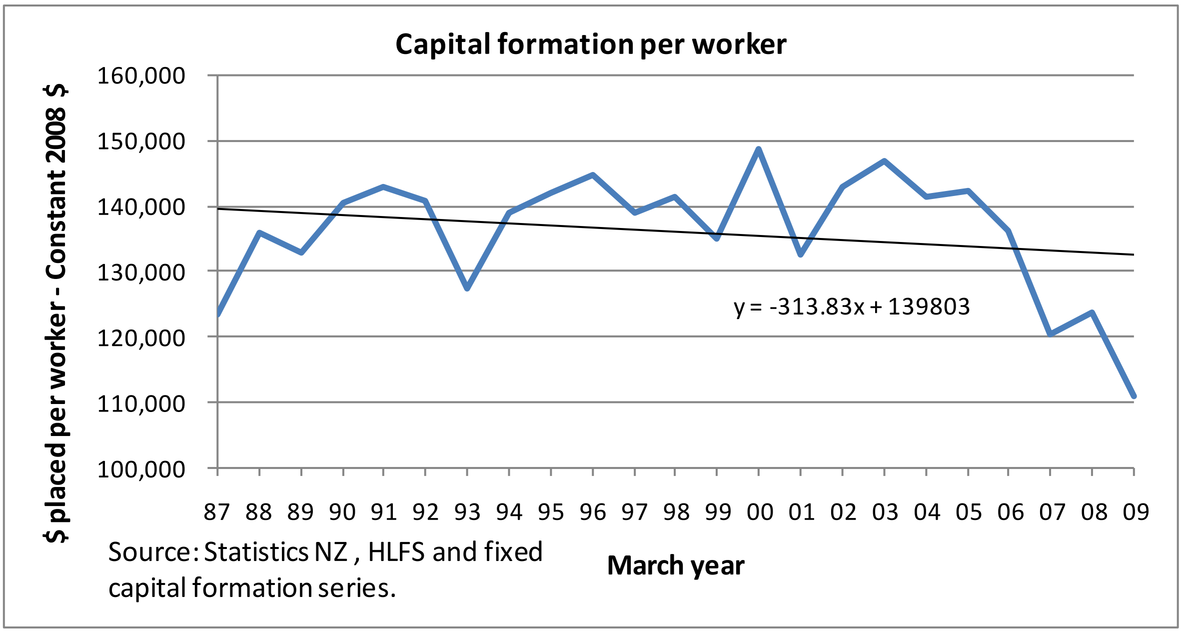
These are usually applied to annual data for industry inputs and outputs. There is generally no consideration about the quality of the outputs and the ongoing cost implications of design decisions, workmanship and call-backs. Such considerations, when included in the planning, are normally done at a project level. Quality issues also arise for inputs, particularly labour skills. Some work has been done overseas on differentiating skill levels for the labour input in productivity studies but we were unable to find any of these results for New Zealand.

Analysis of the four measures above is now considered.

4.1 Work placed per person

Figure 1 shows the value of work put in place per on-site worker in the building and construction industry in New Zealand. The trend is downward over the period shown, although until three to four years ago it was fairly level and averaged about $140,000 per worker per year. There is some variation in the ratio from year-to-year and this probably reflects the changing work mix and the overall workloads.

Figure 1. Value of work placed per worker



Work placed per worker in New Zealand was compared with other countries. In Table 1 the value of buildings and civil structures placed per construction person is shown for New Zealand and three other countries. The value of work was converted to US dollars, and the table shows the ratio for New Zealand is the lowest of all four countries.

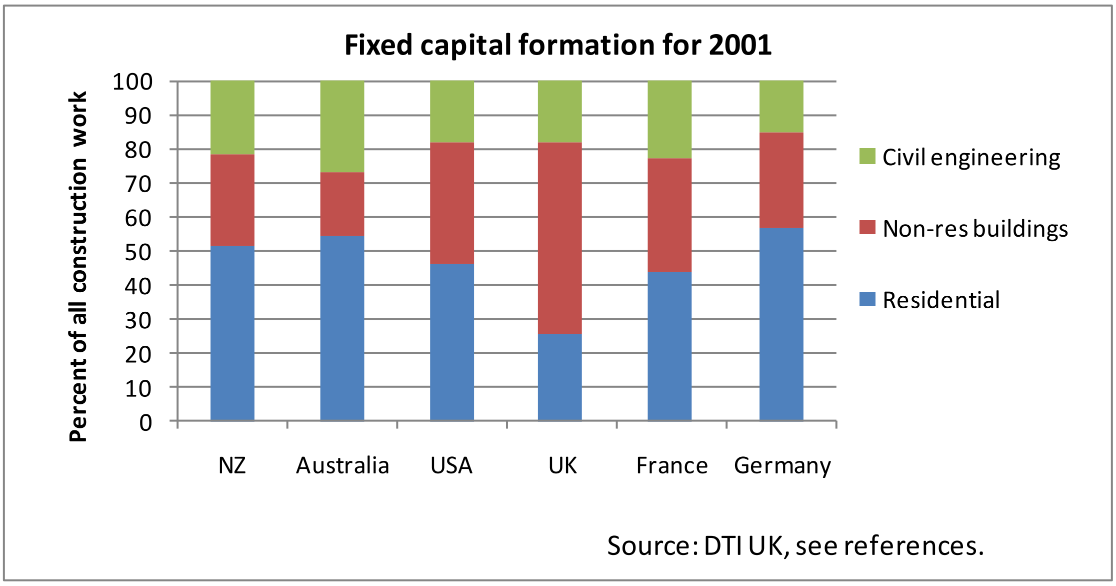
Table 1. Work placed per construction person

Fixed capital formation				
New buildings and civil structures for 2006				
	UK	Australia	USA	NZ
Value (1)	£ million	$A million	$US billion	$ NZ million
	130,415	143,797	1,089	21,633
PPP (2)	0.65	1.39	1.00	1.54
$US (3)	200,638	103,451	1,089	14,047
Employment (000) (4)	1,836	892	6,239	187
$US FCF/ person (5)	109,295	115,950	174,485	75,050
Value added (6)	£/person	$A/person	$US person	$NZ/person
	38.2	77.1	103.5	45.3
US$/ person	58.8	55.4	103.5	29.4

(1) Value of fixed capital formation for buildings and civil structures
(2) Purchasing power parity factor (similar to exchange rates).
(3) Capital formation values converted into $US.
(4) Construction industry employment
(5) FCF $US/ construction employment.
(6) Value added by the construction industry

On the surface this implies lower productivity per worker in New Zealand than elsewhere i.e. each worker puts in place a lower value of construction work than other countries. However this measure is influenced by a number of factors such as the mix of work type, the amount of pre-fabrication, and what is included in the value of work.

Figure 2. Capital formation types by selected countries



Other countries generally have a similar mix of work types (see Figure 2). However, the US and UK capital formation data is believed to be inflated by items that are not building and infrastructure related (such as oil refineries, power generation equipment and flood protection schemes), which should be in the plant/equipment or land improvement capital asset types and not in structures. There are also economies of scale considerations, and probably more standardisation of designs for housing in other countries, so that would tend to favour their labour productivity ratios.

The relative importance of each of these is not known, but it seems likely that all play a significant part in producing different ratios overseas.

Another consideration in using fixed capital formation (FCF) data is that it covers new structures, additions to existing structures, and work to an existing building that significantly extends the life of a structure. It does not cover routine maintenance and repairs work, or decoration and replacement of fittings (e.g. new bathrooms and kitchens). It is known that a significant amount of the workforce is involved in repairs, maintenance and renovation, and if the proportion of new to maintenance/renovation work changes over time (as the building stock ages for example), this has the effect of reducing the capital formation per worker productivity measure over time.

Hence using the value of FCF per worker is not always a useful indicator of productivity for new construction.

4.2 Work placed by work type

Ideally we would wish to separate work value and labour numbers for each of residential building, non-residential building and civil structures. While we have individual capital formation data for the three asset types, the labour numbers (and value-added) in each segment are not generally available internationally or locally.

In New Zealand the annual Business Demographic Survey (BDS) carried out by Statistics NZ provides employment by sub-industry group. These include numbers for new housing (RB), non-residential buildings (NR) and other construction (OC), and a variety of sub-trade groups (e.g. services installation, finishing etc). In the Appendix the BDS employment ratio (dollar work placed per worker) was calculated for each sub-industry group, and then all industries added together. The results for recent years are that the new housing sector puts in place about $156,000 of work per job, non-residential $82,000 per job, and civil engineering about $142,000 per job, in 2008 dollar terms. In other words, in terms of labour productivity the new housing industry is the most productive.

This is a little surprising as we had expected civil engineering to be have the highest dollar:employment ratio since it is believed to be plant intensive. It seems likely that the quite high pre-fabrication component in new housing (e.g. frames and trusses, windows, doors, kitchen and bathroom fittings and joinery) has affected the ratio. It may also be the type of civil engineering undertaken locally is small-scale and/or labour intensive e.g. footpaths, walkways, roads, bridges, retaining walls, water, stormwater and sewage reticulation, rail track work, tanks and silos.

4.3 Value-added per person

This is a measure commonly used in productivity studies for the overall economy and for individual industries. Value-added is the wages, salaries and operating surplus (i.e. profits) less depreciation of plant. It excludes the inputs from other industries (e.g.

materials, business services etc). Thus we have subtracted other industry efficiency gains (e.g. pre-fabrication which is in the manufacturing industry sector or designers who are in the business services sector), and we are looking only at the construction industry (i.e. persons on-site and persons in construction firms directly supporting on-site construction.)

These results are shown in the lower part of **Table 1** where New Zealand value-added is about $45,000 per construction worker. The overall economy value-added per worker in New Zealand was about $54,000 in 2006 so construction is below average on this measure. The results in the table indicate a similar picture to that for capital formation per worker i.e. New Zealand ranks lower than the other countries by a significant margin.

Figure 3 shows the trend in value-added per worker employed in the construction industry. The value-added is in constant dollars and two measures of labour are used. The Household Labour Force Survey employment numbers are the average numbers employed during the year and include full and part-time workers. The dotted line is for employment numbers adjusted to the equivalent worker numbers assuming a standard 40-hour week (i.e. average hours worked are over 40 hours). For both measures the linear trend is very similar and since 1988 labour productivity has declined slightly by about 0.1% per year, although the change in the last three years is much greater than that.

Figure 3. Labour productivity

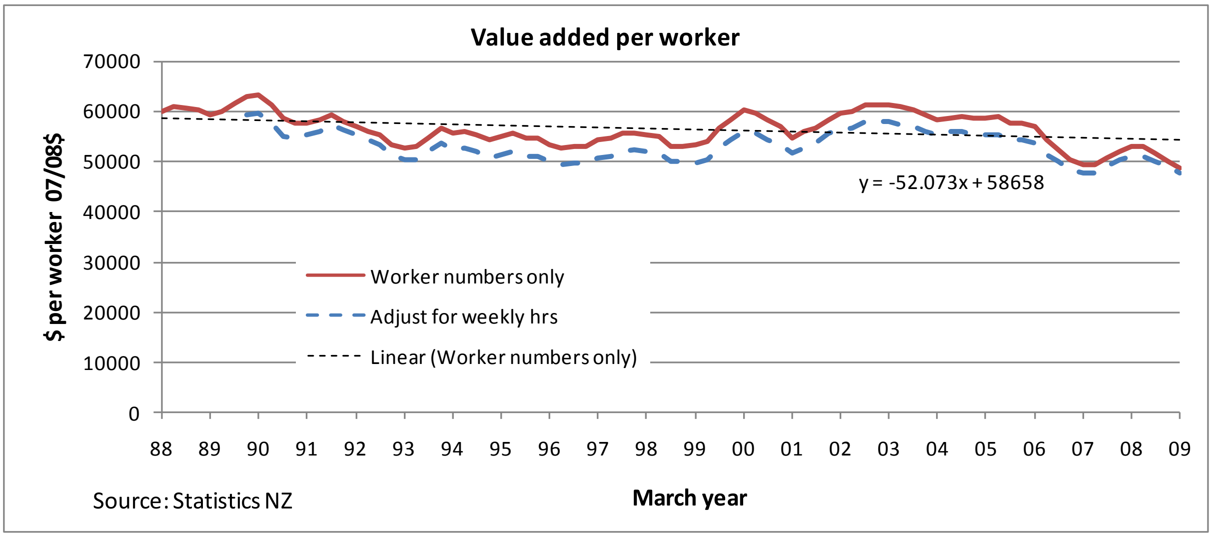


Table 2 shows value-added for a three-sector breakdown: all buildings construction, other construction (i.e. civil engineering), and construction services. A more detailed breakdown was preferred but Statistics NZ was unable to supply to that detail. The construction services group are mainly the sub-contracting industries i.e. concreters, plumbers, electricians, plasterers, painters etc. A detailed list is in the Appendix in

Table 6. The highest number for value-added per worker is in the civil engineering sector at approximately $69,000 per worker (in 2008 dollars). Construction services, which provides most of its output to the building sector, is lowest at $52,000 per worker and building construction (residential and non-residential combined) is a little higher at $57,000 per worker.

It is interesting to compare these numbers with the FCF per worker in Section 4.2. For housing and non-residential buildings combined the workers in these two sectors together put in place about $122,000 per year of FCF in recent years. For civil engineering the number is $142,000 per year per worker. So other industries outside construction add about $70,000 per worker or 50-60% of the final value of the work as put in place.

Table 2. Value-added per worker by sub-industry

Value -added by sub-industry				
March year	**2005**	**2006**	**2007**	
	Value-added $ million			
Building construction	1872	2363	2626	
Civil engineering	1402	1771	1964	
Construction services	3847	4513	5264	
	Number of employees + working proprietors			
Building construction	42,178	44,882	46,091	
Civil engineering	24,140	26,730	29,300	
Construction services	91,866	97,727	101,891	
	158,184	169,339	177,282	
	Value added $ per worker - $ of day			
Building construction	44,383	52,649	56,974	
Civil engineering	58,078	66,255	67,031	
Construction services	41,876	46,180	51,663	
	Value added $ per worker - 2008 $			average
Building construction	52,247	58,163	59,830	56,746
Civil engineering	66,752	71,824	69,331	69,302
Construction services	49,296	51,016	54,253	51,521
Source: Annual Enterprise Survey for value-added.				
Employment is from the Business Demographic Survey.				
Building construction is ANZSIC groups E301,E302				
Civil engineering is E310				
Construction services are E321 to E324, E329.				

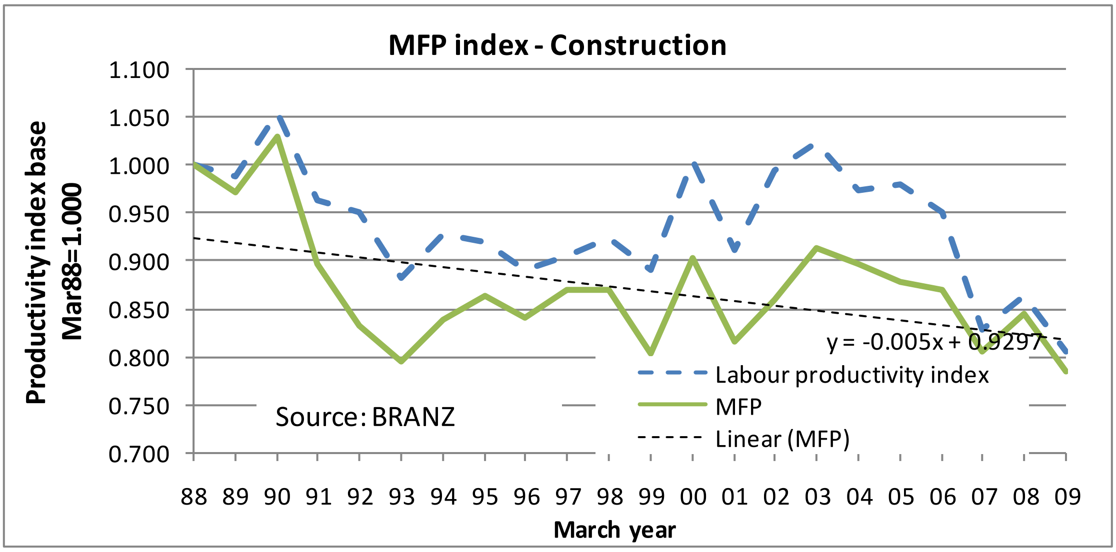
What is value-added measuring? It is the total of wages, salaries and profits, so if these increase then productivity may be increasing. Wages can increase due to more hours worked or higher hourly rates. The former may not be a productivity improvement because the denominator in the productivity measure (i.e. labour hours) also increases. But higher hourly rates are a productivity increase by this measure, as is any increase in profits with no change in inputs (e.g. higher margins due to increased demand). This may seem a strange way to measure productivity but it is saying that when value-added per worker increases the industry output has become more highly valued in the market (increased profits), and its workers are paid more, and hence this is a productivity increase.

4.4 Multi-factor productivity indexes

The problem with the partial productivity indexes (like labour productivity) is that the changes in the trend could be due to changes in supply of other factors of production such as capital. A better measure is total-factor productivity where all inputs are combined in the denominator. In practice it is not possible to measure all inputs easily (e.g. technology, regulation, land) and usually only labour and capital are combined. These measures are called MFP, rather than total-factor productivity, as there is acknowledgment that not all factors of production have been included.

The calculation is usually done in an index form, where an index of output (e.g. value-added) is divided by a composite index of inputs (e.g. labour and capital). Davis (2007) describes one method of doing this (see the Appendix) and the results derived by BRANZ using the report's method are shown in Figure 4. The labour and capital stock indexes are combined into one index in the denominator using their relative shares of income (i.e. wages/salaries versus profit) as weights. The trend since 1988 is a decline of about 0.5% per year. However, since the mid-1990s MFP appears to have stabilised. The labour productivity index is also shown for comparison – it is value-added divided by employed numbers, averaged over a year, re-based as an index of 100 at 1988. Most of the difference between the two series occurred in the early 1990s and it is speculated that capital stock built up for the mid-1980s building boom was under-utilised in the early 1990s.

Figure 4. Multi-factor productivity construction industry



What is the MFP measuring? To some extent it is a measure of our ignorance of what factors contribute to construction industry output. After allowing for labour and capital inputs it is a measure of all the other factors within the industry that contribute to the production process. It is a measure of technological progress (i.e. more efficient plant, new building techniques), on-site and firm management efficiencies, compliance impacts, economies of scale, cyclical workloads, changing mix of work types, changing skills levels, and the mix of skills etc. The relative importance of each of these factors is unknown but we know from a later chart (Figure 5) that cyclical workloads has some effect, although the correlation is not high (Rsq=0.11).

The supply of materials does not directly appear in this index because it is a measure of value-added within the industry, not the effect of outside changes in other industries (i.e. manufacturing). However improvements in building materials indirectly appear in the MFP. For example pre-fabricated components, more panel products and other material improvements have reduced the need for less skilled labour on-site. This raises the average hour wage on-site and improves the value-added to site hours ratio.

4.5 Production functions

The final measure of productivity to be examined is the use of production functions. These functions are usually of the form below:

$Q = A L^{\beta 1} K^{\beta 2}$

Where Q = the industry output e.g. value-added.

A = technology/managerial efficiency coefficient.

L = labour used e.g. labour hours.

K = capital stock in the industry e.g. value of productive stock (plant, machinery and equipment).

All of Q, A, L and K change with time and β1, β2 are constants.

The equation can be solved using time series data (see the Appendix). The result is the coefficient for technological-managerial efficiency declined at about 2.1% per year between 1987 and 2005. There are a number of assumptions in this method including one that the share of labour and capital does not change with time, which is somewhat unrealistic, and the result of a 2.1% decline in productivity is likely to be an over-estimate.

4.6 Preferred productivity measure

The recommended productivity measure is the MFP index shown in Figure 4. This is an annual index but there is currently about two years' delay in producing it due to infrequent capital stock updates.

The simple labour productivity index, shown on the same chart, follows the MFP index quite closely. So it is suggested that the labour index be used as a proxy for productivity to monitor approximate trends. It is available on a quarterly basis with a four to six month delay from the end of the quarter, but it suffers from seasonal fluctuations. To remove the fluctuations a rolling four-quarter sum is used, as is shown in Figure 3. (The calculation is the rolling four-quarter sum of value-added or work placed value divided by the average 40-hour equivalent employment for the year to the quarter.)

The simple index should be calculated for both value-added and capital formation. The value-added metric is used for measuring performance only within the industry, and work placed metric (FCF) is for the performance of the industry and its suppliers.

As data for the MFP index calculation becomes available, more accurate measures can then be produced.

4.6.1 Pros and cons of the various measures of productivity

Productivity is a measure of output per unit input and a choice of a measure is made on several factors including:

- What outputs and what inputs are measured?
- Over what time period do we measure?
- What use is to be made of the productivity measure?
- Can quality improvements be captured?

The main outputs of the industry are buildings and engineering structures and the first measure of productivity examined was the value of these structures per labour input, the latter being worker numbers or labour hours. This is an adequate measure if we are mainly concerned about producing structures as cheaply as possible, given the available labour resources. But it does not tell us whether any efficiency gains have occurred within the industry (either labour or capital plant improvements) or outside it (e.g. pre-fabrication which is in manufacturing, or improved design which is in the business services sector).

Hence the widespread use of the value-added metric, which measures performance only inside the industry. Adding capital to the denominator in the MFP index allows us to monitor whether the industry is making improvements in the use of both its labour and capital inputs, thereby contributing to economic growth. The main failing of the MFP index is that it does not allow for quality changes.

Quality is difficult to measure in a composite output metric, and if included would require the segregation of structures in quality classes and the identification of inputs into each segment. This has not been done elsewhere due to data difficulties, such as identifying quality groups of structures and separating out new build inputs from maintenance/remedial work inputs.

Quality changes are indirectly included if we use the capital formation per worker metric. Assume that an increasing proportion of the construction workforce is engaged on remedial work because of declining quality. Capital formation placed per worker would decline over time because the denominator in the index increases as more workers are required for maintenance (it is impossible to separate out maintenance/repair workers from new structure workers in the official data).

However the same argument applies for an aging building stock, where maintenance work increases with time due to aging assets rather than quality issues. So the capital formation per worker index measures a combination of effects, including changes in efficiency, quality and an aging building stock.

The MFP index is different because it includes the costs of maintenance/remedial work as well as new work. However it still does not capture quality effects, because with value-added as the metric we have maintenance/remedial work appearing in both the numerator and denominator of the productivity index and the MFP index may not change, even though quality may change with time.

Neither the value-of-work-placed metric nor the value-added metric is totally satisfactory but the value-added multi-factor index method is preferred. It measures how the industry is valued by society at large (through profits and wages) per unit composite input by the industry. Also it is simple to calculate and monitor trends, and comparisons with other industries can be readily made.

The multi-factor index method is widely used in New Zealand and overseas. There is already an economy-wide productivity index for New Zealand, which is made up of value-added, capital and labour as described above. Statistics NZ has plans to extend this to individual industries over the next few years, and it is recommended that their indexes be used, when available, to monitor productivity in construction compared to other industries.

In the meantime the index developed in the paper for the DBH (Davis, 2007) should be used for an annual index, albeit with some delay, and as an approximation the value-added per worker index should be used on a quarterly basis.

5. AREAS FOR PRODUCTIVITY IMPROVEMENT

The above discussion has looked at measurement of productivity and the remainder of this study examines potential productivity improvements. As discussed in the literature review there are many studies on the factors influencing productivity. The findings are applicable locally and particular themes relevant to New Zealand are:

- Skills training, particularly for on-site management, and management of multi-projects at the firm level. Improvement here will reduce re-work and waiting times.
- More modularisation of housing and less one-off designs. It may also be possible to do more modular pre-fabrication for non-residential buildings such as education and small health centres. Industrial buildings are fairly similar in type and are likely to be candidates for a degree of standardisation.
- More benchmarking at the firm level to encourage improvements. Use quality management systems in firms.
- Investigate what lessons can be learnt from innovative and efficient firms in the industry.
- Increase the average firm size to achieve efficiencies.
- Undertake industry-government liaison for programming of government works to mitigate boom-bust cycles.
- Streamline regulation and compliance costs of central and local government.

These themes are applied to the three-level industry structure suggested by Davis.

5.1 Individual project level

At the lowest level of the project two important factors to improve productivity are:

- Skills training – on-site skills, management and design skills.
- Benchmarking.

Up-skilling of on-site management is vital for productivity gains. There are a number of studies overseas (Picard, 2004) of on-site time utilisation showing that direct hands-on time varies between 30% and 80% of available time, depending on the project. No equivalent New Zealand studies were found but anecdotal evidence suggests time utilisation can be improved on many projects in New Zealand. Wasted time is due to poor supervision and construction planning, and also poor design can contribute to inefficient construction.

The importance of design factors on new housing costs was included in a survey of builders undertaken by BRANZ (see the Appendix, Figure 8). Among the factors plan complexity and site slope had a quite important influence on costs. Project productivity performance needs to be measured. For example labour hours for various tasks and downtime hours need to be recorded and where possible compared to 'good performance' benchmarks. Otherwise areas for improvement are not identified.

A major cause of customer dissatisfaction is call-backs, and poor or less than expected ongoing performance of buildings. Designers need to consider the operational requirements of their designs and make the owners more aware of the various trade-offs between initial cost and ongoing performance.

5.2 Firm level

At the firm level the following are likely to improve productivity:

- Improved management skills
- Firm size efficiencies
- Modularisation
- Benchmarking and quality systems
- Lessons learnt from good performers
- Encourage life-cycle analysis by designers, as appropriate for individual projects.

Firm level efficiencies are possible in the management and resource allocation of simultaneous projects. There is need for training in multi-project management. As the industry builds more residential multi-units to achieve better urban intensification the typical firm's type of work will change from detached low-rise to more medium-density multi-storey residential construction. The scale of average residential construction is likely to increase and average firm sizes will need to get bigger to handle the larger projects.

When compared to many other countries our new housing is very much 'custom' designed and built. Previous work (Page, 2007) has shown the 'group builders' in New Zealand are able to offer houses 15% cheaper than one-off designs from small builders, which are the predominate source at present. While pre-fabrication of frames and trusses is common, modularisation and standardisation are rare and appear to offer efficiency savings, particularly for multi-unit construction.

Benchmarking (e.g. customer satisfaction, safety incidences, defect call-backs, predictability of project time, repeat clients etc), is applicable at the firm level, as it is for component metrics on individual projects. Some large contractors are now benchmarking against industry averages using key performance indicators, which improves their performance and helps win new work.[1] Quality systems in construction firms appear to have good paybacks in terms of reduced re-work.

The literature indicates innovation by firms is important for productivity gains. Currently innovation in New Zealand construction firms is low and appears to be declining (see Table 3.)

Construction firms have lower innovation than firms in the economy as a whole. Construction firms do little research and development in New Zealand, although some of the larger companies in the non-residential sector have trialled various pre-fabrication systems to speed up construction at the individual project level. Most innovation in the industry comes from the materials manufacturing sector, rather than the construction companies.

[1] http://www.constructing.co.nz

Table 3. Innovation in construction

Businesses undertaking innovation						
	Type of innovation					
	Goods or services	**Operations processes**	**Managerial**	**Marketing innovatn**	**Total innovation rate**	
	Construction		Percentage			
2005	12	22	33	26	41	
2007	16	16	26	21	38	
	All industries		Percentage			
2005	**30**	**29**	**31**	**29**	**52**	
2007	**26**	**23**	**27**	**26**	**47**	
Source: Business Operations Surveys, Statistics NZ						
Survey is undertaken at 2 year intervals and						
percentages are for a two years of data.						

5.3 Industry-wide level

At the industry level the following factors influence productivity in the medium and long-term:

- Government-funded skills training
- Mitigation of boom-bust cycles
- Regular review of regulation and compliance costs
- Consideration of modularisation for education, health and correction buildings.

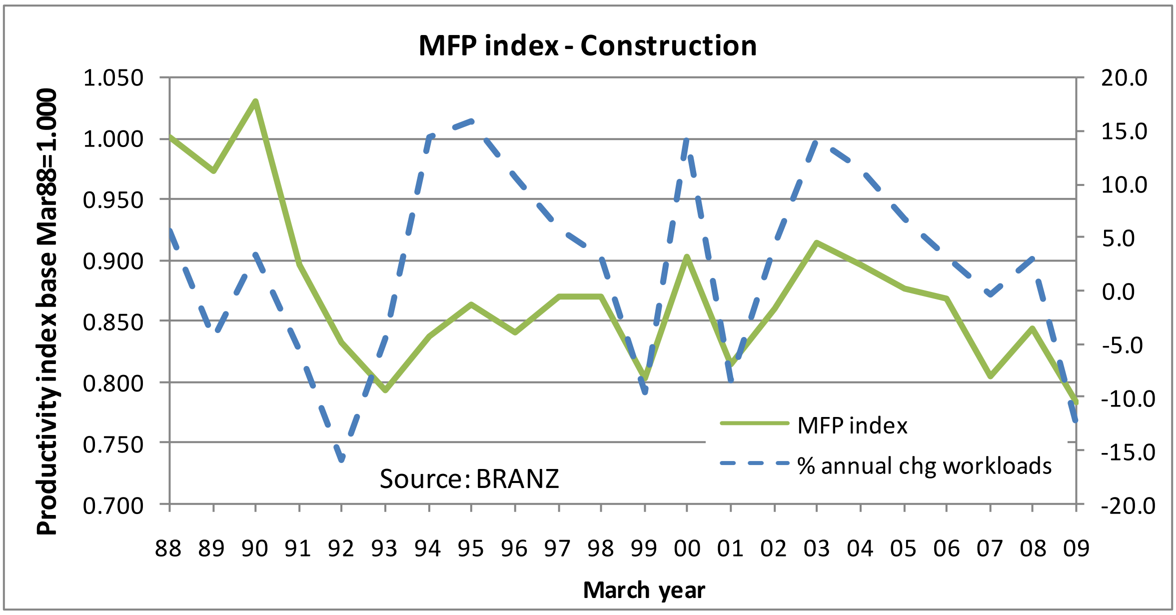
The government scheme for practitioner licensing and ongoing CPD will help to improve skills. Various tertiary training paths for new entrants are generally available, with a significant level of government funding and subsidies.

Some firms are reluctant to invest in training because labour can readily move, hence the taskforce recommendation that bidders for government work have a training programme and be actively up-skilling their workers.

Simplified and non-prescriptive regulation can lower transaction costs and facilitate innovation. The Simple House manual being developed by the DBH may help lower compliance costs and adequate funding of standards is important.

The literature (Zhi, 2003) indicates workload cycles usually have an effect on productivity and government-funded projects can help reduce the workload fluctuations. Figure 5 indicates this for New Zealand where changes in the MFP index move in cycle with the changes in workload from the previous year.

Figure 5. MFP and workloads



6. BUILDERS' SURVEY OF FACTORS AFFECTING COSTS AND PRODUCTIVITY

Two surveys of builders were undertaken as part of this project. The first survey asked about the importance of a given list of cost factors for new housing. The second survey was more general on factors influencing productivity (defined as outputs per unit input). The results are:

First survey on new house costs:

- The main factors influencing new house costs are materials and labour costs, the ground slope of the site, and floor plan complexity.
- Some other design variables (including window sizes, wall multi-claddings and an upper storey) were assessed as having a low effect on house cost.

Second survey on general productivity influences in the building industry:

- The main factors identified as affecting productivity were the level of trade skills, project organisation and design detailing.
- Plant, standardisation and pre-fabrication/modularisation were rated as having a fairly minor influence on productivity.
- The responses were similar for both housing and non-residential contractors.

Full details of the results are in the Appendix.

7. DISCUSSION

There are various definitions of productivity and particular metrics are used for various situations. At the project or firm level a company will be interested in comparisons and can use benchmark indicators. For the whole industry there is a need to use an aggregate measure. Either a work placed per person or a value-added metric can be used for this, depending on whether it is wished to monitor the wider economy productivity (manufacturing and construction) or just the trends within the construction industry. The MFP index developed for the DBH is suggested for monitoring medium to long-term trends.

How should quality trends be included in productivity measures? There is no simple answer because quality changes are difficult to measure in an aggregate index. Instead, it is suggested at the project level owners are encouraged to consider such factors as ongoing operations and maintenance costs when they consider alternatives. They may also wish to consider environmental impacts for certain types of building and green rating measures, as these may have revenue impacts for commercial buildings.

At the firm level designers and contractors can benefit from quality assurance schemes. Quality management is critical for construction projects, as almost all projects require some re-work. A number of studies have been done on poor quality costs, and two studies (Love et al, 1999, 2000) found the cost of re-work due to poor work or poor design ranged from 2% to 12% of total contract value.

Another study (Rosenfeld, 2009) looked at the trade-off between the cost of quality control and the cost of re-work for eight projects. They found that an investment of about 2% of the total project cost provides the best return in reducing re-work costs. The investment includes quality staff and procedures, auditing, routine process controls, routine tests during construction, instruction and training. The benefits were found to be cost reductions in re-work, penalties, handling investigations and complaints, legal fees and compensation. The study did not record other cost savings such as unreported re-work, loss of existing and new customers, and reputation damage. The author estimated these are at least equal to the measured loss, and for many projects an expenditure of up to 4% of the project value on quality management will reap net benefits.

What areas can the New Zealand industry improve on? The short and most urgent list is:

- On-site and multi-project management skills within firms
- Benchmarking at the firm level and adoption of quality management systems
- Assessing the potential for modularisation and standardisation
- Scaling up of the average firm size in the house building industry.

Modularisation is not always suitable because many non-residential buildings are different (apart from education, health and industrial buildings). Housing would appear to have scope for modularisation and standardisation, particularly for the lower and medium cost range. The group building companies are mainly in the medium cost segment use and use sets of standard plans, and modularisation of parts of the building (kitchens and bathrooms) appears to be possible. Many new houses are for well-established households and owners are becoming more focused on amenity and the value of the service provided by the dwelling. While the first home market is sensitive to cost, other owners may have other priorities.

In developed economies consumption is increasingly spent on service goods and experiences, rather than the basic needs of food, clothing and shelter. Some Danish authors (Bang et al, 1999) have suggested this applies to the housing market where they found the main priority in new housing is space, a good level of comfort, privacy, finish etc. Many of these amenities were also found in a New Zealand study (Page, 2007b). The Danish authors argued that a willingness to pay an increasing share of household income on housing may be an indication that in developed countries housing is becoming a luxury good associated with modern lifestyles. In this scenario the productivity ratio is the benefit divided by the price. The benefits include floor area, space volume, comfort, lighting, privacy, finish, maintenance and resource-efficiency.

This is a quite different measure to the usual productivity ratio of cost/inputs. It is likely these amenity characteristics are sought after in New Zealand homes, and are one of the reasons so much of our construction and design are one-offs. If this is the case then it becomes harder to achieve cost savings, and productivity metrics based solely on the cost may not be an adequate metric.

Despite this trend to amenity there are advantages in efficiency improvements across the various housing segments. The areas for productivity improvements described above, at the various levels of the industry, are worthwhile in themselves.

Earlier work (Page, 2007) has suggested group house builders are able to construct more cheaply than small-scale builders with savings of around 15%. The Appendix has data from an old census of the industry indicating that larger firms are more productive.

The two surveys of builders on new house cost factors and building industry productivity found some interesting results. The new house survey indicated that apart from labour and material costs, the ground slope and floor plan complex had a significant effect on costs. In contrast window sizes, more than one wall cladding and an upper storey did not have a major effect on new housing costs.

The other survey on industry productivity was surprising because standardisation and pre-fabrication/modularisation rated low as productivity influences. In contrast skill levels, project organisation and the design details were important for productivity gains, and this reflects the findings of the productivity literature.

8. FURTHER WORK

Further work in the following areas will enable a better understanding of how to improve productivity in the New Zealand construction industry:

- Examine Statistics NZ financial and workforce data of individual construction firms to assess variations in performance between and within sub-industries. This would need to be on anonymised data so firms are not identifiable. Publish this data in sub-industry aggregate form as a benchmark for firms to improve their performance. Also show the results for different firm sizes to see how important economies of scale are in the various sub-industries.
- Carry out surveys of medium and large construction firms to assess adoption of quality management systems and attempt to ascertain the costs and savings associated with these systems. Publicise the results of these surveys in aggregate form, to encourage better take-up of quality management in construction.
- Survey the industry to ascertain the proportion of work on new construction, routine maintenance, premature failures and decoration/remodelling for housing. The aim is to ascertain how much of the workforce operates in each segment. Develop appropriate performance measures for each segment.

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10. APPENDIX

This Appendix has the following sections:

- Employment breakdowns
- Production function modelling
- Census of building and construction 1978-79
- Builders' survey of new housing cost factors
- Builders' survey of general productivity factors

10.1 Employment within various sectors of building and construction

The value of work placed by the construction industry is shown in Table 4 for capital formation. It includes new work, additions, and work on existing assets that significantly prolongs the life of the assets. Routine maintenance and repairs are not included. The table also shows value-added, and construction industry employment (including full and part-timers), and includes on-site employment and office activities that directly support construction firms. Support sectors such as designers, surveyors and management consultants are not included unless they are on the payroll of the construction firm.

Table 4. Capital formation and employment

Fixed capital formation and construction employment Construction Industry								
		Residential	Non-res	Other	Total	Total	Value	VA/
Year	Employment	buildings	buildings	Construction		FCF/	added	person
end March	(000) (1)	<---------------$ million 07/08$		--------------------->		person	07/08$M	07/08$
87	103.7	5701	4165	2941	12807	123,504	7001	67,510
88	99.6	6174	4954	2397	13525	135,760	6860	68,854
89	97.3	5960	4518	2438	12916	132,706	6626	68,086
90	95.0	6892	4238	2217	13348	140,465	6900	72,617
91	88.4	6847	3533	2229	12608	142,708	5854	66,258
92	75.5	5843	2319	2454	10616	140,606	4943	65,476
93	79.6	6109	2273	1762	10144	127,441	4826	60,628
94	83.5	7163	2727	1706	11597	138,883	5331	63,849
95	94.7	8158	3519	1762	13439	141,876	5990	63,236
96	102.9	8255	4147	2475	14877	144,541	6313	61,339
97	113.3	8676	4261	2811	15747	138,986	7062	62,331
98	114.9	8982	4001	3259	16243	141,424	7300	63,564
99	109.0	7827	3876	2995	14697	134,839	6684	61,324
00	113.2	9314	3682	3820	16816	148,587	7835	69,226
01	116.4	8072	3963	3389	15424	132,535	7305	62,775
02	112.7	8235	4371	3484	16090	142,801	7712	68,446
03	125.0	10258	4433	3673	18365	146,889	8815	70,504
04	145.0	11849	4436	4181	20466	141,170	9725	67,082
05	153.8	12216	5088	4545	21848	142,076	10380	67,504
06	165.7	11635	6014	4907	22557	136,110	10835	65,378
07	186.8	11407	5503	5566	22477	120,340	10637	56,953
08	187.2	11839	5394	5921	23154	123,686	11109	59,341
09	182.6	na	na	na	na		10113	55,384
				Average 1987 to 2008		137,179		65,104

(1) Household labour force survey year average
Capital formation has been adjusted to 2007/08 values using the CGPI.
Source Statistics NZ

The value of work placed per construction worker varies between $148,000 and $120,000 over the period. The variation is likely to be due to changes in the mix of work, as well as efficiency changes. To assess the effect of the work types a regression analysis was done. The construction industry employment was regressed against the value of work by year in residential buildings, non-residential buildings and other construction (i.e. civil engineering). The period analysed was 1987 to 2005, and FCF (shown in Table 4) is used to measure volume of work, adjusted to constant dollars using the capital goods price indexes. The regression showed good correlation (Rsq=0.97) indicating the volume of work is a good indicator of employment in the industry as measured by the Household Labour Force Survey (see Table 5).

Table 5. Employment regressed against value of work

B&C Employ = c1 + c2*RB + c3*NR + c4*OC
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.984
R Square	0.968
Adjusted R Squ	0.963
Standard Error	6.066
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	19989.0363	6663.01209	181.0732199	1.24717E-13
Residual	18	662.352046	36.7973359		
Total	21	20651.3883			

	Coefficients	*Standard Erroi*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	4.34397	7.258934	0.598	0.557008711	-10.90648466	19.594423	-10.9064847
X Variable 1	0.00383	0.001170	3.270	0.004250808	0.00136861	0.0062863	0.00136861
X Variable 2	0.00769	0.002117	3.635	0.001894868	0.003246811	0.0121413	0.00324681
X Variable 3	0.01466	0.002422	6.054	1.00988E-05	0.009572985	0.0197492	0.00957298

		Employment 2008 (000 persons)	%	Work placed$/person
Residential bldgs	i.e. 3.8 jobs per $1M RB	45.3	26	261,270
Non-residential bldgs	i.e. 7.7 jobs per $1M NR	41.5	24	129,971
Other construction	i.e. 14.7 jobs per $1M OC	86.8	50	68,208
	Other	4.3		
		178.0	100	

The coefficients on the explanatory variables can be interpreted as the value of work required to support one job. For example the coefficient on residential building work is 0.00383. For the regression, employment was in thousands of persons and value in million dollars so the coefficient indicates 3.8 construction industry jobs are created for every $1 million of expenditure on housing. It is similar for non-residential building where the ratio is 7.7 jobs per $1 million, and civil engineering with a ratio of 14.7 jobs per $1 million. The inverse of these is the value of work placed per construction worker and shows residential is $261,000 per worker, non-residential buildings $130,000 per person, and civil engineering only $68,000 per person. However the dollar value of capital formation per worker is somewhat different to those found using the BDS data later in this section.

The table also has the implied employment for 2008 in each of housing (26% of all construction industry employment), non-residential buildings (24%) and civil engineering (50%).

Whether the three ratios represent reality is open to conjecture. The regression finds the three coefficients that give the best fit. Their t values are quite high but the coefficients have a quite large range. For example at the 95% confidence level the range for the residential coefficient is between 0.0014 and 0.0063, with an expected value of 0.00383.

The results of the regression are not what is expected, in that we had thought that civil engineering would have a high dollar work placed per person due to the high plant content and low labour content of other construction compared to buildings work.

A more direct measure of employment by work type is available from the business demographic survey (BDS) carried out annually by Statistics NZ. They survey employment by industrial classification, and the numbers are shown in Table 6.

The numbers include employees plus enterprises. The latter are included because a lot of enterprises are one-person firms, and working proprietors are not counted as employees. The numbers will be a slight over-estimate, however the totals are close to those from the household labour force survey, which is considered to be a more accurate count of industry employment.

A series of regressions were then carried out for each sub-industry as was done for the total industry in Table 5. The regressions were done using annual data for the period 2000 to 2009. The results are in Table 7, where the coefficients represent the amount of employment in the sub-industry per $1 million of work done on each of housing (RB), non-residential buildings (NR) and civil engineering (OC). The Rsq values are high for most sub-industries, indicating a quite good fit. For example for the concreting services sub-industry, for every $1 million spent on each of RB, NR and OC the employment is 0.08, 0.36 and 0.42 persons per year in that sub-industry, and the Rsq is 0.99.

Adding up for all sub-industries the employment is 6.4 person per $1m of RB, 12.1 persons per $1m of NR, and 7.1 persons per $1m of OC. The inverse gives the amount of work placed per worker: residential $156,000 per worker, non-residential buildings $82,000 per worker and other construction $142,000 per worker.

These ratios are somewhat different from those in Table 5, partly because the models cover different periods. Which set of percentages is best to use? Both methods indicate the residential sector is the most 'productive' in terms of value of work placed per worker. But the two methods rank the other two sectors differently. Directly measured employment, via the BDS, would seem to be most reliable. The bottom of Table 7 indicates that the employment ratios are approximately 6.4 persons per $1 million of new housing, 12.1 jobs per $1 million non-residential, and 7.1 jobs per $1 million of civil engineering.

Table 6. Employment from the Business Demographic Survey (BDS)

Sub-industry employment From Business Demographic Survey	Enterprises + employees								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
E301100 House Construction	19,817	19,068	19,507	21,776	25,534	28,427	31,265	33,159	35,091
E301900 Other Residential Building Construction	202	221	265	454	925	1,356	1,645	1,930	2,233
E302000 Non-Residential Building Construction	8,781	9,060	9,636	9,984	10,953	12,395	11,972	11,002	12,555
E310100 Road and Bridge Construction	11,135	10,963	10,202	11,548	12,546	13,791	14,772	15,191	15,915
E310900 Other Heavy & Civil Engineering Constn	7,935	7,927	9,978	9,573	9,840	11,748	13,389	15,554	15,161
E321100 Land Development and Subdivision	3,554	3,094	2,789	2,636	2,068	1,592	1,812	1,952	2,123
E321200 Site Preparation Services	6,473	6,557	6,956	7,352	8,253	9,457	10,033	10,476	10,936
E322100 Concreting Services	2,132	2,247	2,324	2,609	2,958	3,405	3,674	3,880	4,044
E322200 Bricklaying Services	2,351	2,226	2,238	2,497	2,855	3,153	3,120	3,228	3,346
E322300 Roofing Services	2,140	2,033	2,119	2,410	2,816	3,025	3,273	3,426	3,528
E322400 Structural Steel Erection Services	370	415	496	577	646	636	667	699	691
E323100 Plumbing Services	7,705	7,647	7,787	8,326	9,057	9,850	10,389	10,755	11,047
E323200 Electrical Services	13,046	13,582	13,389	14,142	15,101	15,413	16,379	17,036	17,618
E323300 Air Conditioning and Heating Services	2,398	2,282	2,374	2,615	2,889	4,341	4,627	4,836	5,188
E323400 Fire & Security Alarm Installation Serv	2,870	2,907	3,273	3,240	3,334	3,022	3,115	3,347	3,330
E323900 Other Building Installation Services	572	543	570	601	710	922	1,017	1,131	1,232
E324100 Plastering and Ceiling Services	3,345	2,949	2,982	3,400	3,928	4,373	4,682	4,704	4,913
E324200 Carpentry Services	4,136	3,957	3,962	4,143	4,287	4,437	4,486	4,228	4,136
E324300 Tiling and Carpeting Services	2,733	2,698	2,837	3,011	3,354	3,680	3,878	4,014	4,155
E324400 Painting and Decorating Services	8,520	8,392	8,489	9,078	9,852	10,689	11,259	11,320	11,394
E324500 Glazing Services	1,194	1,220	1,280	1,375	1,551	1,563	1,755	2,266	1,778
E329100 Landscape Construction Services	2,303	2,534	3,171	3,794	4,519	5,777	6,446	6,876	7,313
E329200 Hire Constn Machinery with Operator	541	631	645	762	894	1,026	1,143	1,277	1,261
E329900 Other Construction Services n.e.c.	3,289	3,380	3,651	3,877	4,467	5,505	5,972	6,440	6,556
Total less land development	113,988	113,439	118,131	127,144	141,269	157,991	168,958	176,775	183,421

Table 7. Sub-industry employment modelling

Employment per $ million fixed capital formation					
	Constant	Persons per $ million 2008$			Regression
	C0	RB	NR	OC	R sq
E301100 House Construction	-7962	3.22			0.70
E301900 Other Residential Building Construct	-3141	0.40			0.66
E302000 Non-Residential Building Constructi	3259		1.56		0.73
E310100 Road and Bridge Construction	8510		)	3.44	0.87
E310900 Other Heavy & Civil Engineering Constn			)		
E321100 Land Development and Subdivision					
E321200 Site Preparation Services	-1834	0.17	0.85	1.04	0.99
E322100 Concreting Services	-1362	0.08	0.36	0.42	0.99
E322200 Bricklaying Services	-20	0.13	0.10	0.22	0.99
E322300 Roofing Services	-1119	0.18	0.42		0.92
E322400 Structural Steel Erection Services	-68		0.10	0.04	0.77
E323100 Plumbing Services	350	0.33	1.12		0.91
E323200 Electrical Services	4833	0.35	1.38		0.84
E323300 Air Conditioning and Heating Service	-3965	0.20	1.12		0.87
E323400 Fire & Security Alarm Installation Se	2558	0.02	0.08		0.23
E323900 Other Building Installation Services	-796	0.04	0.24		0.81
E324100 Plastering and Ceiling Services	1300	0.34	1.04		0.95
E324200 Carpentry Services	3159	0.08	0.03		0.71
E324300 Tiling and Carpeting Services	-353	0.14	0.46		0.92
E324400 Painting and Decorating Services	1300	0.34	1.04		0.95
E324500 Glazing Services	-329	0.04	0.30		0.69
E329100 Landscape Construction Services	-6783	0.21	1.09	0.94	0.98
E329200 Hire Constn Machinery with Operatc	-738	0.03	0.15	0.15	0.97
E329900 Other Construction Services n.e.c.	-2897	0.07	0.69	0.82	0.99
	-6096	6.39	12.13	7.07	

Source: Business Demographic Survey, annual data 2000 to 2008.

Employment for each sub-industry was regressed against the 3 components of fixed capital formations (RB, NR, OC). R sq for each regression is shown.

Employment = c0 + c1*RB + c2*NR + c3*OC   c0 to c3 are constants.

Most coefficients had t statistic > 2.5, i.e. significantly different from zero.

10.2 Multi-factor productivity calculations

The MFP index for construction was calculated using the method in Davis (2007), and the results are in Table 8. Labour numbers were used instead of labour hours worked. The calculation requires the income share between labour and capital, and national account data for the construction industry was used (as shown in Table 9). Estimates were made for capital stock after 2005, since more recent data is not yet available from Statistics NZ.

Table 8. MFP calculations

Multi-factor productivity index for construction

	Construction	Capital		Indexes --->				MFP
	Value added	stock K	Employ L			Composite L, K index		
Mar Yr	1992/93$M	1995/96$M	HLFS (000)	VA	K	L	It	VA/It
88	4031	3122	99.6	1.000	1.000	1.000	1.000	1.000
89	3894	3161	97.3	0.966	1.012	0.977	0.993	0.973
90	4055	3131	95.0	1.006	1.003	0.954	0.977	1.030
91	3440	3221	88.4	0.853	1.032	0.887	0.952	0.896
92	2905	3216	75.5	0.721	1.030	0.758	0.865	0.833
93	2836	3171	79.6	0.704	1.016	0.799	0.886	0.794
94	3133	3315	83.5	0.777	1.062	0.838	0.928	0.837
95	3520	3461	94.7	0.873	1.109	0.951	1.011	0.864
96	3710	3742	102.9	0.920	1.199	1.033	1.095	0.840
97	4150	3978	113.3	1.030	1.274	1.137	1.184	0.869
98	4290	4188	114.9	1.064	1.341	1.153	1.223	0.870
99	3928	4342	109.0	0.974	1.391	1.094	1.214	0.803
00	4604	4538	113.2	1.142	1.454	1.136	1.265	0.903
01	4293	4717	116.4	1.065	1.511	1.168	1.307	0.815
02	4532	4875	112.7	1.124	1.561	1.131	1.307	0.860
03	5180	5083	125.0	1.285	1.628	1.255	1.407	0.914
04	5715	5535	145.0	1.418	1.773	1.455	1.581	0.897
05	6100	6207	153.8	1.513	1.988	1.544	1.725	0.877
06	6367	6407	165.7	1.580	2.052	1.663	1.818	0.869
07	6251	6407	186.8	1.551	2.052	1.875	1.925	0.806
08	6528	6357	187.2	1.619	2.036	1.879	1.919	0.844
09	5943	6257	182.6	1.474	2.004	1.833	1.881	0.784

Capital stock after 2005 is estimated by BRANZ

Composite L, K index $I_t = I_{(t-1)} * ((K_t/K_{(t-1)})^{\wedge wKt} * (L_t/L_{(t-1)})^{\wedge wLt})$

Table 9. Labour and capital income shares

Construction Industry				
	Compensation of employees	Gross op surplus	% share	
Mar yr	$ million current		Labour	Capital
87	1,522	1,222	55.5%	44.5%
88	1,579	1,330	54.3%	45.7%
89	1,601	1,373	53.8%	46.2%
90	1,632	1,580	50.8%	49.2%
91	1,507	1,326	53.2%	46.8%
92	1,469	966	60.3%	39.7%
93	1,380	1,044	56.9%	43.1%
94	1,447	1,302	52.6%	47.4%
95	1,643	1,617	50.4%	49.6%
96	1,762	1,887	48.3%	51.7%
97	1,945	2,107	48.0%	52.0%
98	2,146	2,171	49.7%	50.3%
99	2,058	2,095	49.6%	50.4%
00	2,309	2,492	48.1%	51.9%
01	2,500	2,253	52.6%	47.4%
02	2,588	2,567	50.2%	49.8%
03	2,882	2,850	50.3%	49.7%
04	3,260	3,232	50.2%	49.8%
05	3,810	3,897	49.4%	50.6%
06			48.5%	51.5%
07		BRANZ estimate	48.0%	52.0%
08			48.0%	52.0%
09			48.5%	51.5%

10.3 Modelling productivity with a production function

The production function described in Section 4.5 is further analysed below:

$Q = A\, L^{\beta 1} K^{\beta 2}$

Where Q = the industry output e.g. value-added.

A = technology/managerial efficiency coefficient.

L = labour used e.g. labour hours.

K = capital stock in the industry e.g. value of productive stock (plant, machinery and equipment).

All of Q, A, L and K change with time and $\beta 1$, $\beta 2$ are constants.

Let $A = ae^{\delta t}$ where managerial efficiency is assumed to change exponentially with time, and δ is the annual change in efficiency.

Where e = exponential (2.714)

δ = constant

t = time.

Taking natural logs of both sides:

$LnQ = Lna + \delta t + \beta 1\, LnK + \beta 2\, LnL$.

This equation is solved by linear regression. The coefficient in the regression on the time term is δ, which is a measure of the annual change in technological-managerial efficiency.

The time series for value-added, labour and capital are shown in Table 10 and the regression parameters are in Table 11.

The regression coefficients are used to model the total output over time (as shown in Figure 6). The modelling parameters for capital stock are only available up to 2005, so the regression was done between 1988 and 2005. The forward predictions of the model are shown in Figure 6, using assumed values for capital stock for 2005 to 2008. The model values for value-added plotted against actual are quite close, except for the forecasts after 2005. We do not yet know the actual values for capital stock for the latter years but the estimates are likely to be fairly correct. Hence we conclude the model does not provide very good predictive accuracy for value-added.

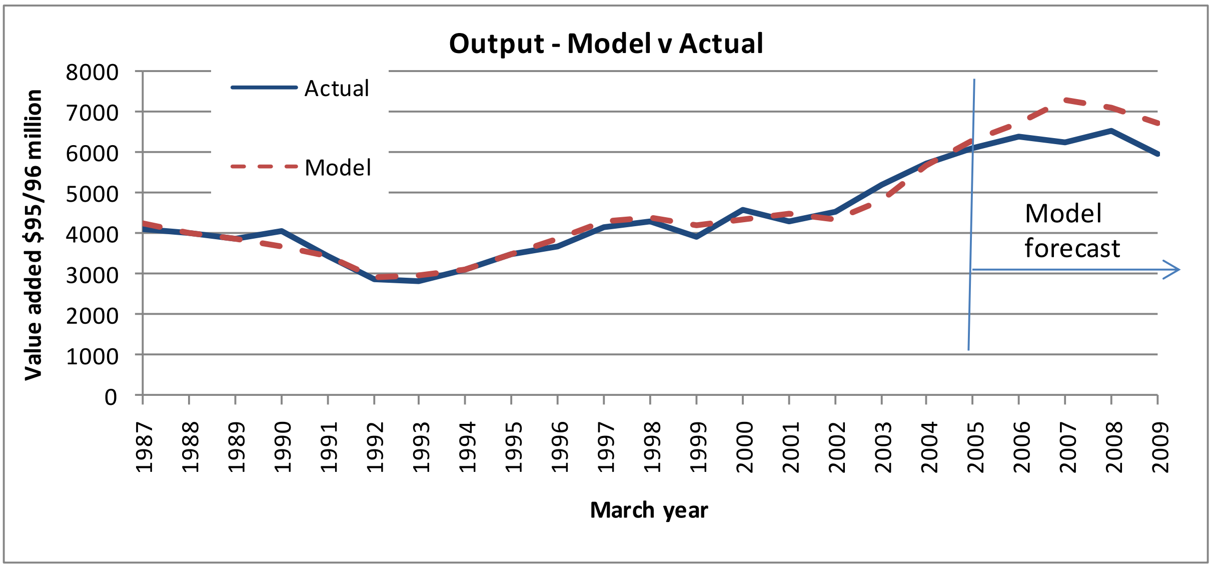
Table 10. Construction industry value-added, employment and capital stock

Building and construction industry resources					
March year	Value added 92/93 $ mill	Capital stock 95/96 $ mill	Employment (000 persons)	VA/employ $/ person	Capital stk/ labour ratio
1987	4114	3,102	103.7	39,672	29,913
1988	4031	3,122	99.6	40,462	31,338
1989	3894	3,161	97.3	40,010	32,479
1990	4055	3,131	95.0	42,673	32,949
1991	3440	3,221	88.4	38,936	36,457
1992	2905	3,216	75.5	38,477	42,596
1993	2836	3,171	79.6	35,628	39,837
1994	3133	3,315	83.5	37,521	39,701
1995	3520	3,461	94.7	37,160	36,537
1996	3710	3,742	102.9	36,046	36,357
1997	4150	3,978	113.3	36,628	35,110
1998	4290	4,188	114.9	37,353	36,465
1999	3928	4,342	109.0	36,037	39,835
2000	4604	4,538	113.2	40,680	40,097
2001	4293	4,717	116.4	36,889	40,533
2002	4532	4,875	112.7	40,222	43,266
2003	5180	5,083	125.0	41,432	40,656
2004	5715	5,535	145.0	39,421	38,179
2005	6100	6,207	153.8	39,668	40,364
2006	6367	6,407	165.7	38,419	38,660
2007	6251	6,407	186.8	33,468	34,303
2008	6528	6,357	187.2	34,872	33,958
2009	5943	6,257	182.6	32,547	34,266
	= capital stock data estimated after 2005				

Table 11. Production function regression analysis

	logQ = Loga + δT +β_1LogL +β_2LogK				
	SUMMARY OUTPUT			1987 to 2005	
	Regression Statistics				
	Multiple R	0.977317			
	R Square	0.955149			
	Adjusted R Squa	0.946178			
	Standard Error	0.047145			
	Observations	19			
	ANOVA				
		df	*SS*	*MS*	*F*
	Regression	3	0.709986	0.236662	106.4793
	Residual	15	0.033339	0.002223	
	Total	18	0.743325		
		Coefficients	*andard Err*	*t Stat*	*P-value*
lna	Intercept	-1.10959	2.366663	-0.46884	0.645923
β_1	X Variable 1	0.890776	0.195594	4.55422	0.00038
β_2	X Variable 2	0.665389	0.392035	1.697271	0.11029
δ	X Variable 3	-0.02319	0.011028	-2.10275	0.052782

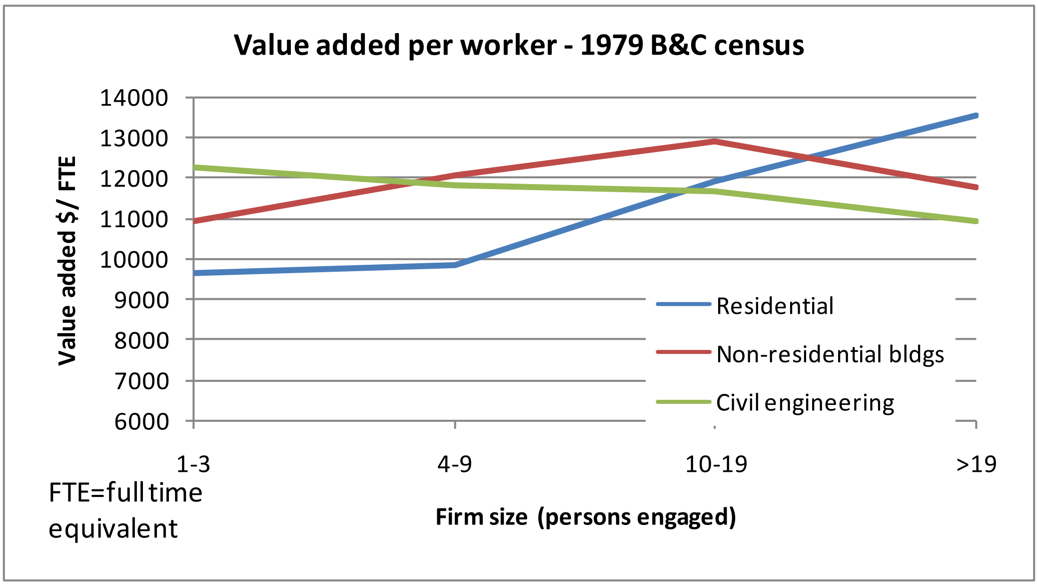
Figure 6. Production function regression model



10.4 1979 Building and construction census

The most recent census of the industry was in 1985. However the published data is somewhat limited and results from the earlier 1979 census are shown below. Figure 7 indicates that productivity trends upward as the firm size increases for building work. However for civil engineering the opposite appears to be true, with a decline in productivity as the firm size increases. Unfortunately more recent data is not available, so we cannot say whether this result still holds for present day firms in the industry.

Figure 7. Value-added by firm size 1979 construction census



10.5 Survey of factors affecting new housing costs

The importance of design factors was included in a survey of builders undertaken by BRANZ (see Figure 8). Apart from the obvious influences of labour and material costs, and building regulation requirements, site-specific factors such as site slope and plan complexity were important.

Council consent and development fees ranked quite high as a cost influence. This is probably due to a lot of publicity of these charges, but earlier work by BRANZ (Page, 2007) has shown they are only about 3% of the cost of a land and house package. Other design factors such an upper storey, a variety of window sizes, and multi-claddings were less important than was previously suspected. Also the organisation of sub-contractors ranked fairly low in the survey. It is speculated this result indicates that the main contractors are 'price-takers', and although they often have a semi-format arrangement with selected sub-contractors, they usually have limited control over their timeliness.

The ranking changed slightly when the ranking is by the percentage of respondents saying the factor was 'very important' (see Figure 9). The sloping site factor becomes more important.

Figure 8. Factors influencing new housing costs – average score

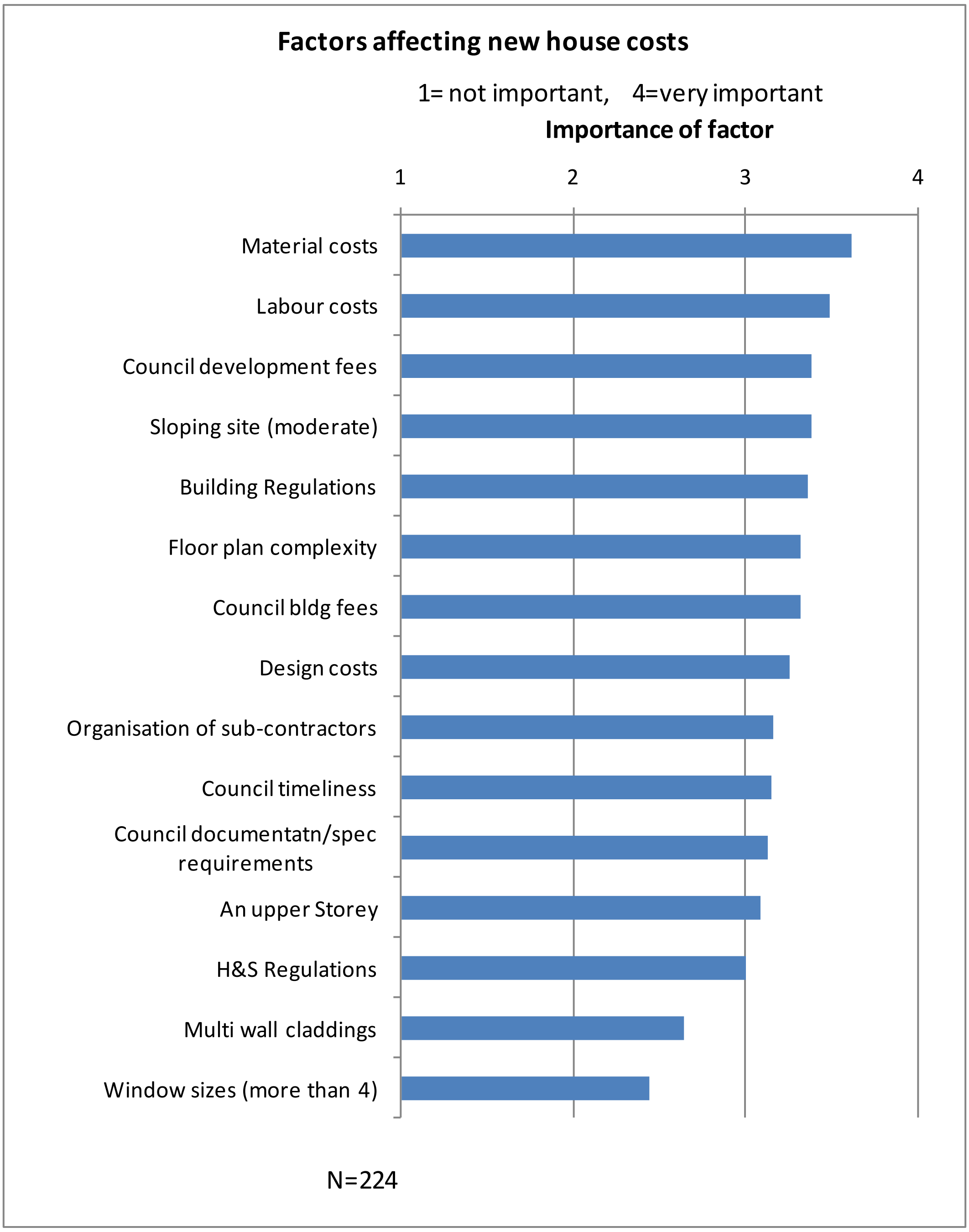
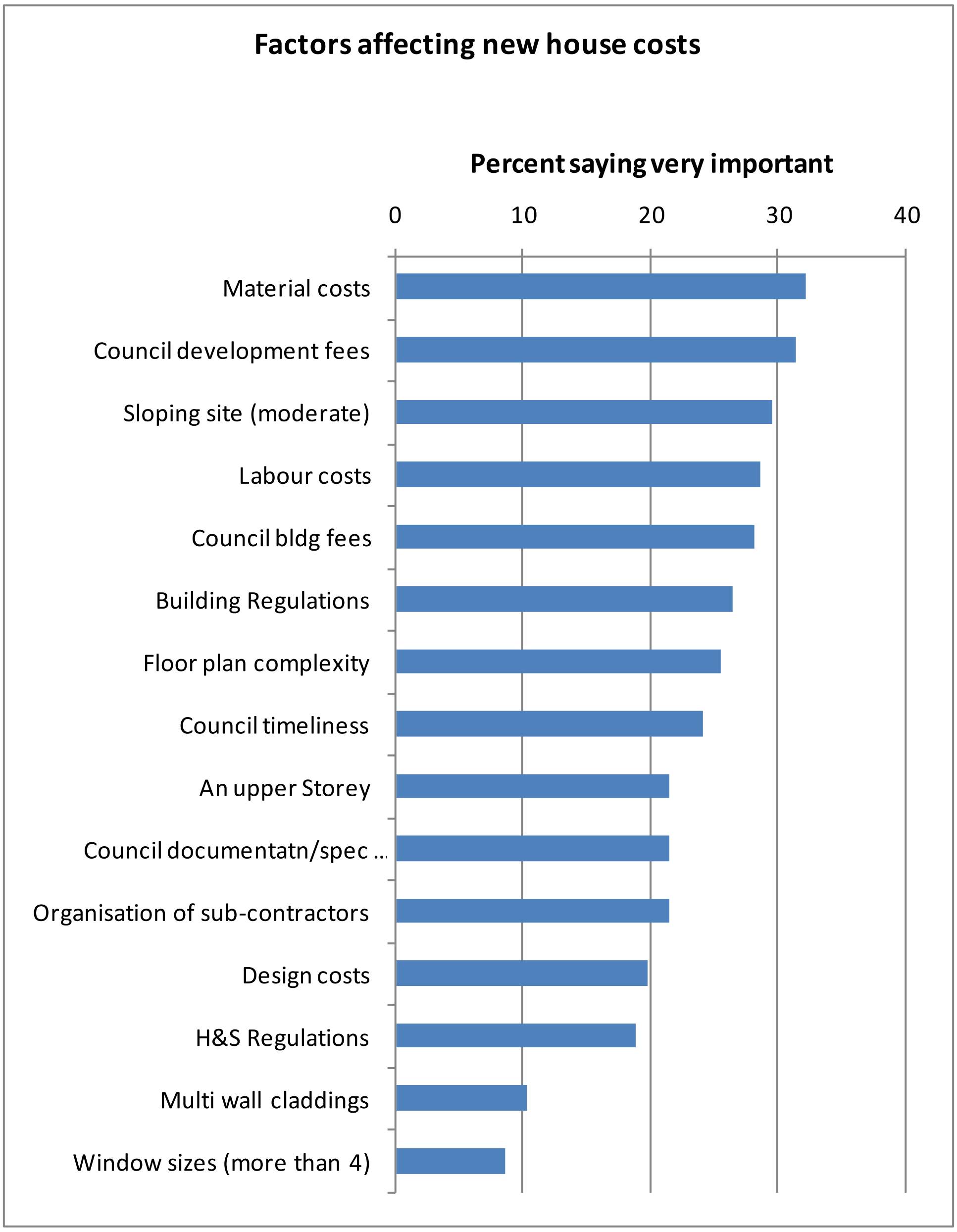


Figure 9. Factors influencing new housing costs – % saying very important



10.6 Survey of factors affecting building industry productivity

New house and non-residential builders were surveyed on the factors affecting building industry productivity. The results are in Figure 10 and Figure 11 and are similar for both builder types with skills, project organisation and design detailing being the most important. Workload levels, procurement, innovation and multi-project organisation also rated quite important. Workload reflects the trend in Figure 5 where productivity changes move in cycle with workload changes. The methods used by firms to procure work are rated important, reflecting the need to keep skills fully employed. It is surprising that standardisation and pre-fabrication are rated quite low as the literature indicates these are potential measures to achieve productivity gains. It may be that firms are saying the industry has gone as far as it can in terms of pre-fabrication, which is already quite extensive for structural framing in most materials. It could also be that the local building industry is unfamiliar with the type of modularisation and standardisation used in other countries and is therefore unable to envisage its use within New Zealand.

Figure 10. Survey of productivity factors – new house builders

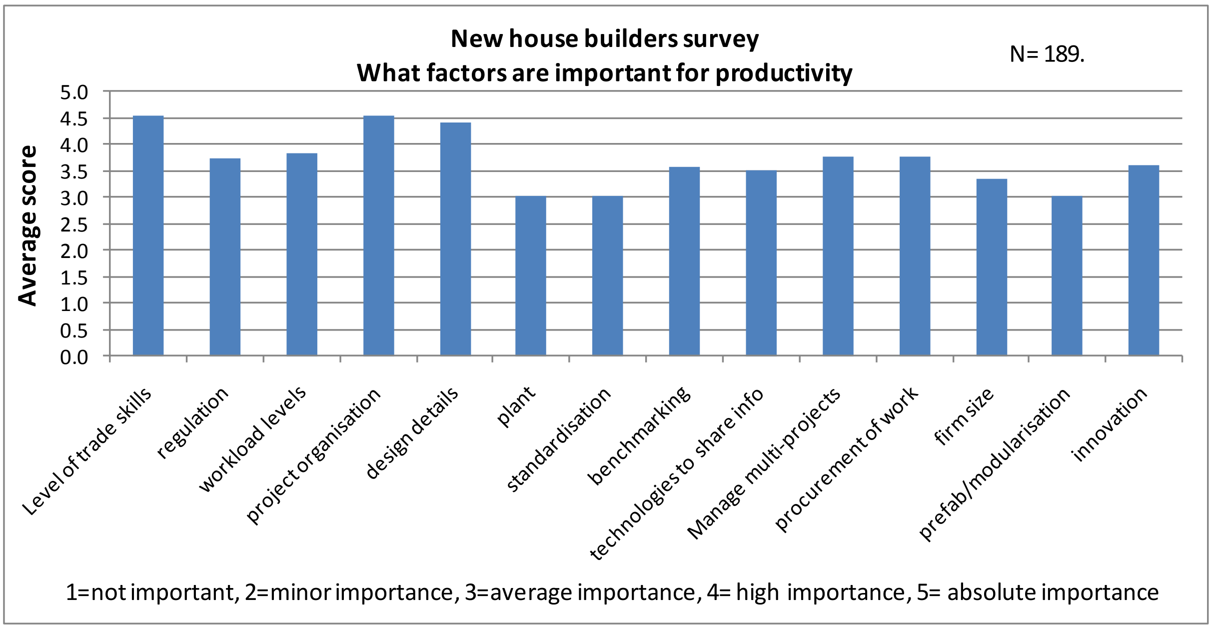
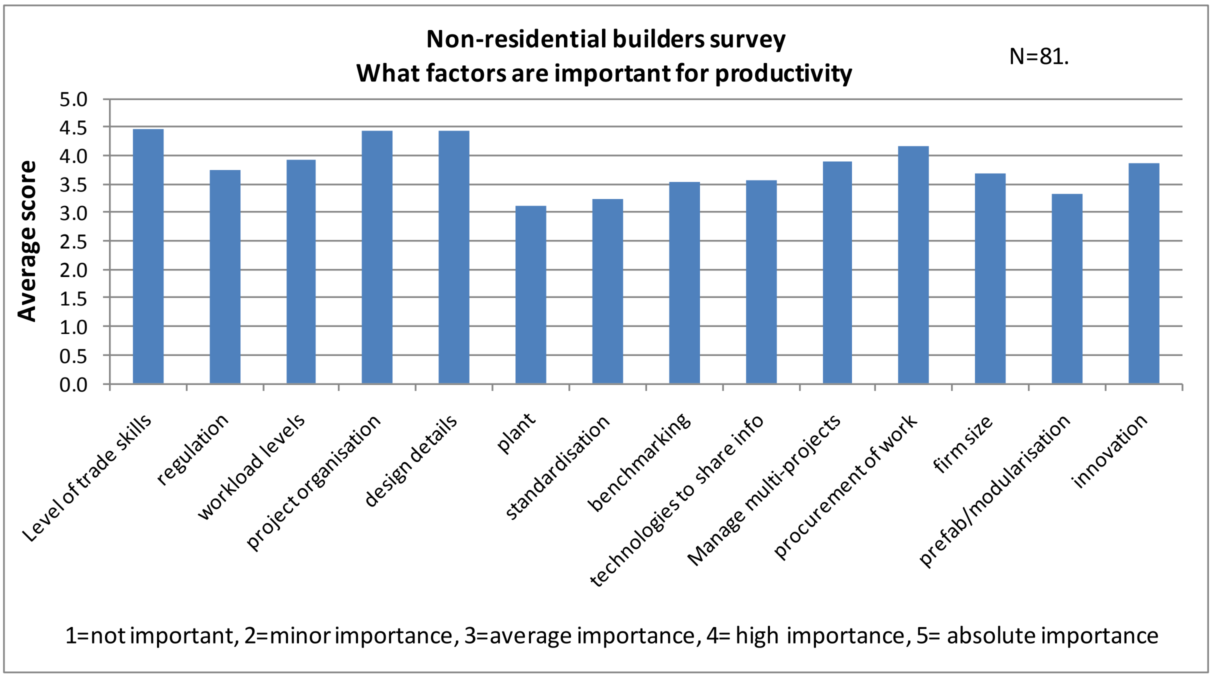


Figure 11. Survey of productivity factors – non-residential builders



The survey forms follow. They were sent at different times, mainly to different firms for each survey. The forms were included as part of the regular building materials survey sent out each quarter, with responses from approximately 190 new house builders and 80 non-residential builders to the productivity questions.

Table 12. Cost factors for new housing

Please tick one of the boxes in each line.

	Very Important	Important	Some Importance	Not Important
Complexity of floor plan	☐	☐	☐	☐
Upper Storey	☐	☐	☐	☐
More than one wall cladding	☐	☐	☐	☐
Many window sizes (say more than 4).	☐	☐	☐	☐
Sloping site (say over 10%)	☐	☐	☐	☐
Council timeliness	☐	☐	☐	☐
Council building fees	☐	☐	☐	☐
Council development fees	☐	☐	☐	☐
Council documentation/ specis.	☐	☐	☐	☐
Building regulations	☐	☐	☐	☐
Health & safety regulations	☐	☐	☐	☐
Organisation of sub-contractors	☐	☐	☐	☐
Labour skills	☐	☐	☐	☐
Labour costs	☐	☐	☐	☐
Material costs	☐	☐	☐	☐
Design costs	☐	☐	☐	☐

Do you have general comments about what factors influence productivity in the industry or the cost of a new house?...................

....

....

....

Table 13. Productivity in the building industry

It would be appreciated if respondents could also fill out this form with the new building form.

How important are the following to your firm's productivity?

PRODUCTIVITY FACTORS **(fill out only once per firm.)**

Consider projects done over the last 3 years by your firm.
In your option how important are the following factors on productivity (i.e. output per unit of inputs).
Please score the importance on a scale of 1 to 5
1= not important, 2= minor importance, 3= average importance, 4= high importance, 5= absolute importance.

Factor	Score
Level of trade skills.	
Level of regulation.	
Level of workloads.	
Organisation & planning of projects (labour, equipment, materials, information).	
Design details and documentation.	
Procurement of plant (i.e. leasing/ sharing/ owning arrangements).	
Standardisation of design (i.e. Similar buildings with minor changes, or limited range of plans.)	
Benchmarking performance of projects.	
Technologies to exchange information with managers, designers & site personnel.	
Management of multi-projects.	
Procurement of work (method used to procure new work).	
Size of firm (i.e. How important is the number of workers on your firm's productivity)	
Prefabrication and modularisation.	
Uptake of innovation by your firm.	

What other factors are important for productivity? ....
....
....

Thank you. Please fold and return with the building survey.

Thank You. Please fold this form and freepost it with the new build survey in the return envelope.