

Planning for Growth? The Determinants of Aggregates Demand in New Zealand

1. ABSTRACT

This study arose out of curiosity about the relationship between population and the demand for construction aggregates. The relationship is not a simple one, and further work identified trends that have serious implications for the social and economic well-being of communities in the medium to long term. New Zealand is a closed aggregates market in which production can be assumed to balance demand. Analysis of official mineral production statistics indicates possible causal relationships between population and total demand, and between economic activity (real GDP per capita) and per capita demand. From about 1966, however, there was a period of steady decline in per capita demand despite continuing economic growth. Total demand – which continued to be supported for a while by strong population growth – followed the same trend seven years later. The underlying reason for the fall in demand appears to have been a paradigm shift in production and application technologies adopted over a relatively short period. The result was a more efficient use of aggregates that suppressed demand and masked the effect of continuing growth of both population and economic activity. The efficiencies peaked in about 1980, and since 1991, economic activity has reasserted itself as the dominant influence on per capita demand, suggesting that the efficiency benefits are now largely embedded in existing infrastructure.

The future aggregates demand scenario that is emerging has serious implications for growth planning, especially in regions with high population growth and in the Auckland, Wellington and Canterbury regions where there is already pressure on aggregates supply.

Key words: aggregates, supply, demand, building, roading, construction, population

2. INTRODUCTION

Recurring themes in growth strategy discussions are the allocation of residential, commercial and industrial land, the development of the transport and other infrastructure and the funding they require. Hardly any consideration has been given, however, to the future supply and distribution of construction aggregates. This could have serious consequences because the supply of affordable construction aggregates is as much a prerequisite for growth as the funding of infrastructure, and because mineral production and processing is one of the more contentious land uses administered under the provisions of the Resource Management Act 1991.

Lack of data to address the issue could be the reason for this lack of consideration. The specific inputs required are information on the distribution and commercial characteristics of potential aggregate resources, and order of magnitude estimates of future requirements. The former is generally well known and adequately addressed in the literature; the latter is a reason for this paper.

3. THEORETICAL BACKGROUND

Elementary economic theory recognises five non-price determinants of demand:

- population
- income
- taste
- the prices of substitutes and complements
- expectations

Official records of national production of construction aggregates provide a basis for examining the effects of population and income on historic demand. New Zealand is essentially a closed market for aggregates (Christie et al.,

2001), and for economic as well as practical reasons annual production from individual quarries is roughly equivalent to annual sales. The total national annual production of aggregates therefore, is roughly equivalent to the total national annual demand, and national aggregates production data can be compared directly with national population and economic statistics.

There is an almost complete record of annual production for the December year since 1947 (New Zealand Mines Department, 1947–1975; Ministry of Energy, 1976–1988; Ministry of Commerce, 1989–1996; Ministry of Economic Development, 1998–2004). A single exception is 1997, when no returns of production were collected or published. New aggregate categories have been added from time to time and others amalgamated, but with a few adjustments, a generally consistent database representing most construction aggregate¹ production was extracted.

The compiled database includes categories of rock, sand, gravel, shingle and limestone used for roads and railway ballast, and rock, sand, gravel, etc used for building. Some categories were included if they had been reported previously under either the “roads and ballast” or “building” headings (for example, decorative stone and scoria). Excluded from the database were material produced for harbour works, reclamation and erosion protection, dimension stone and materials not sourced exclusively from quarries or gravel pits (for example, rock or clay used for fill).

The included categories account for about 90% of total aggregates production since 1967 and up to 98% of earlier recorded production.

4. POPULATION EFFECTS

In Figure 1(a), total construction aggregates production in New Zealand is compared with the estimated mean resident population for the December year. A strong positive relationship is apparent until 1973 with a correlation coefficient ($r_{1947-1973}$) of 0.9836. Following its strong growth in the 1950s and 1960s, aggregates demand declined from 1973–1991

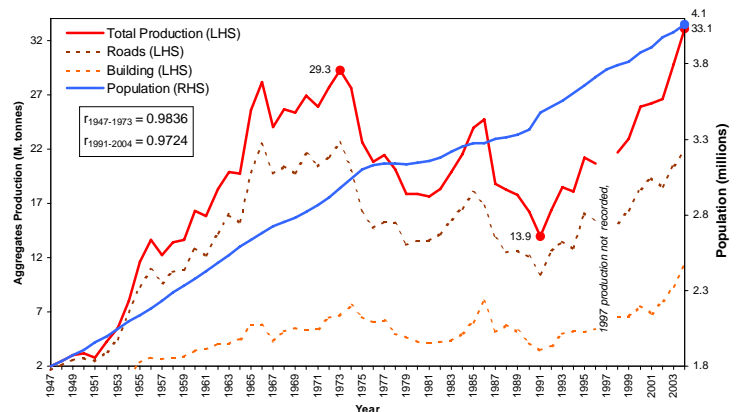


Figure 1(a): Aggregates and Population, 1947–2004

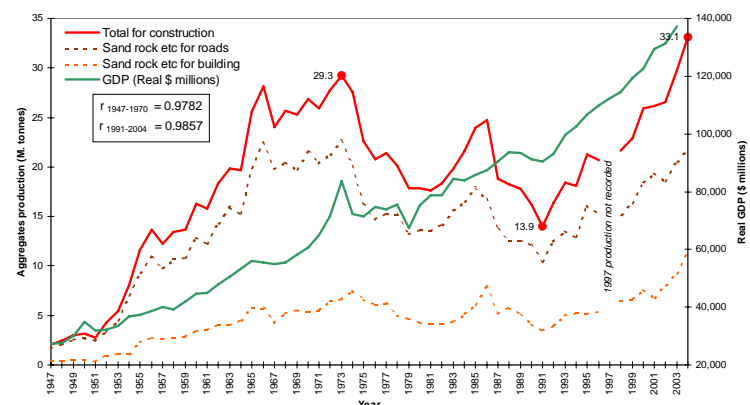


Figure 1(b): Aggregate Production and Gross Domestic Product

in spite of continuing but less vigorous population growth. From a record high of 29.3 million tonnes (Mt) in 1973 production fell to 13.9 Mt in 1991 before recovering. By 2003 production had grown to 29.8 Mt, just exceeding the previous maximum, and in 2004 it reach a new record of 33.1 Mt, and a strong correlation with population ($r_{1991-2004} = 0.9724$) was again apparent.

The demand for both roads and building products followed the same general pattern, but with demand for roads more variable than demand for building.

5. INCOME EFFECTS

In this study, Gross Domestic Product (GDP) has been adopted as an appropriate measure of income from local production.² Figure 1(b) shows the relationship between the same

1. In this paper construction aggregates refers to naturally occurring materials used in road, railway and building construction and maintenance.

2. GDP can be defined as “the market value of all final goods and services produced within a country in a given period of time” (Mankiw, 1998, quoted by Briggs, 2003). In New Zealand, GDP is measured variously as the value of production, the local expenditure on production, and the income from production.

production data and Consumer Price Index adjusted Gross Domestic Product (real GDP) for the following March year. Once again, there is a strong positive relationship in the early part of the record – but only until 1970 – with a correlation coefficient ($r_{1947-1970}$) of 0.9782.

Aggregates production faltered in the early 1970s in spite of exceptional economic growth, and the decline in production that followed occurred in spite of continued but rather erratic economic growth. A strong positive relationship with real GDP is once again apparent from 1991 ($r_{1991-2004} = 0.9839$).

In Figure 2, per capita demand is compared with economic activity (real GDP per head of population) in order to eliminate the effect of population, and a similar historic pattern can be seen. Again there is a strong positive relationship until 1970 ($r_{1947-1970} = 0.9223$), but the peak per capita demand (slightly less than 10.5 tonnes) occurred four years earlier in 1966, before falling to just over 4 tonnes in 1991 and then recovering. By 2004 per capita demand had reached about 8.1 tonnes, and a

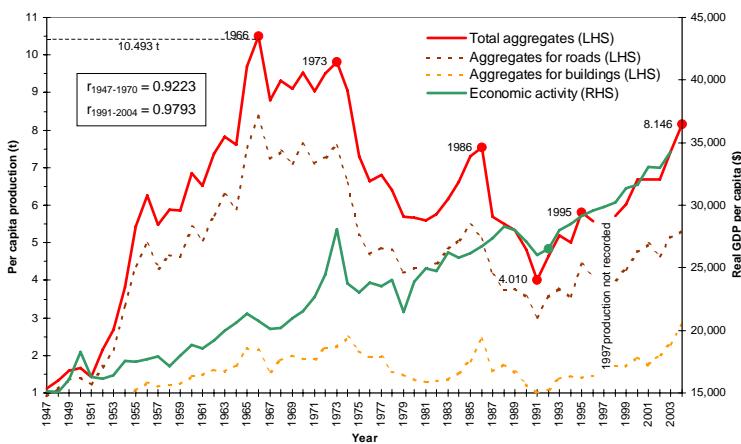


Figure 2: Per Capita Aggregates Production and Real GDP Per Capita

strong positive correlation ($r_{1991-2004} = 0.9793$) was again apparent. Throughout the entire record however, per capita demand fluctuated in sympathy with economic activity – the so-called business cycle. This suggests a causal relationship throughout, but with the intervention of some other factor or combination of factors that suppressed demand. The strong correlation evident from 1991 suggests that a permanent adjustment or shift in the relationship had occurred.

6. CHANGES IN TASTE

The data contains a clue to the likely cause of the adjustment. The decline in annual per capita consumption persisted for 25 years (1966–1991) but a slow down in the rate of demand growth had started about ten years earlier. The time-span of suppressed demand therefore, was approximately 35 years, which is consistent with the 30- to 40-year life of Transit New Zealand road pavements (Transit, 2006). In addition, renewed growth in demand from 1991 is consistent, with changes largely “embedded” in existing infrastructure.

It is postulated that the adjustments to the population and economic relationships from 1966–1991 were the cumulative effect of significant technical advances in the production and use of construction aggregates. In economic terms, they were the result of a change in taste.

Rapid growth in the consumption of construction aggregates from 1947–1970 had coincided with large-scale infrastructure development needed to support social and economic expansion following the austerity of the Second World War and the economic depression that preceded it. Major construction projects included hydroelectric power development, highway improvement and construction of motorways and airports. New and latent construction technology was introduced, traditional design methods were replaced by rational design, and this in turn required inputs from specialised and ancillary disciplines, such as geotechnical and earthquake engineering, engineering geology, geomechanics and hydrology. Such projects also required better performing aggregates.

Engineers, scientists and technologists from both the public and private sectors rose to the challenge with some spectacular results, especially with regard to the consumption of aggregates for road construction and maintenance.

6.1 Aggregates for Roads

Significant advances in the understanding of the suitability of local raw materials for road construction and maintenance resulted from the work of Kear, 1965; Reed, 1966; Buckland,

1967; and Sameshima et al., 1978. The New Zealand Geological Survey also contributed by mapping the distribution of rocks suitable for aggregates production.

Ferry and Major (1987) have described the improvements in road construction standards throughout much of the period. Base course aggregate grading specifications for layered-road construction had been adopted by the Main Highways Board in the 1930s and refined by the National Roads Board with the introduction in 1954 of the B/2 specification that, amongst other things, limited clay content. Increased loadings however, especially by tandem axle vehicles, caused potholes and other shallow deformation failures even in new construction. Ferry and Major state: “Not appreciated today is the proportion of road maintenance resources devoted to pothole and other shallow deformation failures on sealed rural roadways in the 1940s and 1950s”.

Examination of well performing base course materials led to the introduction of the first M/4 base course specification in 1958 (further refined in 1960 and 1974) because of which “the incidence of potholes and other shallow deformation failure was reduced by an order of magnitude” (Ferry and Major). Around this time, lime and cement stabilisation of aggregates replaced previous methods using caustic soda, and later the use of geo-textiles to protect sub-base aggregates was introduced.

From 1950–2004 the ratio of per capita consumption of aggregates for roads to that for building fell dramatically from nearly 6:1 to 2:1 (see Figure 3), reflecting the large volumes of

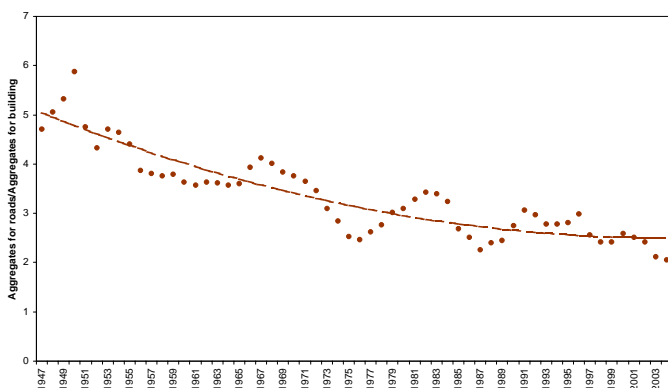


Figure 3: Ratio of Per Capita Aggregate Consumption for Roads and Consumption for Building (3-year averages)

aggregates – alluded to by Ferry and Major – that had previously been required just to maintain existing roads. The actual volumes used in road maintenance are not known, but something of the scale can be inferred from the fact that today – even after the various savings – road maintenance accounts for about 60% of consumption of aggregates for roads, and about 45% of all construction aggregates.

It is likely that the economic benefits contributed to a reduction in expenditure on roads from about 1966. Expenditure on public roads, which had averaged 2.62% of Gross National Product from 1959–1966, fell to below 1% in 1984 and 1985 (Department of Statistics, 1960–1988).

6.2 Aggregates for Building

The savings in aggregates consumption for roads is even more remarkable when improved efficiency in the use of aggregates for building is taken into account. Technical advances in structural design during the 1960s subsequently resulted in a more efficient use of structural concrete and a significant saving in aggregates consumption as well (W R Miller, personal communication, 27 March 2006). The advances included:

- Reduction in the factors of safety required in the design of reinforced concrete members when ultimate strength design replaced the previous working-strength design philosophy.
- Reduction in the load factors to be allowed for in the design of reinforced concrete members.
- Growth of the use of pre-stressed concrete products, permitting significant reductions in the thickness of concrete required.
- Higher concrete strengths achieved through the use of additives and improved concrete batch design.
- Replacement of concrete masonry with plasterboard on wooden frames to achieve requisite noise and fire proofing.

More exacting standards for concrete aggregates were introduced progressively (for example, NZS 3121:1974 and NZS 3121:1980) with particular emphasis on grading, cleanness and the absence of deleterious materials. There was also greater awareness of the chemical reactivity of some aggregate materials and their

potential to cause the failure in structural concrete that resulted in more discerning selection of resources for production of aggregates for concrete.

6.3 Aggregates Production

The introduction of exacting standards for aggregates and the technology required to meet them, the cost of plant, equipment and improvements in transportation resulted in a consolidation of the aggregates industry. The introduction of more sophisticated processing and handling equipment, and improved quality control resulted in cleaner, better-graded and better-shaped products. Of particular note, the development of semi-autogenous crushing equipment by two New Zealand engineers³ in the early 1970s was an international advance in the production of high specification concrete chip and sealing chip.

Consolidation of the industry also resulted in significant economies of scale with the average CPI adjusted price of construction aggregates falling by over 40% from 1955–1968 (O’Brien in prep). Many small quarries throughout New Zealand closed – some because their resources were incapable of producing durable aggregates, but others for purely economic reasons.

7. FUTURE DEMAND FOR COARSE AGGREGATES

The data presented confirms population and national income (represented by Gross Domestic Product) as determinants of aggregates demand in New Zealand, with adjustments to the relationships from 1966–1991 attributable to a spontaneous change in taste. The trend in per capita aggregates demand therefore, is a plausible basis for anticipating future short run demand.⁴

The post-1966 data presented here is considered a reasonable and convenient approximation of total coarse aggregates⁵ production in New Zealand. As noted above, the post-1966 production data represents only about 90% of total aggregates production, but

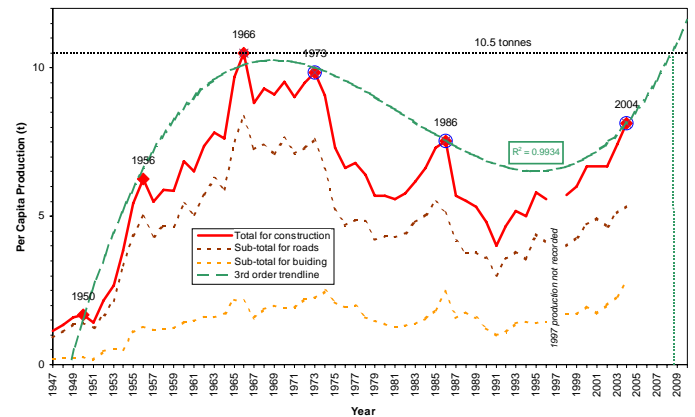


Figure 4(a): Peak Per Capita Demand: Projection of 1947–2004 Trend

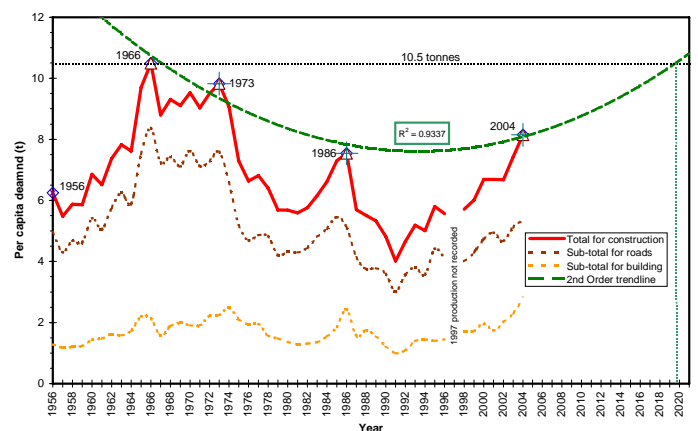


Figure 4(b): Peak Per Capita Demand: Projection of 1966–2004

the 10% shortfall is about the same as the typical annual production of fine aggregates (ie sand).

In 2004 therefore, coarse aggregates consumption reached a new record level equivalent to approximately 8.1 tonnes per head of population and it seems inevitable that eventually the previous record per capita consumption of 10.5 tonnes will be surpassed. With a more than 50% increase in the usually resident population in the meantime, the industrial and social implications are too important to ignore.

Cyclical peaks in production are the key data because they indicate the minimum production capacity required if to avoid shortages in some years. Production peaks since 1950 indicate a rapid growth in consumption to 1956, a slowing of growth until about 1966 followed by the decline and recovery already described. This can

3. J. MacDonald and F. Bartley.

4. The short run is the period in which market conditions are considered likely to be fixed.

5. Aggregates generally coarser than 4.75 millimetres.

Aggregates demand scenario	Peak per capita demand of 10.5 tonnes by:	Expected coarse aggregates demand (Mtpa)	
		Low population estimate	High population estimate
High growth	2009	43.8	44.9
Low growth	2020	45.4	48.7

Table 1

be represented by a third-order polynomial with the general form

$$y = c_3 x^3 + c_2 x^2 + c_1 x + b$$

Forward projection of this trend (Figure 4(a)) suggests that peak per capita demand might return to 10.5 tonnes by 2009.

Treating peak demand production from 1966–1973 as a second order polynomial with general form

$$y = c_2 x^2 + c_1 x + b$$

provides a more conservative estimate of expected behaviour. The best case indicated by the data is that peak per capita demand should recover to 10.5 tonnes by 2020 (Figure 4 (b)).

The two trends provide a basis projecting high and low coarse aggregates demands. Using Statistics New Zealand 2004-based national population projections for 2009 (which range between 4.175 million to 4.272 million depending on the fertility, mortality and net migration assumptions used) and the similarly between 4.325 million and 4.636 million for 2020, the projections are set out in Table 1.

The most optimistic outcome is that national peak aggregates demand will increase to between 45.4 and 48.7 million tonnes within the next 15 years, an increase on total production recorded in 2004 of 37% and 45% respectively.⁶ To give these percentage increases some perspective, each is equivalent to more than the present annual consumption of the whole of the Auckland Region, and equivalent to the total production output from six to eight quarries of similar size to the largest currently operating in the region.

6. These national projections are generally consistent with a supply and demand model for the Auckland Region by Findlay (2000) and with concerns expressed in an earlier report by the University of Auckland's Department of Planning (1997), and by Johnson et al. (1998).

8. OTHER DETERMINANTS

The quantitative relationships discussed are not immutable. In particular, peak aggregate demand projections make no allowance for the effects of any changes in taste, changes in the prices of substitutes and complements, or changes in expectations during the next 15 years.

8.1 Change in Taste

Another technical adjustment seems unlikely during this period. A feature of the changes that occurred in the third quarter of the last century is that many were “latent” developments that had their origins in the 1930s or earlier, and were adopted as improvements to a comparatively “low-tech” base.

In contrast, current aggregate production and application technologies are sophisticated, and further improvements – such as the computerisation of production control and design – have been adopted progressively, especially where there are obvious advantages in economic efficiency or the use of matériel. In addition, the adjustments that occurred from 1966–1991 followed at least 15 years of high-intensity infrastructure development that prompted significant government and private sector research and development effort. There appears to be no indication that current infrastructure expansion and replacement requirements – significant as they might be – have prompted comparable research and development activity.

However, the long-term implications of the trends do indicate a need for sustained and integrated research effort into future sources, production and use of construction aggregates. At issue are the national interest, the allocation and use of national resources, and existing resource allocation mechanisms, and a leading central government role seems appropriate.

8.2 Prices of Substitutes and Complements

Continued fuel price increases may well have a significant effect on road transport patterns in the future, but whether, or the extent to which this might transfer to demand for construction aggregates is uncertain. Fossil fuels are a complement of aggregates consumption and the infamous oil price hikes of 1973 and 1978 were both followed by a fall in per capita consumption. The effect was indirect however, and was channelled through economic activity, which is “neutralised” in projections of peak demand.

Permanent oil price increases may lower the peak demand for aggregates for road maintenance, but an increase in the use of transport alternatives such as rail or coastal transport would lead to other demand for aggregates (for example, railway ballast and harbour works) offsetting some of the effect.

8.3 Expectations

Public expectations have the potential to offset any remaining savings. There is ongoing pressure throughout the country for improvements to existing roads and other infrastructure, and proposed and deferred construction projects have the potential to sustain the growth in demand for many years. A recent announcement of increased central government funding for road construction and maintenance⁷ indicates that the most likely effect of expectations is to further increase total demand for aggregates in the short to medium term at least.

9. DISCUSSION

The primary focus here has been the determinants of demand. For convenience, national data has been used and similarly the demand projections presented are national projections. It is unlikely that expected increases in demand will be distributed evenly throughout the country. Logically, the increases are more likely to be skewed towards high population growth areas, and will be felt especially in Auckland, Wellington and Canterbury where there is already pressure on local aggregates supply.

While there is no shortage of in situ aggregate resources in high demand regions, it is difficult for producers secure them. Conflicting land uses are the main impediment. An example is the sub-division of rural land into lifestyle blocks well beyond the fringes of the major metropolitan areas, which has been allowed apparently, without much regard for future rural production (Pickmere, 2004 and Eames, 2005).

Such barriers to the development of new aggregate resources are progressively forcing production deep into the rural heartland, and it is estimated that in the Auckland Region for example, approximately 20% of construction aggregates consumed in 2004 were imported from outside the region. Continuation of that trend would have serious implications for both the construction industries in the major metropolitan areas and the community at large. The most obvious implication is the direct effects of increased transport distances on the delivered cost of aggregate and consequently, the affordable rate of construction of urgently needed infrastructure, the cost of renewal and maintenance of existing infrastructure, and the impact of such inefficiency on local economies.

Pricing within the aggregates industry is normally competitive with average values⁸ hovering above the economic cost of production (O'Brien, in prep) and increased transport costs therefore, would accrue to consumers. Since the overwhelming consumption of aggregates is for the construction and maintenance of publicly owned infrastructure, most of those costs will be borne by central and local government agencies, and ultimately by taxpayers and ratepayers.

Less conspicuous, but just as real, are significant ongoing costs to the community at large (ie the externalities). These include congestion costs associated with increased use of heavy vehicles on state highways, the social cost of the increased incidence of distance-related heavy vehicle accidents, the cost to New Zealand under the Kyoto protocol of increased greenhouse gas emissions, and the environmental costs of NO_x emissions.

7. New Zealand Government, Budget 2006.

8. Average values recorded by the Ministry of Economic Development are compiled from prices at the quarry gate, and are therefore exclusive of transport costs.

The public interest would be well served therefore, if those developing growth strategies were to include measures to ensure the availability of resources for the future supply of construction aggregates at affordable cost.

10. ACKNOWLEDGEMENTS

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