ECONOMIC ASPECTS OF BICYCLE TRANSPORT

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ABSTRACT: *The paper commences with a discussion of the factors which influence the demand for and supply of bicycle trips. This is followed by an assessment of the relative price elasticities of demand and supply for bicycle travel in Australia.*

A short review of the publicly available statistics relevant to bicycles in Australia then concludes that the meaningful information required for bicycle analyses must be collected in specially conducted surveys.

The fourth section of the paper discusses the likely impacts of the implementation of a bikeplan upon the demand for and supply of bicycle and private car trips. These findings are then used to devise a method of break even analysis for evaluating such projects.

The paper concludes with the application of this method to an Example Bikeplan. Statistics for Adelaide are used to clarify the results. However, the Example plan does not represent the proposed Adelaide plan. Adelaide was chosen because of the availability of details regarding public transport subisidies.

INTRODUCTION

In recent years there has been much investment in bicycle systems in Australia. They have been implemented in Canberra and Geelong and either proposed for or adopted in many cities such as Melbourne, Adelaide, parts of Sydney, Newcastle and Maitland.

Compared with other investments in transport infrastructure, the capital and operating costs of bicycle plans are relatively low. The budgets available for prior evaluation of these investments have therefore been commensurately low. The funds necessary to carry out the comprehensive origin - destination surveys, traffic forecasting and assignments that are routinely used as the basis for prior appraisal of investments in other modes have not been available.

The benefits and costs of all transport investment projects include both pecuniary (market valued) and non-pecuniary elements. The latter are either measurable but not directly market valued such as noise, or are intangible, for instance social dislocation. Determinations of shadow prices for the non-pecuniary components of costs and benefits often require detailed econometric analyses and usually intensive data collection. Such exercises are rarely undertaken even for major project appraisals.

Commonsense indicates that bicycle transport involves a greater proportion of non-pecuniary benefits and costs than other modes, a factor which further precludes conventional approaches to the economic evaluation of bicycle schemes.

Low project costs and hence low allocations for bicycle plan evaluation, coupled with the difficulty of evaluation engendered by the relative importance of non-pecuniary benefits and costs therefore characterise the bicycle investment problem. This paper seeks to clarify the economics of bicycle transport, review some available bicycle statistics and describe a method of economic evaluation of bicycle plans devised by the author that has been applied to the Newcastle and Adelaide bicycle plans.

THE MARKET FOR BICYCLE TRIPS

Apart from a minority of trips where bicycles are rented, bicycle trips are wholly both demanded and supplied by one and the same persons. This is in contrast to commercially oriented goods and services where the demand and supply sides of the market are clearly separated. This situation complicates the analysis of of bicycle utilisation but nevertheless, the components of demand and supply are fundamentally the same. In deciding whether to cycle or not, personal income and tastes, etc. are traded off against marginal resource cost combinations in the normally accepted economic sense, and demand - supply analysis therefore clarifies human behaviour.

This situation is also fundamental to both the analysis of say private car transport and home production. The circumstances of these latter two examples are the same as that of bicycle trips, except that for the former, larger proportions of variable costs are market valued.

The demand curve for a good or service at a particular time traces out the quantities that consumers in a market will purchase at different prices, given that all other variables other than prices are constant. If these other variables change, shifts of the whole demand curve will occur. Such variables include the number of consumers, their incomes and wealth, their tastes, the prices of substitute and complementary goods and services, institutional constraints on consumption, improved information to consumers regarding hidden components of price such as risks or welfare spinoffs and income distribution, income taxes and welfare payments.

The supply curve is independent of the demand curve as it indicates the maximum quantity of a good or service that will be supplied by producers at different market prices, other variables remaining constant at any given point in time. The supply curve is established by the long term marginal cost of production of the industry producing the good or service concerned. Factors which cause shifts in the supply curve analogous to those discussed above for demand include changes in the costs of inputs to the relevant productive process, the adoption of new technology in that process, institutional constraints and taxes levied on production, risk and uncertainty about future markets for inputs and output, subsidies and protective measures.

The factors used by transport planners in analysing trip production do not comprehensively cover both sides of the market. Some such as age, education and bicycle ownership are indicators for population, wealth and income and hence represent demand characteristics. Other variables relate to costs through terrain, trip distance etc. and therefore relate to supply. Trip analysis is aimed at predicting points of intersection of demand and supply over time. Although such information is pertinent, it is insufficient to assay social benefits and costs of say a bikeplan. The latter depend primarily upon the level of consumer surplus that will be generated in a number of inter-related markets and involve factors beyond the limited scope of trip production analysis.

Factors Affecting the Demand for Bicycle Trips

The number of bicycle trips that will be demanded at any point of time in the market depends upon the number of consumers, their incomes and wealth, their tastes, the prices of substitute and complementary goods and services, pertinent institutional market constraints, welfare spinoffs and differences between perceptions and actual prices (costs).

Numbers of Potential Consumers

The number of potential consumers clearly is the number of persons who can ride a bicycle who also have access to one. Age is obviously an important determinant of this variable since the young and very old are physically incapable of riding a bike.

Population projections for Australia indicate an ageing distribution which will tend to reduce the number of potential consumers. Alternatively household size is diminishing and if the number of bicycles per household remains constant, bicycle access per person will tend to rise.

Bicycle ridership can be expected to be closely correlated to bicycle ownership and hence ownership statistics would be a good proxy for this variable. However, they are rarely available.

Consumer's income and wealth

Wealth and income are closely related. A major feature of bicycle ridership in the past has been that as real incomes rose, demand for cycling fell. More recently however, cycling has undergone rejuvenation even though average real disposable incomes have been rising. This renewed popularity is attributed to increased leisure, a greater consciousness of personal health and the environment, and markedly increased costs of motor vehicle ownership which tend to reduce real income levels. Some of the latter costs are non pecuniary in that they are associated with, say, increased traffic congestion. Increased leisure, and consciousness of health and environment are most often related to higher education and hence would be positively correlated with higher levels of income and wealth. This implies, that for some market segments at least, cycling has become a "normal good" ie. as real incomes rise, consumption of cycling also rises.

The historically reverse relationship to that cited above, ie. as real incomes rose cycling decreased, is exemplified by the fourth factor which indicates that cycling is being used to maintain incomes as vehicle costs rise. The latter behaviour is characteristic of an "inferior good" which is a technical economic term that does not imply that cycling is of lower quality than other means of transport in any sense. It solely refers to the response to falling real incomes of some individuals.

Consumer's tastes

Part of the increase in cycling in developed countries that is attributable to the "normal good" segment of the market in particular, largely arises from changes in consumer tastes. There are a number of reasons for such shifts in preferences. Undoubtedly one important reason is improved information concerning personal health and the environment and the contributions that cycling can make in these directions. Another is fashion effects which are indicated by the high rate of upsurge in demand. The latter are usually not long lived but create short run shifts of the demand curve. The educational and encouragement aspects of a Bikeplan are aimed at changing tastes towards cycling. If successful, they will engender long term changes of tastes. The extent of fashion effects will only become apparent over time. Cycling also provides a great deal of recreational enjoyment (amenity) to many as evidenced by its adoption as a leisure activity.

Prices of substitutes and complements

As the prices of substitutes for bicycle travel rise, consumers would be expected to substitute cycling for other forms of transport in an attempt to somewhat maintain their purchases of other goods as mentioned above in the discussion of income and wealth. The costs of making any journey include components such as time, relative discomfort and exertion, risks of losses through accidental injury, damage to property, theft and unreliability, social costs such as impacts upon road conjestion, pollution, and regulatory and enforcement costs.

Walking and other land transport are clearly substitutes for cycling. In its futuristic publications, Telecom has made much of telecommunications technology as a substitute for transport in the future. However, those publications have been criticized by behavioural scientists. Nevertheless, for children and students with low values of time and limited budgets, bicyle trips may be substitutes for telephone calls.

The relative costs of many of the substitutes for cycling are clouded by misconceptions of consumers and are discussed in detail below.

Goods and services that are complementary to cycling are limited and low cost. They include protective clothing and bicycle accessories. In theory, price rises of these goods will suppress the demand for cycling but, in practice, such effects are imperceptible as they involve a very small proportion of personal budgets.

Institutional market constraints

A few regulatory constraints on cyclists such as the requirement for lights and reflectors have virtually no impact upon demand as they involve very low costs. However, limitations upon motor vehicle usage by those under 18 years of age (and adults convicted of road offences who have had their driving licences withdrawn) do effect the demand for cycling.

Welfare spinoffs

The health enhancement and environmental effects of bicycle riding have been mentioned above as influencing consumer's tastes towards cycling. Such impacts represent welfare spinoffs, their effects being felt in other markets. These spinoffs appear to have had a significant impact upon the demand for cycling in mature economies over the past decade and have been concurrent with a rise in ultruism.

The extent of such spinoffs is very specific to different individuals, terrain and the vagaries of climate. For some individuals in some situations, these spinoffs may be negligible, given that for a significant part of the market, cycling is an inferior good.

In addition to the spinoffs mentioned above, there will also be collective welfare gains to some existing cyclists, arising from their interdependence with others that are similar to those found in the economies of clubs that arise purely because cycling becomes more popular.

A further spinoff is that to the extent cycling reduces passenger car utilization it may also reduce road congestion. However, because bicycles are slow they are capable of suppressing movement of long lines of motor traffic. Such benefits will not be realized unless the increased bicycle traffic is smoothly integrated with, or separated from, other vehicles. Bicycle plans aim to achieve the dual implicit goals of both reducing traffic congestion and the operating costs of all vehicles.

Differences between perceptions and actual costs

Many of the factors mentioned above such as consumers' tastes and welfare spinoffs are intangible. Others are measurable but not market valued, and shadow prices can be estimated only at considerable cost after intensive data collection and analysis. It is not surprising therefore, that travellers usually do not perceive many of the costs and benefits that arise from trips.

The absolute size of the health benefit appears to be over-estimated by many bicycle protagonists. The case for health benefits largely rests on the impact cycling can have on cardiovascular disease. Youths are naturally healthier and typically engage in more vigorous activities than other sections of any community and therefore are less in need of cycling as a source of prophylactic exercise than older persons.

The 1978 survey of cycle paths and lanes in Canberra found that about 40 percent of cyclists were over 26 years of age. (GHD Parsons Brinckerhoff Pty. Ltd.). Proportions over 35 years old ranged around 15 to 20 percent. However, users in this latter age group equalled a maximun of only 409 per day. The number of riders who would benefit from such exercise was therefore an insignificant proportion of the population of Canberra that fell into that age group.

Similarly, the proportion of total person trips undertaken by bicycle in Australian cities is extremely low. A large rate of increase in bicycle utilization could therefore have an imperceptible impact upon motor vehicle usage and overall pollution and other environmental factors. If additional bicycle traffic was not smoothly integrated with other modes, greater congestion and possibly more pollution could arise from trips converted to bicycles.

The possible overemphasis of health and environmental effects of cycling would make that mode more attractive than it would be if riders were better informed.

Misconceptions about the relative costs of other modes also exist. Almost all transport analysts believe that passenger car owners seriously underestimate the costs of running a car since they concentrate on variable items. This behaviour would tend to make cycling less attractive as an alternative to passenger car travel.

Finally, it appears that bicycle riders probably seriously underestimate the costs of cycling itself. Such costs are reviewed in the section on supply factors, but since price (cost) relativities of alternative modes are issues relevant to demand, such misconceptions warrant mention here.

The risk of fatality or serious injury has been demonstrated to be considerably higher for bicycle users than for passengers of other land transport modes by analysis carried out for the Geelong Bikeplan. In Australia such estimates by GHD who have developed a number of bike plans range around five times higher for bicycle users.

If as suggested by some bicycle movement members that accident risks are about equal to those of other modes over equal travel time, this simply shows that the risks of accident are greater for cyclists on a trip by trip basis. In other words, when it takes longer to complete a trip by bicycle than by car, the accident risk component of cost is proportionately greater. This assertion implies that bicycles are safer in congested traffic when they are faster than motor vehicles, which does not ring true.

Factors affecting the supply of bicycle trips

The supply curve for a good or service is given by the long run marginal cost of the producing industry over the relevant range of outputs. In this case, the relevant "firms" in the industry are bicycle riders themselves. A list of items which contribute to the costs of individuals taking bicycle trips is shown below. All items add to long run marginal costs.

- Repairs and maintenance of bicycle (only partly market valued if not done at bicycle shop).*
- Depreciation of bicycle.*
- The state of bicycle technology.
- Travel time.
- Discomfort and exertion.
- Cost of protective clothing.*
- Accident risk and cost.
- Risk and cost of untimeliness due to say, bad weather or traffic conditions.
- Risk of bicycle theft and cost.
- Risk to personal security and cost.
- Interest on Capital invested in bicycle*

Those items which are directly market valued are indicated by an asterisk.

It is obvious that non-pecuniary items, that is those which are not directly market valued, dominate the list. Of these travel time, accident risk and cost, risk of bicycle theft and cost, and risk to personal security can be measured in some way.

The slopes of the demand for and supply of bicycle trips in Australia

As mentioned earlier, the demand for bicycle travel now appears to be made up of two market segments. For the first, consumers regard bicycle travel as a "normal good" and increase their consumption along with wealth and income. Increased leisure time through higher incomes making work less of a necessity is partially used for cycling by this group.

To the other market segment which is the largest despite recent trends, cycling is a means of mobility either because of low incomes, age constraints on motor car operation or other reasons of necessity. For these people cycling is an "inferior good" in the sense that if their incomes rose or institutional barriers were lifted, they would use bicycles less and other forms of passenger transport more.

The bicycle movements state that there has been an upsurge in the popularity of bicycle travel in Australia in recent years. An attempted mail in survey of bicycle retailers conducted over 30 outlets in Adelaide only attracted 3 responses and is insufficient to base firm conclusions upon. The results cannot be published in this report for reasons of confidentiality, but although total bicycle sales do not show a significant trend, it appears that there has been a definite change in market structure if BMX models are taken out. The figures indicate that sales of juvenile bicycles have fallen since 1976 while adult cycle sales have constantly increased and show a strong upward growth trend. This limited information is concurrent with the involvement of the bicycle movement and agrees with their statements concerning the increase in trip demand by adults at least.

The upsurge in the popularity of bicycle travel promulgated by the bicycle movements can be viewed at the extremes in two ways. Either an inelastic demand curve has been moving relatively rapidly to the right across a fairly stable elastic supply curve, or shifts in supply have caused movements along a stable elastic demand curve. Either way the growth in utilization is the same, as shown in Figures 1a and 1b, actual price (cost) levels are not observable because of the dominance of the supply curve by non pecuniary factors.

The demand curve for cycle trips is made up of two components. The inferior good segment would have an inelastic demand curve because of the necessity aspect of cycling to the young and adults with low incomes. The dedication shown by higher income devotees to cycling also indicates an inelastic demand curve for part of the "normal good" segment. These phenomena would be tempered by an elastic component of demand composed of leisure and "fashion" cyclists. Nevertheless, since the latter constitute a minority, the demand for cycle trips can be considered to be basically inelastic.

On the other hand the supply curve of cycling trips is considered to be relatively stable and elastic. Although the real marginal costs or some aspects have diminished in real terms over the years,(1) other costs, especially those associated with accident, discomfort and risk have decidely risen because of both increased road congestion and street crime, to offset pecuniary cost reduction effects upon the supply curve. The supply curve for cycle

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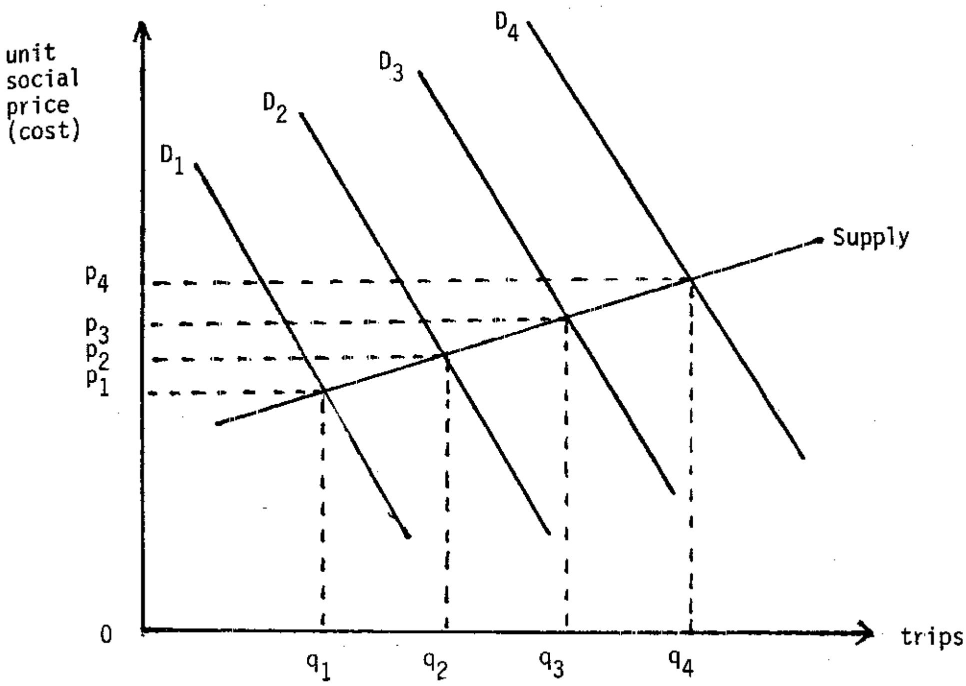
1. For instance the nominal cost of a ten speed bicycle is approximately the same as it was 20 years ago.

Figure 1. Possible Bicycle Trip Market Phenomena Over Time

(a) Demand caused popularity.



(b) Supply caused popularity.

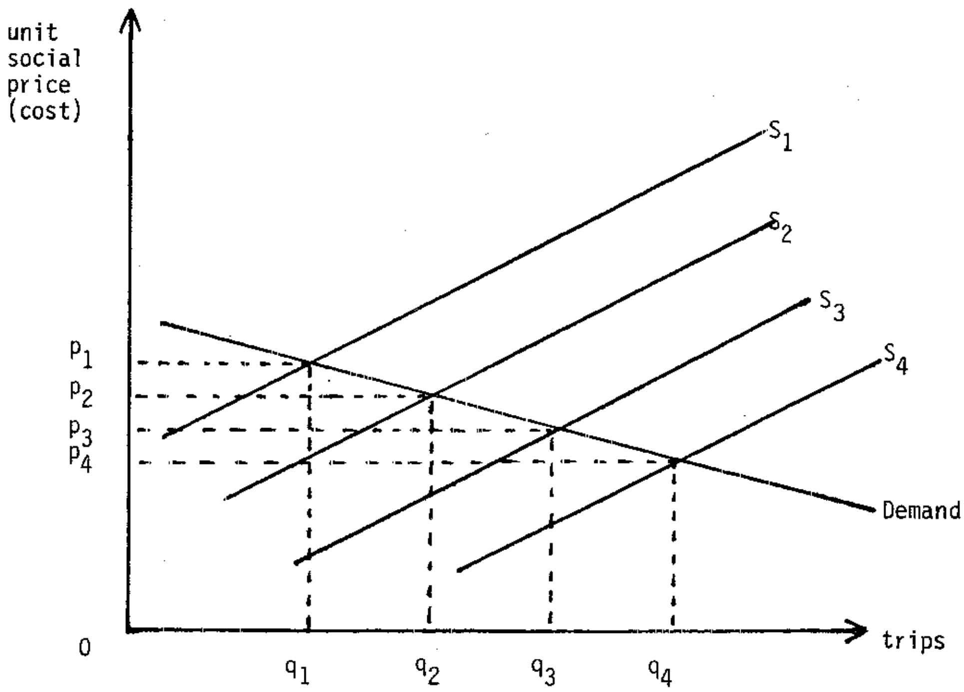
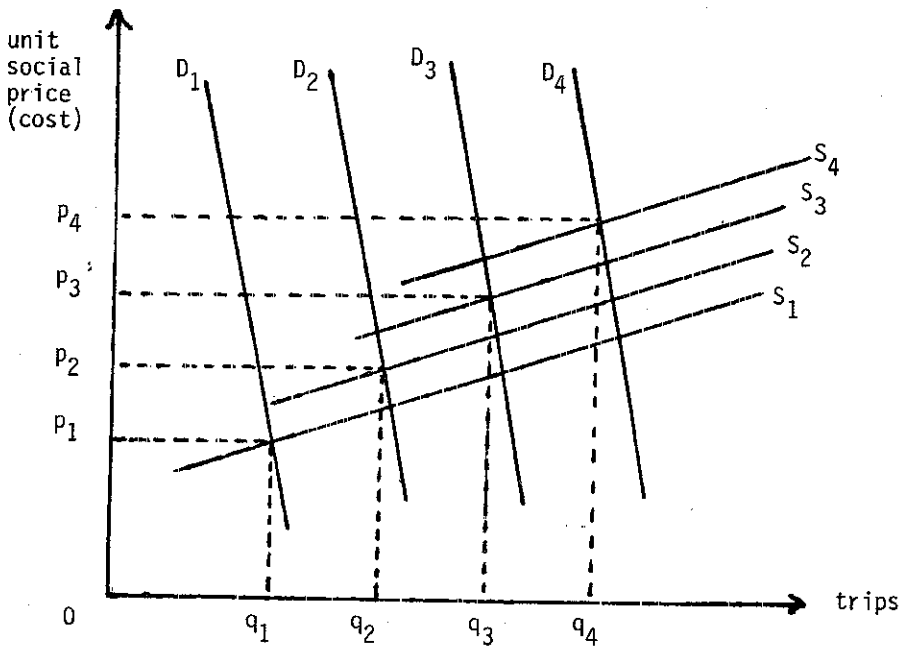


Figure 2. Postulated Bicycle Trip Market Phenomena Over Time



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trips has therefore probably been moving to the left ie cycling has become more expensive in real terms over time or alternatively has at least been stable. Given that the demand curve is inelastic and has been moving to the right while the supply curve has either been stable or moving to the left and the equilibrium level of trips has been increasing over time, simple geometry indicates that the supply curve must be elastic. This postulated situation is demonstrated by Figure 2.

BICYCLE STATISTICS

Detailed statistics comparable to those available for motor vehicles and passengers on public transport are not available for bicycle usage. Furthermore, the two series that are at least partially relevant have serious deficiencies.

Figures concerning bicycle imports and exports are not indicative of increases to the stock of bicydes because of the exclusion of domestically produced vehicles. Recent press reports of domestic production being either shut down or moved overseas, may make this criticism less warranted in the future.

The road accident statistics that are collected by the State traffic authorities are detailed concerning the accidents themselves, but apart from fatalities, they generally do not distinguish between totally, partially or non capacitating outcomes and hospitalisation requirements. Hence these statistics are largely incomplete for assessing bicycle accident costs.

Consequently, meaningful information regarding bicycle users behaviour and market forces must necessarily be collected in specially conducted surveys.

It must be emphasized that climate, terrain, risk factors, age and income distribution considerably affect bicycle usage. Adelaide which is relatively warm and flat, inner Sydney which is highly congested and hilly, Darwin which is extremely hot, humid and very wet for a large part of every year, and Canberra which can be extremely cold in the winter, can all be expected to have significantly different absolute levels and seasonal patterns of bicycle utilisation. Under these circumstances, the results of surveys carried out in other cities cannot be applied to a bicycle problem in another location without considerable circumspection. This situation is exacerbated if overseas information is assumed for an Australian situation. As well as geographical factors, cultural and economic differences can be pronounced. Unfortunately the funds necessary to collect local data are generally limited for the reasons mentioned in the introduction to this paper.

LIKELY ECONOMIC IMPACTS OF A BIKEPLAN

In loose terms, consumer surplus is that amount above market price (cost) that consumers would be prepared to pay to achieve a certain level of consumption if they were levied individually. For a market situation, consumer surplus is equal to the area under the compensated demand curve above the price (cost) line.

It is usual for demand curves to embrace both income and substitution effects, that is they are determined at fixed aggregate money income. For the exact calculation of consumer surplus however, the compensated i.e. pure substitution effect or constant aggregate real income demand curve should be used. However, in most cases, the error caused by assuming that the income effect is zero and using the ordinary or "Marshallian" demand curve is very small. In most economic evaluations therefore the ordinary demand curve is used.

The question of the importance of the income effect in the demand for bicycle trips in Australia is discussed in the Appendix to this paper and the likely error is found to be insignificant.

For this reason, the balance of this paper ignores the compensated demand curve for cycling.

In the economic evaluation of projects, the change in consumer surplus in each time period (usually a year) over an appropriate time horizon is first estimated. This stream of benefits is then compared with an equivalent stream of project costs to assess the economic viability of the proposition. It is normal to discount both streams to account for the reduced value of income and expenditure at some time in the future compared with immediate consumption or savings. Allowance is not made for inflation in economic evaluations unless differential rates are expected to apply to different benefit or cost items. Furthermore, the discount rate may not be directly related to market interest rates as it represents time preference for consumption.

Three main criteria are usually calculated from the discounted streams. These are the benefit-cost ratio, the net present value and the internal rate of return. In this paper only the benefit-cost ratio is used and then <u>only</u> in a conceptual sense, because of data deficiencies and the demand and supply curves being affected by so many immeasurable factors that consumer surplus was indeterminable.

Future Effects of a Bikeplan on Demand Factors

- Number of potential consumers. There will be no effects of the scheme upon this factor unless households without bicycles acquire them because of the scheme. Such actions will shift the demand curve to the right.

- Consumers' real incomes. A very small effect will arise from the impact of savings made in switching from say private cars to bicycles upon real disposable incomes. This will shift demand to the right but is not strictly relevant to the calculation of consumer surplus.

- Consumers' tastes. Depending upon the relative success of the encouragement aspects of the Plan, changes in this variable will shift the demand curve to the right, as the plan incorporates encouragement programs aimed at changing tastes towards cycling and away from other modes.

- Prices of Substitutes. These will only change because of spillover effects. To the extent that the plan reduces traffic congestion and the costs of operating (say) private motor vehicles, the cost of substitute forms of transport will fall resulting in some shift of the demand curve to the left, ceteris paribus. However, cycling is a minor mode relative to motor vehicles and hence, significant unit cost reductions in say private vehicle operation (as compared with bicycle operation) will be difficult to achieve. This effect is therefore adjudged to be imperceptable on a unit cost basis, although in aggregate, relative to the cost of the Bikeplan, it could be significant. For instance, a saving of 0.01 cents per private car km would not shift the demand curve for cycling significantly but at a total of say only 5 million kilometres travelled per day, that saving would amount to $18.25 million per annum.

- Prices of Complements. Cycling accessory prices etc., are not expected to change as a result of the Plan. Hence the effect of this factor upon demand is expected to be neutral.

- Institutional Constraints. The plan is not expected to have any effect upon institutional constraints per se. However, enforcement effects will be significant on the supply side of the market.

- Welfare Spinoffs. To the extent that bicycle utilization increases as a result of the implementation of the plan, health, environmental, recreational amenity and collective welfare gains from "club effects" are all likely to increase causing a shift to the right of the demand curve. Likely impacts upon the cycling demand curve from spinoffs in the motor vehicle trip market have been discussed above.

- Perceptions of Costs. The promotional aspects of the Bikeplan are aimed at making consumers more aware of cycling as an alternative means of transport, the lower costs of cycling generally, and the specific cost advantages provided by the Plan. These efforts will change tastes and perceptions in such a way as to shift the demand curve for cycling to the right.

None of the factors listed above are expected to have significant impacts upon the demand for cycling that will shift the demand curve to the left. Hence, the Bikeplan can be expected to have the net effect of shifting demand out to the right. Such movement will tend to enhance consumer surplus and thereby create social benefits depending upon the direction and extent of likely shifts of the supply curve.

Future Effects of a Bikeplan on Supply Factors

As in the case of demand, the effects of the bike plan on supply were established by comparing the project (with) case with the base (without) case. Only effects attributable to the bike plan are discussed.

Bicycle plans aim to have impacts upon surfaces used by bicycle traffic, apprehension, exertion and discomfort, and risk (accident, theft and personal security) that effectively change the notional technology of bicycle trip production. As such, the implementation of a plan can be expected to shift the supply curve for bicycle trips. The following individual factors are relevant:

- Repairs and maintenance of bicycles will be decreased on a per km basis because of improved pavement surfaces.
- Depreciation and interest on capital of bicycles will be decreased because of enhanced bicycle life due to improved pavement surfaces.
- Travel times can be expected to be reduced because of improved pavement surfaces, smooth integration with or separation from other modes on heavily trafficked routes.
- Discomfort exertion and apprehension will be markedly reduced by traffic effects and possible avoidance of say steep grades enabled by construction of new routes.
- Accident risk and cost for existing cyclists will be reduced. However such risks and costs for induced cyclists may be increased if they substitute bike for private car and public transport trips.

Generated trips are in this category compared with walking or staying at home. Hence opposing forces will come into play.

Overall accident reduction despite increased cycling is the main thrust of bicycle plans and hence a net overall reduction is expected from this factor particularly in regard to fatalities and serious injury accidents. The Geelong Bikeplan analysis indicates that this goal can be achieved.

- o Bicycle theft and associated costs are expected to be reduced by the enforcement components of the plan and the provision of proper bicycle parking facilities at major traffic modes.

- o Personal Security Through the enforcement program and concentration of bicycle traffic on designated routes, the plan will enhance safety from personal attack.

All of these factors can be expected to result in changes in the production function for bicycle trips for each potential cyclist utilizing the road network embraced by the plan. These changes will increase the technical efficiency of bicycle trip production and as such, move the supply curve to the right. Such a shift will tend to enhance consumer surplus and may result in gains in social welfare given the nature of interaction between base and project case demand and supply curves.

Unless there are economies of scale in bicycle trip production, the public cost of providing the physical and administrative infrastructure of the bikeplan will tend to shift the supply curve for bicycle trips to the left, ie the opposite direction to the effects listed above. However, these costs are those against which the social benefits, (gains in consumer surplus) must be weighed over time in the notional benefit-cost analysis used later in this paper for economic plan appraisal. Hence this shift is not pertinant to the determination of consumer surplus.

Impacts of the Bikeplan upon the Market for Private Car Trips

The demand for private car trips has been repeatedly demonstrated to be inelastic. Recent high rates of escalation of car operation costs appear to have suppressed growth in vehicle usage in most countries. Nevertheless, the demand for personal mobility in a relatively safe, comfortable private vehicle remains relatively inflexible. The shift towards smaller vehicles in response to higher fuel and vehicle costs is more indicative of attempts to shift along the supply curve by consumers - producers (who are one and the same) rather than movement of the demand curve.

The supply curve for private car trips has traditionally been viewed to be elastic. Historically, variable costs have risen in real terms relative to fixed costs of car ownership and therefore, other things being equal, the supply of private car trips has probably become less elastic over time. However, changes in vehicle technology and a shift towards small vehicles have tended to ameliorate this effect and the assumption of an elastic supply curve still appears to be valid.

Impacts of a bicycle plan upon the private car trip market have been discussed in part previously. These effects include:

- a shift to the left of demand as bicycle trips are substituted for private car trips in response to lower prices (costs) of bicycle operation, enhanced tastes for cycling and greater cycling welfare spinoffs.

- a shift of supply curve to the right to the extent that the plan changes the production function of private car trip production through reduced accident risk and improved vehicle efficiency. Both of these outcomes will result from smooth integration with or separation of bicycle traffic from other modes ameliorating congestion and improving the smoothness of motor vehicle operation.

The effect of converted trips upon the demand for motor vehicle trips will be insignificant, since even if they account for 50 percent of all bicycle trips, the bicycle trip market represents such a small proportion of all person trips that the impact upon demand in the private car trip market will be insignificent and certainly less than the anticipated shift to the right in the bicycle trip market. Furthermore, since the demand for private car trips is inelastic any such effect will be felt through social price (cost) rather than the level of car travel specifically.

Similarly, the impact upon the supply curve for private car trips will also be small. However, as mentioned earlier, a single bicycle can delay long lines of motor traffic and hence, the congestion amelioration effects of the plan, although slight on a per km basis, are expected to be significant in aggregate.

Impacts of the Bikeplan upon other markets

There will be impacts of the plan in numerous other markets such as those for motor vehicle fuels, tyres, health services, etc. and bicycles and bicycle accessories. These effects are not likely to be significant relative to those described above for the bicycle and private car trip markets. They have not been considered in this paper in detail for that reason.

Gains in consumer surplus

The market situation brought about by the implementation of the bikeplan can therefore be represented by that shown in Figure 3. That pertaining to the market for private car trips is shown in Figure 4. In both cases the gain in consumer surplus is identified by the hatched areas. It should be noted that the gain in consumer surplus between the price lines in both cases is brought about by the rightward shift of the supply curve and that the resulting cost saving $(P_b - P_p)$ is less than the marginal cost reduction indicated by the vertical distance between the supply curves. This arises because the demand curve is not perfectly inelastic.

Figure 3. Lik fro

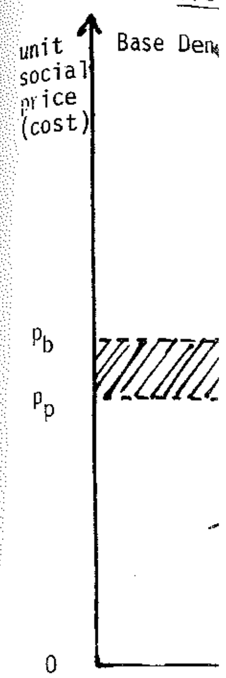


Figure 4.

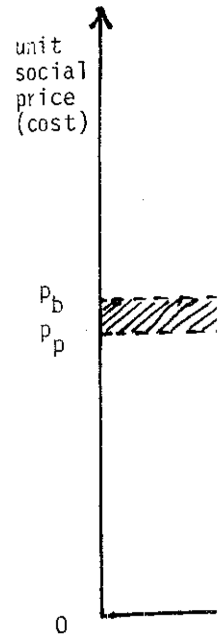


Figure 3. Likely Changes in Consumer Surplus to Cyclists Arising from Bicycle Plans.

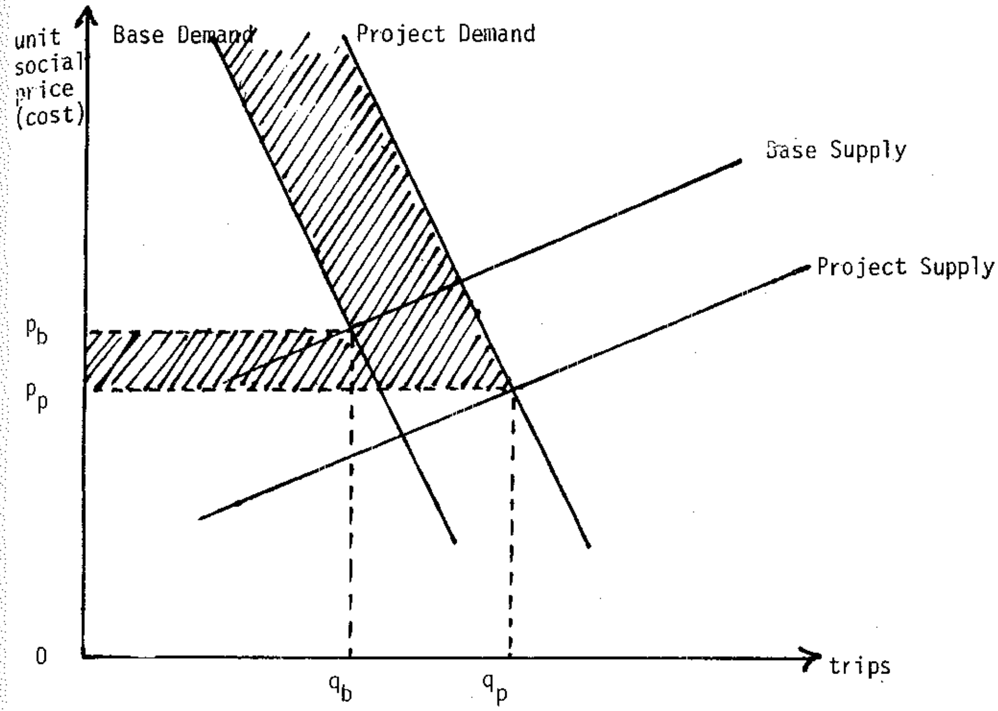
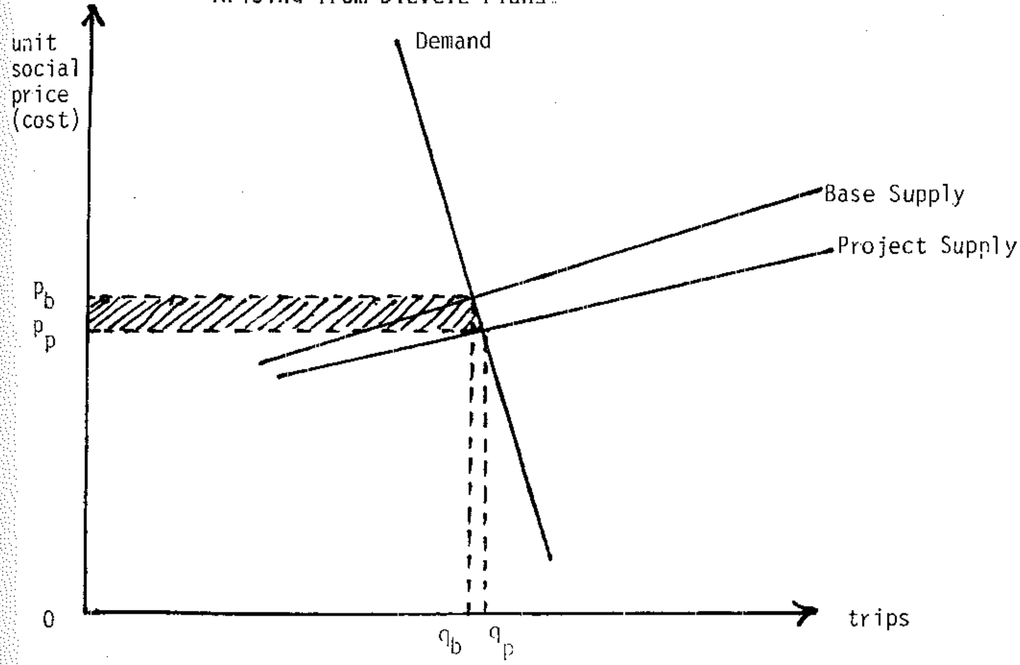


Figure 4. Likely Changes in Consumer Surplus to Private Motorists Arising from Bicycle Plans.



Although it has been demonstrated that the supply curve will shift to the right with the implementation of the Bikeplan (that is it reduces long run marginal costs of bike travel) there would still be a net gain in consumer surplus even if costs with the plan caused the supply curve to shift to the left as long as a substantial shift of the inelastic demand curve occured to the right. (ie as long as patronage or bicycle travel increased markedly). This would occur because the gains between the demand curves would be greater than the losses of consumer surplus between the price lines.

The immeasurability of bikeplan benefits

If the functional form of the four demand and supply curves in both markets were known in every year of the appraisal period, then the calculation of the areas under the demand curves above the price (cost) lines in both markets could be readily undertaken and changes in consumer surplus determined using calculus.

Alternatively, for many propositions in which intangible factors are of minor importance, the intersection points of demand and supply curves can be calculated using pecuniary data. Approximations of the changes in consumer surplus arising in each period are then made using published results which indicate the slopes of demand and supply in the relevant markets. These estimates are then weighed against project cost and the usual criteria calculated. Likely effects of changes in consumer surplus arising from social (intangible) factors are then described and superimposed on the results of the investment analysis. The resultant tradeoffs can then be carried out by policy makers to assess the project's viability and priority.

In bikeplan evaluations the usual systematic procedures described above cannot be carried out for three main reasons. Firstly, the demand for and supply of bicycle trips are largely influenced by non-pecuniary factors, many of which are intangible to the point of being difficult to define let alone measure and value, such as discomfort and amenity.

Secondly, the tangible factors which influence the trip market cannot be measured without expense beyond the budgets available for most bikeplan studies. There is a lack of complete sound data concerning such basic factors as bicycle operating financial costs, up to date trip frequency and origin - destination data. The latter would be especially expensive to collect for non-student riders who could be responsible for major portions of shifts in demand and supply and hence would be important contributors to the benefits flowing from a Bikeplan

A third reason is that even if the measurable data discussed immediately above was readily available, the results of analysis based upon it alone would be so partial as to render the results obtained misleading. This conclusion arises because intangible factors clearly dominate both the demand and supply functions. The economic analysis necessary to place shadow prices upon all of the non-pecuniary effects given an appropriate data base, would probably be as expensive as the Plan itself. The results of such analysis would be subject to statistical and other errors arising from methodological convenience and therefore not absolutely conclusive.

These considerations are summed up by the adage that "perfection has an infinite cost". Hence, experienced subjective judgement based upon briefings on important issues is inevitably viewed to be more efficient by many decision makers than expensive exhaustive and complicated detailed appraisals.

An Alternative Analytical Method

When funds for feasibility studies are limited and data on potential demands and supplies are non existent, a form of breakeven analysis is often employed in Asia. For example it is argued that a transport project would be worthwhile if a certain number of malaria victims could be saved from death through the access afforded to medical and ambulance vehicles. A further example is that an irrigation project is worthwhile if at least a certain additional tonnage of rice could be produced annually.

In such cases, project costs are converted to an annuity over the life of the project, and a selected demand or supply factor is used to determine a "breakeven" level of its contribution to increased consumer surplus. In this form of analysis the slope of the relevant supply and demand curves are crucial, as they have a marked impact on the conclusions. For instance, transport cost savings ie vertical supply curve shifts, only reflect increased consumer surplus, if the demand curve in the relevant trip market is absolutely inelastic. Otherwise, such savings over-estimate social benefits.

The data to hand in Australia will not enable prediction of the extent of the shifts of the cycling demand curves that will occur with the implementation of a bikeplan. Experience in Australia and overseas where proper monitoring has taken place suggests that this could be initially substantial. However, the results are specific to particular cities because of climatic and terrain factors alone as well as more complex socio economic considerations. The shifts in demand for cycling must therefore be taken as given but indeterminant.

The elasticities of the demand and supply curves are postulated above for both the bicycle and private car trip markets along with the direction of shift (if any) of these curves with implementation of the plan, the latter excluding the effects of plan costs from supply. These slopes and shifts indicate gains in consumer surplus in each period which can be weighed against project costs, the implications of which have been shown previously. It should be noted that in both cases the reduction in unit cost brought about by the bikeplan can be expected to be less than the reduction in long run marginal costs that is indicated by the vertical distance between the supply curves.

Figure 3 shows the gain in consumer surplus between the demand curves to be greater than that depicted to arise from the shift in supply. This cannot be substantiated in any way as none of the demand effects outlined previously can be quantified with information to hand. However it is clear that if some supply oriented criterion equals part of the area that represents gains of consumer surplus to base case cyclists or motorists i.e. $(p_b - p_p)\, q_b$, and the value of that partial area exceeds project costs in the period (year) concerned, then the bikeplan is clearly viable in that year.

Hence if the sum of the discounted annual comparable gains in consumer surplus arising from some supply factor exceeds the present value of the project cost streams, the proposition can be considered to be viable on these grounds alone. That is, discounted benefits exceed discounted costs.

It is therefore possible, using the present values of project cost streams to calculate break even points for supply factors that are expected to undergo long run reductions in marginal costs causing shifts of the supply curve to the right. The same procedure can be accomplished by converting the present value of costs to an annuity and calculating break even criteria on an annual average basis. The figures indicate that these criteria are only calculated for base case consumption levels and do not take induced or generated consumption into account. If more than one such criterion is judged to be achievable, the proposition can be considered to be economically viable with surety.

EVALUATION OF AN EXAMPLE BIKEPLAN

The components of supply selected for this break-even form of evaluation of the example bikeplan are discussed below. In accordance with Australian Commonwealth Treasury practice, a rate of 10 percent was applied to discount project costs to 1983 and of course, inflation was not taken into account. The plan was assumed to be implemented over a ten year period and although benefits were expected to be realized beyond that time the plan was evaluated over that horizon. In economic evaluation it is more usual to use a 20 year time horizon.

Project costs

The financial costs of a 4 E's strategy bikeplan are shown in Table 1. The engineering and infrastructure components of the plan were assumed to be in place by 1992 and if properly maintained should not depreciate. Wear and tear is expected to be negligible over this period and hence a complete salvage value of $8m in 1992 was assumed in that year.

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TABLE 1

EXAMPLE BIKEPLAN

PRELIMINARY IMPLEMENTATION AND MAINTANENCE COSTS (1983 PRICES)

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YEAR	ENGINEERING	EDUCATION	ENFORCEMENT	ENCOURAGEMENT	TOTAL COST	TOTAL DISCOUNTED COST (a)
1983	1,500.0	200.0	100.0	100.0	1,900.0	1,900.0
1984	1,500.0	200.0	100.0	100.0	1,900.0	1,727.3
1985	1,500.0	200.0	100.0	100.0	1,900.0	1,570.2
1986	500.0	200.0	100.0	100.0	900.0	676.2
1987	500.0	200.0	100.0	100.0	900.0	614.7
1988	500.0	200.0	100.0	100.0	900.0	558.8
1989	500.0	200.0	100.0	100.0	900.0	508.0
1990	500.0	200.0	100.0	100.0	900.0	461.8
1991	500.0	200.0	100.0	100.0	900.0	419.9
1992	- 7,500.0 (b)	200.0	100.0	100.0	- 7,100.0	- 3,011.1
TOTAL COSTS:	0.0	2,000.0	1,000.0	1,000.0	4,000.0	5,425.8

(a) Discounted at 10 percent.

(b) Includes a salvage value to total engineering of $8,000,000.

The results obtained from this process and annuity determinations were:

- Present Value of Cost Stream. $5,425,800 in 1983 prices in 1983, including, 100 per cent salvage value on engineering works in 1992.
- Annuity Equivalent of Cost Stream. The annuity equivalent of the above present value at 10 per cent interest over a ten year period is $883,024 per annum.

Two supply factors were selected as breakeven criteria because financial estimates of their worth that are readily acceptable could be calculated in a simple fashion. These were serious accident savings to existing bicycle riders, petrol savings to existing passenger car users. The procedures followed are related in turn below:

Serious Accident Saving Criterion

The social costs of the different types of accidents are not known. However, the costs of fatal accidents can be assessed in broad terms by valuing lives. The social costs of serious incapacitation such as quadraplegia are probably higher than those of fatalities as additional costs of care and maintenance are involved. Hence, valuation of life is in a sense a minimum assessment of the social cost of serious bicycle accidents. The valuation of life is a complex question and to date no entirely satisfactory approach has been devised. Nevertheless, the present value of forgone future earnings is often used as a useful proxy.

Average weekly earnings were assumed to rise from $158.50 to $262.10 between 1975-6 and 1980-81. A simple linear trend gave $303.54 in 1982-83. Present values of forgone weekly earnings were calculated using this figure for persons aged 16 (ie with a complete 49 year working life ahead of them) and persons aged 40 (25 years left) at an interest rate of 10 per cent ~~was used~~. The results obtained were:

Age	PV of Future Earnings
16	$171,998
40	$157,600

These values were used as proxies for the social costs of fatal and incapacitating accidents. Previous calculations showed that the costs of the Bikeplan were equivalent to an annuity of $883,024 over a ten year period to 1992. The infrastructure of the Bikeplan will of course continue far beyond that time horizon and therefore, a full salvage value of engineering works was taken into consideration at 1992.

Dividing the annuity by these values of life indicates that 5.1 16 yr. olds or 5.6 40 year olds need to be saved from fatal or incapacitating accidents per annum directly by the implementation of the Bikeplan.

<u>Private Car Petrol Savings Criterion</u>

The current average price of petrol was assumed to be 48 cents per litre. Excise on super grade petrol is 5.155 cents per litre. In line with normal economic practice the excise was excluded as a transfer payment but no adjustment was made for the oil levy which simply ensures that petrol costs are the equivalent of border prices for crude oil. Hence adopting a price of 42.85 cents per litre, the following petrol savings at current prices are necessary as a result of the Bikeplan to make it a breakeven proposition.

$$\frac{\$5,425,000}{0.4285} = 12,662,310 \text{ litres}$$

Converting this figure to an annuity at 10 percent interest yields

2,060,733 litres per annum

Again circumstances in Adelaide were used to clarify this criterion. At 30 June 1981 there were 547,000 cars and station wagons in South Australia and based upon population distribution, some 70 percent of these would have been located in Adelaide. Allowing for some growth to 1983, it was assumed that 400,000 private vehicles fell into this category. At an average fuel consumption of 10 km per litre, a saving equivalent to 51.5 km per vehicle per annum alone, would be necessary to justify the bikeplan. If vehicles travel 12,000 km per annum on average, such savings represent less than ½ percent of annual petrol consumption. Such savings also represent approximately 100 ml of petrol per vehicle per week.

<u>Equity Considerations</u>

The final assessment of the Example Bikeplan must necessarily be carried out subjectively by policy makers. The relevant decision process involves four steps which are:

- subjective assessment of whether the criteria are achieveable or not

- subjective assessment of equity implications

- consideration of budgetary requirements against the availability of funds

- determination of the priority of the bikeplan against all other projects and policy initiatives open to the government concerned

A further criterion was calculated to assist in these deliberations which was termed "Fiscal Requirements Criterion". This can be viewed as either an indicator of the value of the social benefits that must arise from the plan for such benefits to exceed project costs, or as an indicator of the sums redistributed directly to base case cyclists (and indirectly to base case motorists) by implementation of the plan.

The first of these approaches is clearly an efficiency problem while the latter would be regarded by many as an equity consideration. However, the work of Hochman and Rodgers (1969) and Scott (1972) indicates that questions of income distribution are also matters of efficiency, but such considerations are beyond the scope of this paper.

Two measures can be adopted. These are the lump sum subsidy per existing rider necessary to implement the scheme over the 10 year time horizon adopted in this study, or the calculation of the annual subsidy per base case rider over the designated 10 year life of the Bikeplan. If these unit subsidies are low and comparable to those granted to other similar groups, then the scheme may be said to have some justification on social equity grounds alone.

If the bikeplan is implemented, these subsidies could justifiably be used as indicators of the relevant policy decision makers subjective assessment of the minimum social welfare gains arising from the plan.

In carrying out these calculations, potential base case cyclists (1) were assumed to be as follows:

1983	194,000
1987	216,000
1992	249,000

Hence the "lump sum" subsidy equivalent for existing (1983) bicycle riders was estimated to be:

$$\frac{\$5,425,800}{194,000} = \$27.97$$

Similarly using the annuity, the average annual subsidies required per base case rider were:

1983	$4.55
1987	$4.09
1992	$3.55

ie an annual average of about $4.06

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(1) Derived from the number of bicycles per household (Hickling 1978), and the product of population and persons per household.

For the clarification of these fiscal criteria, figures drawn from the Adelaide public transport system were used in a manner which relates solely to equity grounds. In 1979-80, the excess of operating cost over income for the State Transport Authority amounted to $47,499,000 and the average subsidy (Government contribution per passenger journey) on Metropolitan train and bus services was 68 cents. (1) Indexing these forward to 1982-83 assuming that the CPI applies and rose from 285.8 to 371.6, yields $61,932,000 and 88.7 cents respectively.

The population of Adelaide in early 1983 was projected to be 956,000 (2). This implies an annual subsidy of the public transport system of $64.78 per head of population per annum. Hence the "lump sum subsidy (present value) of the bikeplan per potential base year cyclist, is estimated to be less than half the <u>annual</u> subsidy requirement per potential public transport user in 1983.

Alternatively, the annuity per base case cyclist can be used to determine public transport passenger journey subsidy equivalents as follows.

1983	5.1
1987	4.6
1992	4.0

In 1979-80, 73,210,000 passenger journeys were undertaken on Adelaide's public transport system. With an estimated population of about 930,000, this represented almost 80 public transport journeys per potential user per annum.

CONCLUSIONS

The breakeven criteria adopted for this study are based upon intuitive assessments of the relevant demand and supply curves, their component factors and the directions that each of those factors will shift the relevant curves upon bikeplan implementation. The geometry of these considerations is such, that if only one of the serious accident or private vehicle petrol savings criteria are assayed to be achievable, then the plan can be said to have a benefit-cost ratio of at least unity. Since the two efficiency criteria are independent of each other, achievement of both implies a benefit cost ratio of at least two.

In determining these criteria only crude estimates of base case cyclists were used. If base case trips exceed current trends, then these criteria will overestimate breakeven levels in the sense that their denominators will be smaller than they are in reality.

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(1) State Transport Authority, Annual Report 1979-80

(2) Department of Environment and Planning, S.A., 1981

TABLE 2

Summary of Breakeven Policy Indicators
(based on 1983 prices)

Item	Units	Level
EFFICIENCY		
Serious Accident Reductions		
15 year olds	no. per annum	5.1
40 year olds	no. per annum	5.6
Private Car Savings		
Travel reduction equivalent	km vehicle per annum	51.5
Petrol saving equivalent	ml per vehicle per week	100
Total petrol savings	l. per annum	2,061,000
EQUITY		
Fiscal Requirements		
lump sum subsidy	$ per base case cyclist	27.97
average annual subsidy	" " " "	4.06
average annual STA trip subsidy equivalent	trips per annum per base case cyclist	4.6
average STA trips (1979-80)	trips per annum per Adelaide person	79.0

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	Level
	5.1
	5.6
	51.5
ek	100
	2,061,000
st	27.97
	4.06
ase	4.6
	79.0

It must be emphasised that these criteria ignore the extent of shifts of demand curves to the right. The Canberra Survey indicated that trip demand could increase by as much as 50 percent with the implementation of bicycle paths. Furthermore, the analysis only encompasses a minority of supply factors. Achievement of one of the breakeven criteria could therefore indicate a benefit-cost ratio markedly greater than unity.

The Fiscal Requirements criteria indicate that the bicycle plan involves much lower "subsidies" per potential user than the current public transport system. Since these criteria as they are expressed, basically relate to equity and not efficiency, it is a matter for policy makers to determine the extent to which these criteria are relevant to deciding whether or not a bikeplan should be implemented.

Finally, the cost of the plan represents a very minor proportion of any South Australian budget and therefore, funds should be available for implementation without too much difficulty should implementation be recommended. In addition, if properly monitored, the plan will also provide valuable information spinoffs for input into future urban planning and transportation studies.

The results obtained for the policy indicators are shown in Table 2.

CAVEAT

The Example Bikeplan outlined in Table 1 bears no necessary resemblance to the Adelaide proposals. Adelaide data was chosen for reasons of exposition because subsidies for public transport were made explict in the annual reports of the relevant authorities. This practice is enlightened and differs from that followed in most other States.

It must also be emphasized, that the statistical basis for the numbers used to calculate the criteria were essentially "ball park" estimates and do not imply precision. The results are purely illustrative and therefore do not imply that an Adelaide Bikeplan would be economically viable.

In the report on the Newcastle Area Bikeplan, the author treated health spinoffs and recreational amenity as reducing costs rather than contributing to the utility of cyclists. The relegation of these factors from the demand function to the supply side of the bicycle trip market was carried out as a reflection of bicycle movement members attitudes. Since cyclists are both demanders and suppliers of trips, the specification of market functions is largely a matter of perception. Nevertheless, it makes no difference to the outcome of the analysis except relegation to the supply side places more emphasis on the efficiency effects of these variables and less on their equity impacts.

REFERENCES

Department of Environment and Planning, South Australia, "Population Projections 1980 - 2011",November 1981, FMV81-02.

Geelong Bikeplan, "Bicycle Accidents", Technical Bulletin 2, 1980.

GHD Parsons Brinckerhoff Pty. Ltd., "Survey of Canberra Cycle Paths", (for the N.C.D.C.), Planning Brief 78/11, Summary Report, March 1979.

Hickling W.H., "Glenelg Cycling Needs Survey", August 1978.

Hochman H.D. and Rodgers J.D., "Pareto Optimal Redistribution", American Economic Review, LIX (September 1969), pp 542-547.

Scott R.H., " Avarice, Altruism, and Second Party Preferences", The Quarterly Journal of Economics, LXXXVI (February 1972), pp 1-18.

State Transport Authority , "Annual Report, 1979-80", (South Australia)

Traffic Authority of New South Wales, "Newcastle Area Bikeplan", (prepared in conjunction with GHD Parsons Brinkerhoff Pty. Ltd.), October 1981.

APPENDIX - THE IMPORTANCE OF THE INCOME EFFECT IN THE MARKET FOR BICYCLE TRIPS

The gross quantity - price elasticity of demand is postulated to be less than zero and greater than minus one. ie. inelastic.

The budget share spent by cyclists on trips is very low, both in terms of money cost and non-pecuniary inputs. Almost all trips are short relative to those undertaken by other modes.

Although absolute levels of income are importantly related to the level of demand, the marginal impact of income upon bicycle usage is expected to be slight for the following reasons :

- for those to whom cycling is a necessity, ie. the inferior good segment, other factors will preclude substitution of other modes even if marginal increases of real income occur. Such factors are legal prohibitions, the high cost of initially acquiring a motor vehicle, the unsuitability of public transport routes especially for short trips and the high cost of taxis relative to weekly welfare payments.
- for those to whom cycling is a normal good, increases in real income are not likely to lead to increased cycling per se unless they are expressed in part as increased opportunities for leisure time. Given the relative uniformity of work conditions in Australia, the latter are an occasional long term phenomena. Hence, the only opportunities for increased leisure time in the short to medium term are likely to arise from significant reductions in secondary employment.
- since the market segment for which cycling is an inferior good is greater than that for which behavior indicates a normal good, the first derivative of the demand curve with respect to income is expected to be negative, making the income effect positive. However, since the effect is the outcome of two opposing responses, the income elasticity itself is expected to be small.

The Slutski Equation states :

$$e_{ii} = e_{ii}^{*} - k_i \cdot E_i$$

where e_{ii} is the gross quantity - price elasticity of good i ie. $\frac{P_i}{Q_i} \cdot \frac{\delta Q_i}{\delta P_i}$

e_{ii}^{*} is the compensated quantity - price elasticity of good i.

k_i is the budget share spent on good i ie. $\frac{P_i \cdot Q_i}{I}$

E_i is the quantity income elasticity of good i ie. $\frac{I}{Q_i} \cdot \frac{\delta Q_i}{\delta I}$

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substituting in the Slutski Equation the effects postulated above :

$$e_{ii} = e_{ii}^{*} - k_i \cdot E_i$$

$$(\to -1) = (?) - (\to +0) \cdot (\to -0)$$

hence $k_i . E_i$ will be very small and positive.

The compensated elasticity of demand will only be marginally higher than the gross elasticity of demand and the error in using the Marshallian demand curve for calculating consumer surplus will be slight.

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ABSTRACT: