THE IMPLICATIONS OF REDUCING DESIGN STANDARDS FOR PROPOSED EXPRESSWAYS

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ABSTRACT: *The paper looks at current freeway design standards and examines ways in which these may be reduced, in order to minimise the impact of proposed freeways. The authors use recent appraisals of Sydney's inner urban freeways to illustrate their argument. The implications of reduced design standards in terms of land take, cost, and on the ability of the freeway to perform its function are discussed. The conclusion is drawn that reduced standards are warranted in densely populated, topographically significant areas where capital cost and enormous impact make it unlikely that freeways to classical design standards will ever be built.*

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The debate concerning the future of urban freeways, particularly in the inner suburban areas of our larger cities has tended to express itself as one of two opposing viewpoints, summarised in the quotations below: -

> "A mature public realisation of the immense capital costs, of the outdated planning, of the environmental and social effects and of the imbalance in transportation budgets, has been responsible for the halting of a number of inner area Expressway projects in recent years"

> "The anti-expressway movement consists of a few ignorant self interested residents, not to mention the screaming fringe, who are manipulating the political system for their own ends at everyone else's expense."

1. INTRODUCTION

The authors of this Paper, who carried out a series of low budget studies (1), commissioned by the Department of Urban and Regional Development, to investigate the range of alternatives to the existing proposals for the inner sections of Sydney's Western and North Western Freeways, don't accept either of the above views. However, we did reach the conclusion that a small reduction in the standards of design of an inner urban primary network, from those normally accepted now in Australia, opens up so many possibilities for saving costs and reducing social and environmental impacts that a new approach to inner city primary networks based on reduced standards should be carefully studied.

The benefits however only become apparent if the full range of planning and design factors are taken into account from the commencement of route selection and design. For this reason the studies mentioned above were structured in such a way as to enable all the factors involved to be assessed at one time, so that trade offs between them could be made.

The study of Sydney's Western and North Western Freeways looked at four major alternatives which covered, in principle, the proposals advocated by the parties to the dispute about these particular freeways.

The alternatives examined were: -

1. DO NOTHING, which in effect meant that the existing road system would be used to its maximum capacity with continuous small upgrading, extension of peak hours and probably increased filtering through residential areas.

2. PROCEED WITH THE DMR PROPOSAL, which consisted of three major freeway facilities using reservations gazetted substantially in their present form almost 30 years ago.

3 CONSTRUCT AN ALTERNATIVE FREEWAY SYSTEM of equivalent standard and slightly lower capacity in an alternative "lower impact" corridor

4 UPGRADE EXISTING ARTERIAL ROADS to what was defined as 'expressway' standard An expressway being a divided road similar in function to a freeway. However it is designed for running speeds of 70 - 80 km/h and access is permitted only at controlled points, either grade separated or with traffic signals

They are illustrated on Figure 1.

It is important to note that alternatives three and four are made possible only if standards of design are lowered, and if the co-operation of other public authorities, who may be inconvenienced, is obtained.

However, before discussing the alternatives in greater detail it is necessary to discuss:-

(a) What is meant by reducing standards

(b) How is cost affected by doing so

(c) What effect does it have on the performance of the system, and

(d) Why a lower standard facility can have less impact

2. WHAT ARE "REDUCED DESIGN STANDARDS"?

The objective of considering design standards in this context is to define where a reduction in freeway design standards could lead to a significant reduction in impact, on condition that it did not lead to an unacceptable reduction in capacity, safety or an unacceptable increase in capital or operational costs.

This could be expressed in terms of the more normal benefit/cost criteria by defining the objective as being to reduce the impact of freeways, whilst not reducing the benefit/cost ratio of the facility. However, the benefit/cost ratio must include a proper estimate of the costs of all the various impacts.

Thus we are principally concerned, in this paper, with those elements of design standards, which if reduced can increase the ability of the designer to reduce the impact of the freeway.

If we assume that the impact of a freeway is caused by the following three principal factors: -

(a) Reserve Width - generally speaking the wider the reserve the greater the land take and hence the greater the impact, hence any reduction in reserve width leads to a reduction in impact

(b) Horizontal Alignment - generally the higher the standard of horizontal alignment the lower the ability to avoid sensitive areas and the greater the impact of the freeway

(c) Vertical Alignment - the higher the standard the less it is able to fit in with natural topography and hence the visual impact is likely to be greater, particularly where the area is hilly

then we may say that its impact is likely to be lessened by reductions in reserve width and horizontal and vertical alignment standards This is particularly so in the inner urban areas of Sydney, in which the authors were particularly interested, as they are areas of significant topography, with small dense communities, highly susceptible to disruption by facilities such as freeways.

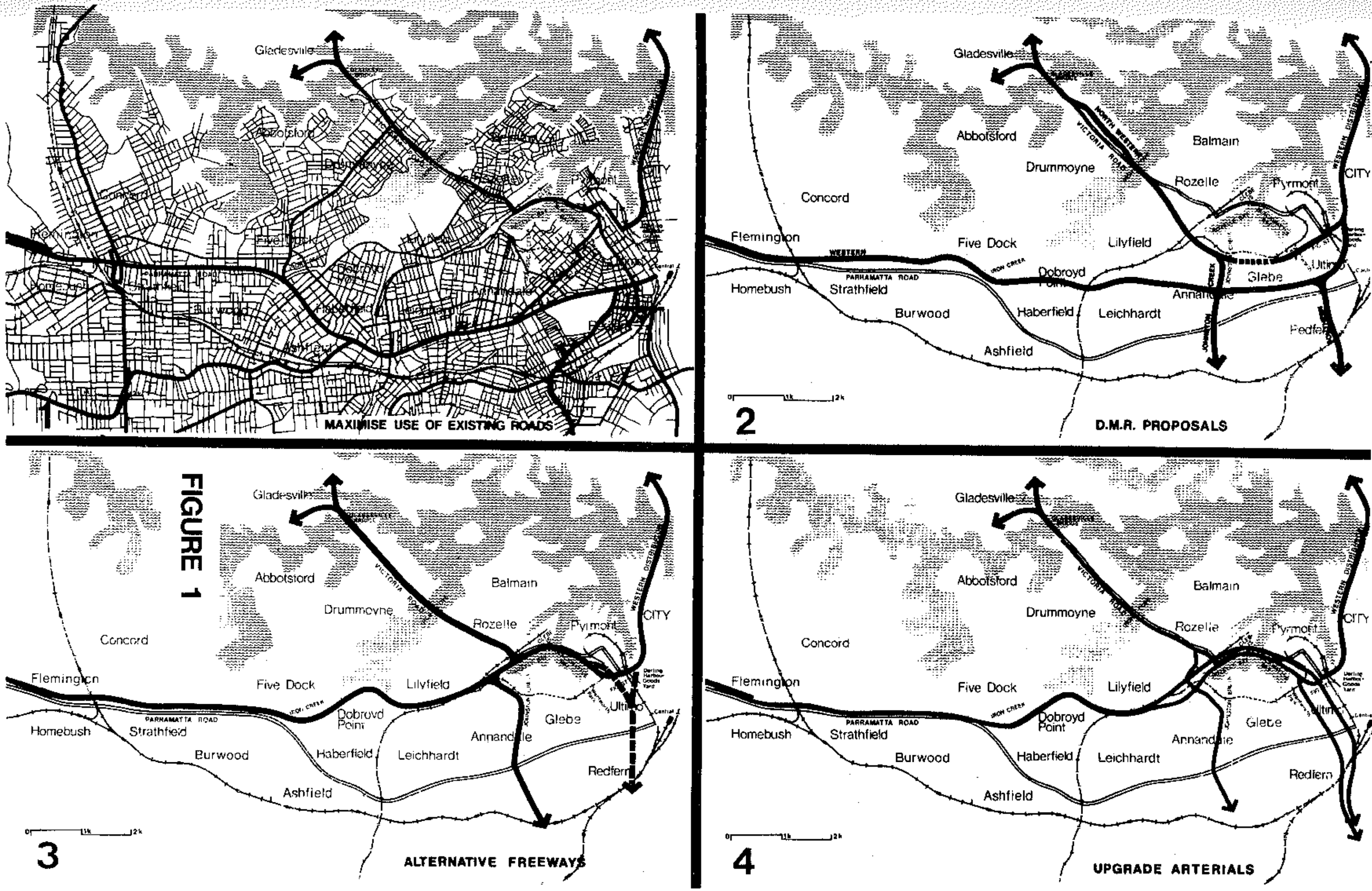
1
MAXIMISE USE OF EXISTING ROADS
Gladesville
2
D.M.R. PROPOSALS
Gladesville
Abbotsford
Balmain
Drummoyne
Concord
Rozelle
Pyrmont
CITY
Flemington
Five Dock
Lilyfield
Dobroyd Point
Glebe
Ultimo
Homebush
Strathfield
Annandale
Burwood
Haberfield
Leichhardt
Redfern
Ashfield
WESTERN
PARRAMATTA ROAD
VICTORIA ROAD
NORTH WESTERN
WESTERN DISTRIBUTOR
3
ALTERNATIVE FREEWAYS
Gladesville
Abbotsford
Balmain
Drummoyne
Rozelle
Pyrmont
CITY
Concord
Flemington
Five Dock
Lilyfield
Dobroyd Point
Glebe
Ultimo
Homebush
Strathfield
Annandale
Burwood
Haberfield
Leichhardt
Redfern
Ashfield
PARRAMATTA ROAD
VICTORIA ROAD
WESTERN DISTRIBUTOR
4
UPGRADE ARTERIALS
Gladesville
Abbotsford
Balmain
Drummoyne
Rozelle
Pyrmont
CITY
Concord
Flemington
Five Dock
Lilyfield
Dobroyd Point
Glebe
Ultimo
Homebush
Strathfield
Annandale
Burwood
Haberfield
Leichhardt
Redfern
Ashfield
PARRAMATTA ROAD
VICTORIA ROAD
WESTERN DISTRIBUTOR

FIGURE 1

It is now possible to define those elements of design standards in which we are particularly interested and these are set out below: -

(a)	Width Related	(i)	lane width
		(ii)	median width
		(iii)	shoulder width
		(iv)	batter clearance
		(v)	cut and fill batter slopes
		(vi)	clearance to structure
(b)	Horizontal Alignment	(i)	speed
		(ii)	minimum radius for horizontal curves
(c)	Vertical Alignment	(i)	grade
		(ii)	vertical curves

2.1 EXISTING STANDARDS

The currently accepted design standards for freeways vary somewhat from state to state but are probably best summarised in the "Guide Policy for Geometric Design of Freeways and Expressways" published by NAASRA (2).

In Section 2 of this document which relates to urban situations NAASRA recognises the special problems of inner urban areas by defining separate standards for inner urban and suburban areas, with inner urban standards being generally lower, although it is indicated that the desirable minimum is in fact the suburban standard.

Table 1 sets down the NAASRA standards for the various elements.

2.2 REDUCTION OF RESERVE WIDTH

The width of a typical inner urban freeway is defined by NAASRA (2) in Figure 2.

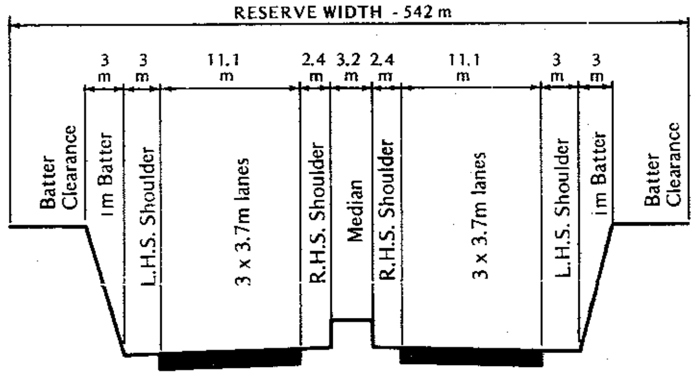

FIGURE 2 NAASRA MINIMUM INNER URBAN FREEWAY CROSS-SECTION

TABLE 1.

NAASRA DESIGN STANDARDS

			Inner Urban	Suburban
WIDTH RELATED				
Lane Width			3.7 m	3.7 m
Median Width	- Minimum	- 4 lane	5.6 m	5.6 m
		- 6-8 lane	3.2 m	3.2 m
	- Desirable Minimum	- 4 lane	8.6 m	12.6 m
		- 6-8 lane	6.2 m	10.2 m
Shoulder Width	- L.H.S.	- 4 lane	3 m	3 m
		- 6-8 lane	3 m	3 m
	- R.H.S.	- 4 lane	1.2 m	1.2 m
		- 6-8 lane	2.4 m	2.4 m
Batter Clearance			6 m	9 m
Cut and Fill Batter Slopes			3 to 1	3 to 1
Clearance to Structures			1.5 m	1.5 m
HORIZONTAL ALIGNMENT				
Speed Minimum			80 km/h	100 km/h
Radius Minimum (Horizontal Curves)			300 m	450 m
VERTICAL ALIGNMENT				
Grade	- Desirable Maximum		3%	3%
	- Maximum		6%	6%
Vertical Curves	- Crests		As per NAASRA "Rural Roads"	
	- Sags		Max Vertical acceleration of 0.5 g	

2.3 REDUCTION IN HORIZONTAL ALIGNMENT STANDARDS

When considering design speed it must be remembered that vehicles do not necessarily travel at or below the statutory speed limit. A study (3) in Melbourne showed that where the statutory limit was 35 mph the 98th percentile speed was 45 mph. Thus where a posted speed limit if 60 km/h it is desirable to use a design speed of 80 km/h, which is that proposed by NAASRA (2) for inner urban freeways.

The design speed is important in determining the minimum radius of curve that may be used. The NAASRA standards (2) define a minimum radius of 300 m, consideration of Table 4 "Minimum Curve Radii" of the NAASRA Guide Policy For Geometric Design of Major Urban Roads (4), suggests that a minimum superelevation of 2 per cent was assumed. Minimum curve radii may be reduced by either reducing the design speed or increasing the minimum superelevation or both.

If design speed were reduced from 80 km/h to 75 km/h and minimum superelevation increased from 2 to 3 per cent the minimum curve radii would be reduced from 300 metres to about 245 metres, a reduction of 18 per cent, without a major effect on performance. In fact superelevation can be increased as high as 7 per cent, according to NAASRA standards (1) which could theoretically allow curves as tight as 210 metres for a 75 km/h design speed.

2.4 REDUCTION IN VERTICAL ALIGNMENT STANDARDS

NAASRA standards (2) suggest a desirable maximum grade of 3 per cent and a maximum of 6 per cent for urban freeways. If one takes the major urban roads standard (4) then the respective figures would be 4 and 8 per cent which would allow significantly greater sympathy between the road and natural surface.

The length of vertical curves is of less signficance in tailoring a road to the topography, although a reduction in design speed from 80 to 70 km/h reduces the length of vertical curves by about 20 per cent.

Thus to summarise it would appear possible to make substantial and realistic reductions in design standards for urban freeways. It is not proposed that this be adopted in most situations but that it be considered in locations in which maintaining the full standards leads to severe impacts on existing development, such as the densely developed inner urban areas of cities such as Sydney.

3. HOW IS COST AFFECTED?

No attempt is made here to investigate the actual cost savings that may be achieved by reducing design standards as this can be only properly assessed for a particular proposal, however some general conclusions may be drawn.

3.1 EFFECT OF REDUCED WIDTH

Reduction in width affects cost in two ways:-

(a) reduces property requirements

(b) affects construction costs

Section 2.2 considered reductions in width and concluded that it was possible to reduce reserve widths by about 40 per cent In inner urban areas it is generally necessary to resume developed properties which involves property costs in the range of $120-$250 per square metre and sometimes higher. Considering the cross-section discussed in 2.2 the 54.2 metre wide reserve could cost between $6,500,000 and $13,500,000 per kilometre for land resumptions The reduced cross-sections could cost between $3,900,000 and $8,000,000 per kilometre a saving of between $3,600,000 and $5,500,000 per kilometre.

Estimating changes in construction costs are much harder as the savings apply to a variety of different elements including lanes, shoulders, medians and batters The example given in 2.2 had a constructed width of 36.2 metres using NAASRA standards, reduced to 26.1 metres by the measures suggested, a reduction of 28 per cent, as the majority of the savings are in the cheaper elements, only 2.4 metres in the traffic lanes the cost saving will be less than this Account must also be taken of more expensive drainage required by reduced batter clearance, the cost of guard rail on the median and the increased cost of providing steeper batters.

Thus overall it would not be unreasonable to expect that the reduction in width would lead to about a 40 per cent reduction in land resumption costs and say 10 to 15 per cent in construction costs Studies (1) of alternative freeway proposals in inner urban areas of Sydney indicated a saving of about 15 per cent in the total cost using lower design standards, however the lower standard freeways in this case employed a somewhat longer route.

4. HOW IS FUNCTION AFFECTED?

In considering the benefits, or otherwise, of reducing design standards for urban freeways it is most important to determine the extent to which the ability of the freeway to perform its function is reduced In this context we have looked at the following aspects of the operation of the freeway:-

(a) capacity

(b) speed

(c) accidents

(d) noise and pollution

4.1 EFFECT UPON CAPACITY

The "Guide to Traffic Engineering Practice" (5) defines the factors affecting capacity with which we are concerned as: -

(a) Lane widths and lateral clearances

(b) Shoulders

(c) Alignment

(d) Grades

(e) Commercial vehicles

LANE WIDTHS AND SHOULDERS

The reduction of lane widths from 3.7 m to 3.3 m width would reduce capacity by 12 to 14 per cent per lane although the left hand shoulder would increase effective width of the left lane to 3.7 metres and if a RHS shoulder were used it would increase that lane to 3.7 metres effective thus the overall reduction would be 3 to 9 per cent.

ALIGNMENT

This has little effect upon capacity but does lead to a reduction in level of service

GRADES AND COMMERCIAL VEHICLES

Grades have little effect upon capacity in terms of private cars but has a significant effect upon commercial vehicles.

The Highway Capacity Manual (6) pp 257-259, indicates that increasing the grade from 6 to 8 per cent would reduce capacity by 10-20 per cent depending upon the number of trucks in the stream

Thus it can be seen that in the extreme case of a long 8% grade on a road carrying a high proportion of trucks with the reduced widths described, the capacity would be reduced to about 75% however this is an extreme case and generally the effect would be less and 8% grades would only be used when essential. It is important to note that lane width reduction and horizontal alignment only reduce capacity by 5 to 10 per cent. Therefore in designing freeways to lower standards particular care would have to be taken when increasing grades.

4.2 EFFECT ON SPEED

Little data is availabe on the effect on speed, however the Highway Capacity Manual (6) (p 294) shows that if a 80 km/h multilane highway operating at a volume to capacity ratio of 0.7 had its capacity reduced by 25 per cent then the operating speed would fall from 55 km/h to 47 km/h a reduction of 15 per cent. however this must once again be considered extreme. In the more normal case when grades are low and capacity is only reduced about 10 per cent the speed reduction would only be from 55 km/h to 52 km/h or 5 per cent.

4.3 EFFECT ON ACCIDENTS

There is little data readily available as to the effect that the reduction in design standards has on accident rates. However a paper by Baker (7) shows in Table 9.4 the representative benefit-cost ratios for various improvements. Of the eleven improvements considered in that paper only four had a ratio less than one and these included road widening and increasing design standards, the cost of these works significantly exceeded the value of reduced accident rates. There is also some evidence to indicate that a reduction in speeds will lead to a reduction in fatal accidents.

Thus we can see that the minimum width of a 6 lane freeway may be expressed as follows: -

Width = 36.2 + [(Depth of Cut x 3) + 6] + [(Depth of Fill x 3) + 6]

Note: if Depth of Cut or Fill is zero then batter clearance of 6 metres is not required

One possible way of reducing width would be as follows: -

(a) Reduce lane width from 3.7 m to 3.3 m (Approx 12 feet to 11 feet)

(b) Reduce median width to 1.0 m and provide a central guard rail

(c) Eliminate RHS shoulders

(d) Reduce LHS shoulders to 2.4 m

(e) Reduce Batter clearance to 1 m, although this will increase drainage costs

(f) Increase batter slope to 2 to 1

Thus reserve width would now be expressed as either: -

Width = 25.6 + [(Depth of Cut x 2) + 1] + [(Depth of Fill x 2) + 1]

For the example shown earlier the reserve width would be reduced from 54.2 metres (178 feet) to 31.6 metres (104 feet) assuming a 1 metre cut fill on each side

Thus whilst it may be unrealistic to impose all of the possible reductions it is apparent that a major reduction may be achieved. Below is set out the impact of the individual reductions on the hypothetical cross-section: -

	Width of NAASRA cross-section	54.2 m	100%
Reduction due to			
(a)	Reduced lane width	2.4 m	4.4%
(b)	Reduced median width	2.2 m	4.1%
(c)	Eliminate RHS shoulder	4.8 m	8.9%
(d)	Reduced LHS shoulder width	1.2 m	2.2%
(e)	Reduced batter clearance	10.0 m	18.5%
(f)	Increase batter slope	2.0 m	3.7%
	Total	22.6 m	41.8%

The savings in width are most sensitive to reduced batter clearance, nearly half the saving and the elimination of the RHS shoulder, about one-fifth of the total saving, other elements each provide about one-tenth of the saving.

If only reduced batter clearance and elimination of RHS shoulder were adopted reserve widths would be reduced by about 15 metres saving about 1.5 hectares of land for each kilometre of freeway, a major cost saving as well as a significant reduction in impact, although this must be balanced against increased drainage costs.

scale and compatible with container terminals, railway yards and grain silos.

(b) Residential Land Take: The area of residential land reserved for DMR purposes in the most recent planning schemes available was accurately measured. The geometry of the proposed alternatives was not considered in the same detail as the DMR's proposals. However, reasonable assumptions were made and reservations for the alternatives were also measured.

(c) Commercial, Industrial, Port and Railway Landtake: This was measured as above. It will be noticed that there is a significant difference between the total landtake of the DMR's alignment and the alternative freeway alignment. This is because the alternative alignment uses large areas of railway land and of the public land which surrounds a number of port installations (e.g. Grain Elevators Board, Seatainers etc.). Where such land is clearly "left over" around major existing structures, or, where the proposed facility is on structure and the space beneath it can continue to be used, e.g. over railway lines, the landtake has not been included, as it does not represent an acquisition cost nor does it impair the use of the land for its existing public purposes. The construction cost of an expressway on structure is, however, included in the comparative capital cost figures. It will be noted that the DMR alignment includes significant structures across Wentworth Park and Harold Park and a tunnel under Glebe, whereas the alternative alignment includes a major bridge over Blackwattle Bay and structures in Glebe Island and over the Lilyfield Railway track and Yards.

(d) Open Space and Land Used for Educational Purposes: Relatively little education land is affected by any of the proposals, but reduction of community open space is particularly significant in the Leichhardt Municipality. The comparison of alternatives within Leichhardt Municipality is:

Alternative 2 :	6 ha
Alternative 3 :	4 ha
Alternative 4 :	1 ha of open space taken

(e) Houses Demolished: These were counted as carefully as possible. It is worth noting that the figure of 2,670 houses for the DMR alignments would have severe effects in some locations i.e. of reducing the population of the suburbs of Annandale by over 17%, Glebe by over 9% and Lilyfield/Rozelle (west of Victoria Road) by almost 10%. All of the alternatives would substantially reduce this impact.

(f) Impact on Local Community: The factors which were taken into account in ranking the degree of community affectation include items, a, b, d and e above, but also include measurement of noise affectation and an assessment of the extent to which communities would be physically divided by new road alignments. The noise affectation of residential areas was measured for each alternative.

(g) Level of Service: Each of the schemes was considered from the point of view of the capacity and level of service provided as an increment to the capacity and level of service to the existing system. The existing system was taken as zero and the capacity/level of service rating of the full DMR proposal as 1. The principal difference between the DMR proposal and the alternative freeway proposal lies in the capacity constraint which would result from the elimination of the Ultimo interchange and the combining of the North Western and Western Freeways through Pyrmont.

(h) Capital Costs: It was not possible within the scope of the studies to estimate actual construction costs. Instead a comparison of the lengths of different types of construction in each alternative was undertaken and a weighted total length was estimated. A comparison of these weighted lengths gave us the likely relative construction costs of each alternative.

Acquisition costs were assessed using average prices per house for residential properties, and an average price for commercial and industrial land (based on information obtained from local estate agents and checked against V.G. values). No acquisition cost was included for government owned land.

4.4 EFFECTS ON NOISE AND POLLUTION

It is generally accepted that decreases in speed and increases in traffic congestion will lead to increased noise and pollution, however, it is important to remember that the principal objective of considering reductions in design standards was to facilitate the location of freeways away from environmentally sensitive areas. Also this increase will only occur at times of significant congestion At times of free flow the generally slower speeds will lead to less noise and pollution. Further the introduction of a freeway, to any standard, should reduce noise and pollution levels in existing overloaded streets.

5. HOW IS IMPACT AFFECTED?

Two principal characteristics of a reduced standard primary road tend to lower its social and environmental impact These are that -

1. It will be smaller

Widths, areas affected by cut and fill and structures and the space required for intersections will all be less than for a NAASRA standard of freeway

2. Route selection will be more flexible

Smaller radii and steeper gradients will allow a greater range of choice of route. This would seem to be so both at the route selection scale and at the detail design scale.

Consider the ways in which the added flexibility in route selection and the smaller scale of reduced standard facilities appeared to reduce adverse impacts in the inner western and northwestern sections of Sydney's proposed freeway system, mentioned earlier, and illustrated on Figure 1.

The measurements of the characteristics of Schemes 2, 3 and 4 on Figure 3 illustrate the progressive reduction in impact made possible by adopting reduced road design standards.

Scheme 1 is essentially a 'do nothing' alternative. It was assessed for purposes of comparisons.

Scheme 2 is a NAASRA standard freeway system.

Scheme 3 is a freeway system in which slight reductions in radii and interchange design have been accepted.

Scheme 4 combines the upgrading of existing roads and the construction of new facilities to establish a high capacity system with design standards which are reduced as the system user approaches the city centre - from high standard freeway to expressway standard.

As the purpose of the investigation was principally to illustrate that there are alternatives that justify detailed examination, a high degree of accuracy for the study was not required and was not claimed.

More accurate costs will, we hope, be placed on each of the factors that can be measured in money terms as the result of further detailed study. The relative values of each of the subjective factors i.e. how important and to what degree are the communities affected? Is the existing landform worth preserving? How much money should be spent on increasing vehicular mobility? Can only be assessed as the result of debate within the community.

The following summarises the basis on which each of the factors was assessed.

(a) Topography and Townscape: A measure of the <u>degree of change</u> to the physical environment - landform and buildings. To some extent this assessment is subjective but it was the study team's opinion that the existing topography and townscape had a positive value. Major engineering structures are out of scale in residential areas, on the other hand they are in

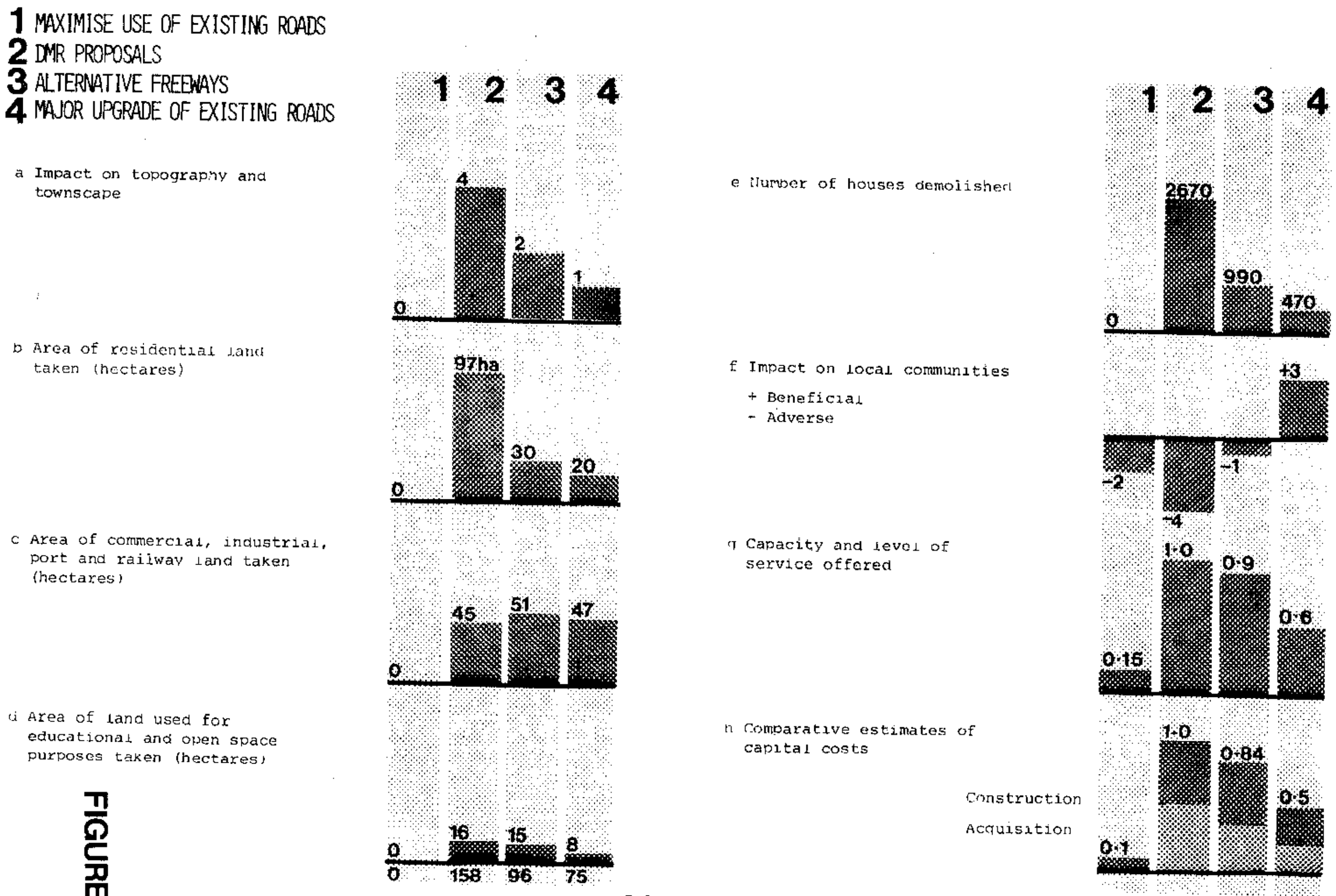

FIGURE 3

COMPARISON OF ALTERNATIVES
(SEE NOTES OPPOSITE)

To provide a basis of comparison of total capital costs i.e. acquisition plus construction, it was assumed that in normal freeway construction the cost of acquisition and the cost of construction would be approximately equal.

The results of these calculations suggest that alternative alignment for a freeway, although offering a slightly lower level of service could be significantly cheaper

6. SUMMARY

The relationship between topography, main transport routes and activities in a big city is a complex one. Existing patterns are frequently far from ideal for the needs of a city that has grown signficantly but this does not mean that they should or can be ignored.

In the case study discussed here some reduction in design standards allowed consideration of alternative corridors which eliminated large scale structures across three valleys with cuts into the densely populated ridges between them. The alternative placed large scale structures adjacent to an existing railway line, a container terminal, grain silos and large scale industrial buildings. The alternative route also avoided the destruction of a number of buildings and areas of townscape which are recognized as having social and aesthetic value. The acceptance of reduced road design standards opened the opportunity to examine the feasibility of using corridors which were already tolerant to the effects of heavy traffic and were already acting as pronounced barriers between existing residential communities. In using the alternative corridors, major alterations to existing movement patterns were also minimized.

An initial assessment of the alternatives, based on a comparison of lane lengths on various classes of construction, i.e. on grade, cut, structure, tunnel or bridge, suggested that the differences between them in construction cost were not significant.

The potential effects of reducing design standards for proposed freeways can be summarised as follows:-

(a) Increased flexibility of route selection which can result in significant reductions in social and environmental costs.

(b) Capital costs are reduced.

(c) Capacity is reduced - but not necessarily in direct proportion to the capital and social cost savings.

(d) travel times on the system are increased.

(e) The accident rate is increased, although fatalities may not be.

(f) The ability to stage develop is increased.

Overriding all the above considerations however is the fact that Australian society seems very unlikely to be able to afford a very high standard freeway system - even it it were desirable. The adoption of a lower standard would seem to make the building of major improvements to inner city roads more likely to happen and hence reduce present costly congestion and accident rates even if not to the maximum extent possible.

Arising from these considerations, the study team formed the opinion that in the design of a future networks, not only should forecasts of both medium and long term travel demand be prepared, but that the implications of satisfying or suppressing that demand should be defined and analysed. The implications of providing varying levels of service should be investigated and a level chosen which is consistent with community aspirations and cost constraints. Finally, the routes chosen should achieve an acceptable compromise between social and direct costs. The standards of design adopted should form part of this overall process and not be seen as the unavoidable 'only way' of doing things.

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