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## THE MULTI-OBJECTIVE APPROACH TO PORT PLANNING: A NEW MIX OF ECONOMIC AND ENVIRONMENTAL ISSUES?

A.S. ATKINS

**ABSTRACT:** *The paper outlines some of the theoretical and policy issues arising from a recent study of some key proposals in the Port of Melbourne 'Forward Development Plan'. The study involves an application of Multiple-objective Planning (MOP) techniques to provide a quantitative evaluation of the intangible factors in environmental studies comparable with the economic evaluation of project impacts. The specific port projects under review are potential road and rail links to the major new container berth complex proposed for Webb Dock, some of which have attracted strong community opposition. The 'MOP' approach is applied to the planning process in order to present a wider range of alternatives to decision makers: in this application the methodology is considered to be an advancement on the next best technique -- namely benefit-cost analysis, supplemented by environmental impact statements.*

THE MULTI-OBJECTIVE APPROACH TO PORT PLANNING:  
A NEW MIX OF ECONOMIC AND ENVIRONMENTAL ISSUES?

Alan Atkins<sup>1</sup>

1. INTRODUCTION

This paper identifies and briefly discusses some methodological and policy issues raised in a study recently undertaken and published by the Centre for Environmental Studies at the University of Melbourne as volume one of the Port of Melbourne Environmental Study (Atkins *et al* 1976). This report is an engineering-economic evaluation of land transport links to Melbourne's new major container terminal at Webb Dock. It is a study of interest for several reasons:

- the study involves an application of advanced multi-disciplinary techniques;
- it relates to an existing - and controversial - policy problem;
- it should provide further insights into the increasingly evident problems associated with port development and urban land use.

This paper is principally concerned with the theoretical and policy issues arising from the application of 'MOP' (Multiple-objective Planning) methodology, and does not cover the impact of these projects upon the community, its institutions, and the formation of opinion. A separate assessment of the effects of port development upon community structure and social choice is presented in King (1977: paper to this ATRF session).

The study involved a trial application of MOP (Multiple-objective Planning) techniques to provide a quantitative evaluation of the 'intangible' factors in environmental studies comparable with the economic evaluation of project impacts. The specific port projects under review are potential road and rail links to the major new container berth complex proposed for Webb Dock, some of which have attracted strong community opposition. The 'MOP' approach is applied to the planning process in order to present a wider range of alternatives to decision makers: in this application the methodology is considered to be an advancement on the next best technique - namely benefit-cost analysis, supplemented by environmental impact statements.

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<sup>1</sup> Senior Research Fellow in Economics, Centre for Environmental Studies,  
University of Melbourne

## 2. BACKGROUND

In 1973 the Melbourne Harbor Trust presented its Forward Development Plan for the Port of Melbourne covering projected expansion needs up to the year 2005. For this study the most significant proposal was that for extensive reclamation and expansion of the berths in Hobsons' Bay (near the Yarra entrance) - best known as the Tasmanian Ferry Terminal - to provide container berths and terminal facilities capable of meeting projected usage for the next 30 years.<sup>2</sup>

Most existing port facilities are at upstream berths in the Port of Melbourne (Victoria Dock, conventional and 'RORO'; Appleton Dock (mixed), and Swanson Dock - now the principal overseas container berth). Up to 1972-73, Hobson's Bay contained the two old piers (Princes Pier and Station Pier) for a dwindling number of passenger ships, and which provided limited facilities for break-bulk freight, and Webb Dock Tasmanian and coastal shipping berth (operated solely by the Australian National Line - ANL).

Webb Dock offers many advantages from the ship-operation point of view as a container berth, but presents some problems from the land transport side. The upstream berths (although adjacent to the CBD) are serviced by road and rail in a wholly industrial area. Webb Dock is located in Port Melbourne, a Local Government Area which includes 'south wharf' river frontage, and also some shoreline within the bay, and contains a mixture of residential, commercial and industrial zones - including one suburb - Garden City - adjacent to the dock site. The main planning problem associated with the Webb Dock location is land transport access: container truck access is along congested city roads and through the residential area to the Dock. There is no direct rail access at present (although the Port Melbourne - suburban - railway line extends to the two piers, less than one mile away from Webb Dock).

The conflicts in interest between port needs and adjacent urban land use were the impetus to this present study: with commencement of the Eastern Searoad Service (ESS) trade to Japan from Webb Dock in 1973, ANL (as terminal operator) found it has to trans-ship a growing number of containers arriving at or leaving the port area by rail to and from trucks between port railheads and Webb Dock. In commercial terms, this short road-haul and double handling of containers was-and is - costing nearly \$1 million a year above existing freight costs. Hence the move to provide a direct rail connection to Webb Dock. In 1973-74, an expert government group representing all the various agencies<sup>3</sup> involved *again* recommended the construction of a divided-road in Garden City residential area called Howe Parade.

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2 There are also strategic Planning issues raised here e.g. why not Westernport of Geelong - or Sydney etc., - instead of Melbourne. These are the subject of volume two.

3 Including: Melbourne Harbor Trust (MHT); Melbourne & Metropolitan Board of Works (MMBW); Lower Yarra Crossing Authority (LYCA); Victorian Railways (VR); Railway Construction Board (RCB); Country Roads Board (CRB); Ministry of Transport (MOT); Port Melbourne City Council (PMCC).

This in fact represented the *third* phase; the first was construction by the Commonwealth of a line to U.S. army stores near Webb Dock during World War II. The local council strongly opposed its retention or development in the 1950s. In the early 1960s the Victorian Railways again proposed rail access to Webb Dock and obtained a rail easement along Howe Parade to replace its existing (but unused) easement along the Boulevard. In 1970 the Victorian Parliament passes the River Entrance Docks Railway Construction Act. The third - and current - phase began in 1971 - 1972 with Council and resident opposition to the Howe Parade line. The government - appointed steering committee reported in 1974 in favour of Howe Parade (in preference to three alternative rail routes). Despite the evident community opposition, this committee was influenced in its decision by the fast-growing overseas container trade at Webb Dock which commenced in 1973.

After once more experiencing strong public opposition to the rail project - and many other features of the Forward Development Plan - the State Government decided to permit no further action until an environmental study of the MHT's development plan had been completed

The Centre for Environmental Studies (CES) of the University of Melbourne was commissioned to undertake a study of the social and economic impacts of the Port Melbourne development plan and associated land transport alternatives. It was proposed that this study would form part of an integrated Port of Melbourne Environmental Study - the other major component being a study of the hydraulic and biological impacts of the proposed port development (especially the Hobson's Bay reclamation).

The CES started work in late 1975 - initially on the strategic and sociological issues, but increased community pressures on the State Government relating to several projects in this area required the Webb Dock land transport study to be undertaken first (Government projects in the Port Melbourne, South Melbourne area include Webb Dock (and rail line); Westgate Bridge and the resultant traffic spillover to suburban streets; and also Newport Power Station).

### 3. STUDY METHODOLOGY

The scope of the CES report on land transport alternatives is ambitious both in its theoretical framework and in detailed content. The following outline first summarises the structure of the study and then discusses how a rigorous engineering-economic technique was developed to cope with conceptual and empirical problems, community surveys, project designs and plan formulation, and finally to identify an acceptable project.

#### 3.1 SCOPE OF REPORT

The results are presented in eleven chapter sections:

- Chapter 1: provides background/history of project *and* outlines methodology;
- Chapter 2: gives brief demographic and socio-economic review of Port Melbourne LGA and for the study area;

- Chapter 3: provides an overview of container operations in the Port of Melbourne, especially at Webb Dock (including characteristics of container truck traffic in study area);
- Chapter 4: contains an analysis of Webb Dock container flows and provides forecasts of future container movements through Webb Dock (including the expected share of total movements);
- Chapter 5: summarises engineering features, design criteria, and cost of all alternative Rail and Road projects proposed for evaluation;
- Chapter 6: reviews and assesses the *Economic Efficiency Impacts*;
- Chapter 7: *Noise and Vibration Effects*; and
- Chapter 8: *Visual Impacts*; of all project combinations;
- Chapter 9: contains the results of an *Attitude Survey* specifically undertaken to test the reaction of Garden City residents to features of the alternative projects;
- Chapter 10: presents a *Multi-objective Evaluation* of alternative systems (to determine a set of *non-inferior* projects). This represents the last step in objective MOP analysis, and presents a small number of projects from among which decision-makers may choose;
- Chapter 11: a *preferred alternative* is selected (although this step involves explicit value judgements) and the implications of this recommendation are examined.

### 3.2 METHODOLOGY

It is emphasised that the study contained in volume 1 is concerned with only part of the Forward Development Plan, (namely the land transport links to Webb Dock) but nevertheless aims to provide adequate guidance for project design, social evaluation and eventual decision-making (by Government and government agencies). The fundamental objective of public investment is to increase or maximise *social welfare* i.e. personal well-being aggregated over the entire community. This broad objective is uni-dimensional: all project effects should be measured in units of *welfare*.

The question here is: what is a reasonable proxy measure for welfare? For some of the goods and services produced in the *public sector* of the economy (and for most of those produced in the *private sector*) the unit of welfare is *money*. But most public investment decisions, and especially transport project effects, are difficult to value in money terms.

Benefit-cost analysis for example is a technique which attempts to measure all project effects *in dollar terms*, so that all significant gains and losses to *the community* can be evaluated according to an appropriate

economic criterion (e.g. economic efficiency)<sup>4</sup>. In recent years it has become apparent that some important project effects were being undervalued, and others (especially *social* and *environmental* effects) were not being identified or valued at all within benefit-cost studies. (despite considerable research effort and some notable successes in these fields). One way out of this problem is to separate the *monetary* and *non-monetary* effects of projects, and group the non-monetary factors into homogeneous groups identified with common 'objectives'. This is one of the features of *Multi-objective Planning*.

*Multi-objective Planning*, which is the approach used in this study, incorporates the basically *economic* principles of benefit-cost analysis within a systematic planning and decision-making framework. Note that it does *not eliminate* the measurement problems of single-objective benefit-cost analysis, but (for a particular range of problems) deals more rigorously with project effects and in particular it has the capacity to reject existing project plans and *generate further project designs* (e.g. where it appears that the set of projects for evaluation does not include potentially superior designs) for inclusion in the analysis. (By contrast, conventional benefit-cost analysis in general simply ranks what is given).

The conceptual basis of multi-objective planning is summarised briefly as follows: because the generally agreed single goal of *public* investment planning (namely to maximise social welfare) is too difficult to measure at the operational level of planning, more specific *multiple objectives* are identified such that project effects - both good and bad - associated with each objective can be measured in commensurate units.

In the port study, two components of *social welfare* are identified as planning objectives: *Economic Efficiency* and *Environmental Quality*.

There are still conceptual problems about multiple-objectives, notably as to the need for such objectives to be *mutually-exclusive* (vide Freeman 1971 and Howe 1971). In the port study these two objectives are defined as:

- 5(i) *Economic Efficiency* which is normally concerned with efficient allocation of resources to maximise production of goods and services, in this analysis is restricted to cover net gains to the community from the *reduction in user costs of transporting containers* to and from Webb Dock container berth as a result of improved road and proposed rail facilities.

<sup>4</sup> Note that economic efficiency is still only a proxy for social welfare. cf. FOSTER (1974) p3. *Rationality (in the context of decision-making in transport) means first selecting certain 'values' ... so that they may be used operationally in policy analysis. Not only must these values be selected but they must be ranked to the extent that the weight to be given to each in any policy may be inferred. With such a value system, or social welfare function - as economists would call it - it seems then possible to deduce what policies are theoretically efficient in the field of transport, before asking what policy instruments may be used and how such policies may be made practical.*

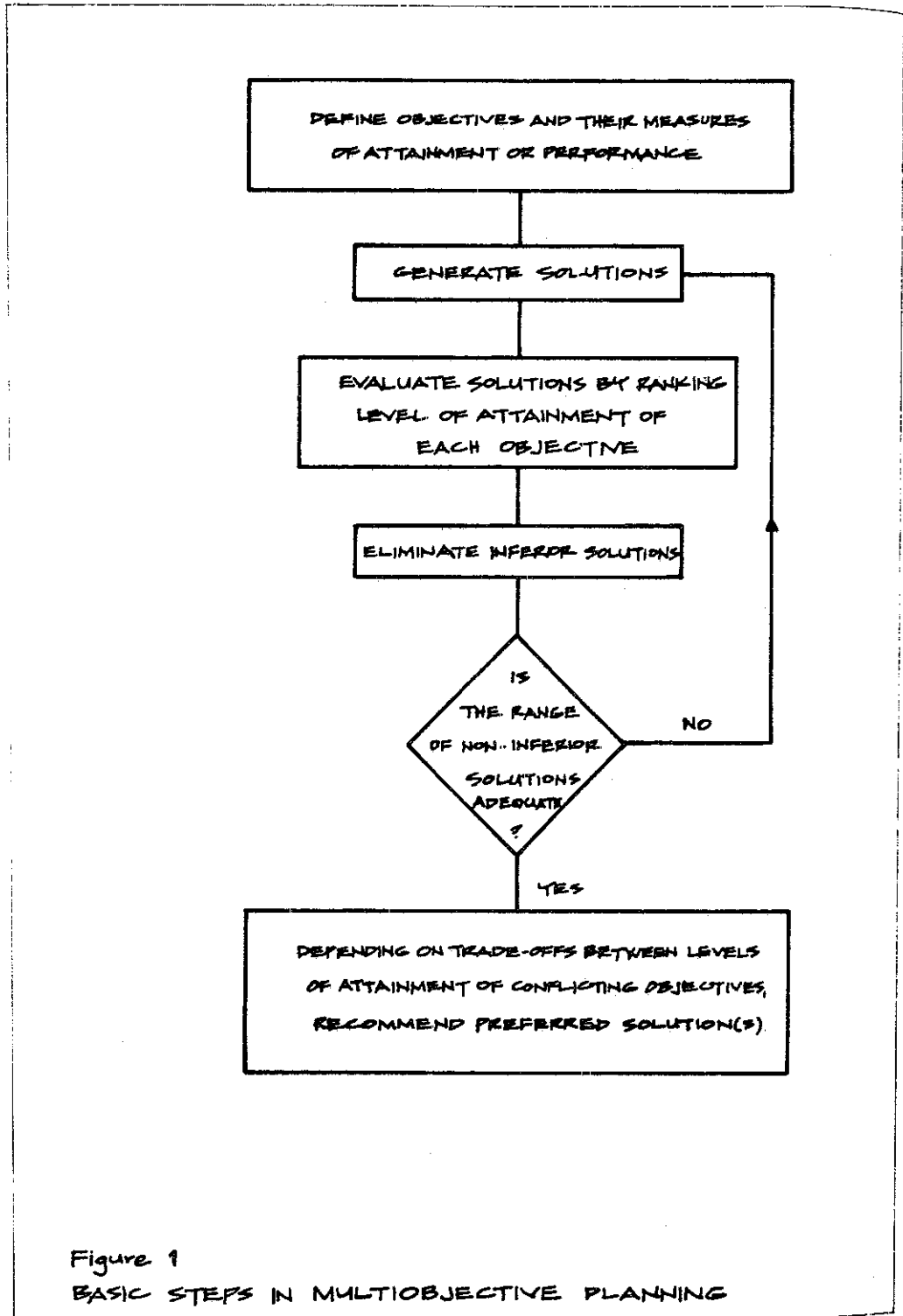


Figure 1  
BASIC STEPS IN MULTIOBJECTIVE PLANNING

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A small traffic assignment model was constructed to re-allocate the project future container traffic (both between road and rail modes, and between appropriate origins and destinations). In common with transport planning practice, the forecast container traffic was re-assigned to each project network in turn, from which the net gains to the community resulting from reduced user costs were computed for each project combination. *These user-cost savings are measured in terms of economic resource costs (i.e. cost to the community) and will generally differ from actual commercial savings resulting from a project.*

- (ii) *Environmental Quality* consists of the enhancement of physical, ecological, social and aesthetic characteristics. In the present study the environmental quality objective is defined somewhat more restrictively to cover *residential amenity* in the suburb of Garden City, specifically as affected by the noise, vibration, and visual intrusion impacts of alternative land transport systems linked to the port.

These two *planning objectives* form the basis of the project design and evaluation technique which follow.

### 3.3 MOP PLANNING PROCEDURE

There are five basic steps in multi-objective planning (*vide* USWRC, 1973, O'Brien 1972):

- (i) Identification of the important components of each objective;
- (ii) evaluation of existing economic and resource capabilities of the system ... and forecasting of future economic and environmental conditions in the absence of planning;
- (iii) development of alternative plans ... reflecting various emphasis between the economic and environmental quality objectives;
- (iv) evaluation of benefits and costs (sometimes termed beneficial and adverse effects) of all alternative plans against the two sets of accounts for *economic efficiency* and *environmental quality* objectives (note that evaluation is usually undertaken both *with and without* the plan, to show *incremental benefits*);
- (v) selection of a recommended plan from among the available alternatives, using public participation to help provide the relative emphasis (or weights) to be given to the *economic* and *environmental* objectives.

These five steps are not a single-pass operation, but part of a dynamic planning process, involving much iteration, revision and feedback. It is the capacity to generate alternative plans which is the other distinguishing feature of Multi-Objective Planning, and which should involve an effective interdisciplinary merging of analytical skills in the development of project designs.



### 3.4 ALTERNATIVE PLANS

The generation and evaluation of alternative plans is central to multi-objective planning. This process leads to the elimination of all inferior plans from the final selection process.

The logic of project selection and preferment is as follows: if two alternative solutions, A and B are compared using multiple criteria, A is an *inferior* solution if it does *not* rank higher than B on any criterion and if it ranks lower than B on at least one criterion. If however, A ranks *higher* than B on at least one criterion, and *lower* than B on at least one criterion, neither is unambiguously better than the other, and both A and B are *non-inferior* solutions (for the particular pair-wise comparison).

The application of steps 3 and 4 (of the five-step multi-objective planning procedure as outlined above) involves repeated pair-wise comparisons between alternatives until *only non-inferior alternatives remain*. The final selection of a recommended plan, step 5, is then applied to this remaining set of *non-inferior alternatives*.

### 4. APPLICATION TO THE WEBB DOCK STUDY

The results of this conceptual framework as applied to the Webb Dock container berth study are briefly outlined.

The first outcome of the MOP approach was to expand the scope of the study to cover *all* land transportation options - both rail and road - rather than selected rail projects and existing road conditions. The procedures resulted in the proposal of *six non-inferior* potential rail link projects (including 'no rail project' as one of the six options), and *five non-inferior* road projects (including 'no road improvement' as a road option). This effectively generated 30 joint road-rail alternatives, each to be separately evaluated on *economic efficiency* and *environmental quality* grounds. Details of the economic efficiency evaluation, including container traffic forecasts, project-and vehicle operation-costing, mode-split traffic assignment, and eventual computation of *net present values of user benefits* (NPV's) are contained in the report (*vide Atkins et al 1976, chapters 4,5,6*). For background to transport evaluation techniques refer CBR(1973;)and Harrison(1974). The end result of the economic evaluation is a table of net present values (NPV's) containing discounted project benefits *less* costs for each of the 30 project combinations. This number of projects resulted because MOP procedures identified 6 non-inferior rail and 5 non-inferior road projects, thus generating 30 mutually-exclusive and independent project combinations.

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The Composition of project benefits was:

- (i) for road projects: vehicle operating costs; travel saving and accident cost reduction
- (ii) for rail projects: the reduction in *resource* costs per container-trip between direct rail; and transshipment for two port railheads.

Note that these *user economic benefits* based on reduced road and rail operating costs are calculated as *incremental* benefits (i.e. benefits calculated *with* the project *less* benefits calculated without the project).

It should be noted that the economic objective - defined here as user benefits-excluded many project benefits and costs which would normally have been included in a comprehensive 'Social Evaluation', such as noise, vibration, visual and aesthetic intrusion, and social disruption generally (c.f. Dasgupta and Pearce 1972; Abelson 1975 and Smyth 1975).

Whilst these effects undoubtedly have economic consequences - some of which enter into market valuations (e.g. by affecting house prices) - our ability to obtain agreed (or stable) dollar values comparable with those for user benefits and costs is very limited at present.

Therefore, in this MOP approach, *all other project* effects form part of the environmental quality (EQ) objective, although it is recognised that there is some scope for moving *some* components between the accounts for each objective when valuation techniques improve (but this should not affect the present analysis).

Thus the components of environmental quality, in particular those relating to *residential amenity*, are measured in absolute units. Eventually, however, the problem of combining them into a single commensurate, but non-dollar unit must be faced.

#### 5. RANKING MODEL FOR ENVIRONMENTAL QUALITY

The major components of the environmental quality effects of projects were traffic noise, vibration and visual intrusion in the nearby residential area of Garden Suburb. As described in some detail in the report, the noise, vibration, and visual/intrusive impact measures for *each project* were both:

- (i) *measured* (in absolute units such as dBA etc); then
- (ii) *rated* on a ranking scale (graded from acceptable to unacceptable etc).

and then combined together in a *ranking model* which was used to measure *changes in residential amenity*. This model is similar in structure to a weighted index such as the CPI (except that the index weights are not constrained to = 100%). The symbolic formulation of this ranking model is:

$$\Delta RA_j = \alpha \sum_i R_i (NO_{ij} - NO_{iE}) + \beta \sum_i R_i (VB_{ij} - VB_{iE}) + \gamma R_{GC} (VI_j - VI_E)$$

where  $\Delta RA_j$  = change in residential amenity relative to existing state due to alternative j (this value is normalised to a convenient scale);

$R_i$  = number of residences affected in area i of Garden City;

$R_{GC}$  = number of residences in Garden City;

$NO_{ij}$  = noise impact in area i due to alternative j;

$NO_{iE}$  = existing noise impact in area i;

$VB_{ij}$  = vibration impact in area i due to alternative j;

$VB_{iE}$  = existing vibration impact in area i;

$VI_j$  = visual/intrusive impact on Garden City due to alternative j;

$VI_E$  = existing visual/intrusive impact within Garden City;

$\alpha, \beta, \gamma$  = weighting functions ascribing relative importance of each impact during specified time periods;

and  $N$  = number of potential areas affected by alternatives - Howe Parade, Williamstown Road and The Boulevard

It is important to note that the components of this index, namely noise, vibration, and visual intrusion are *not* measured in absolute units (e.g. of noise, etc), but represent *scaled attitudinal ratings* of each component. In effect, these basic observations and measurements of traffic noise, vibration and visual intrusion (as recorded in chapters 7,8 and 9 of the main report) have been transformed into *utility scales*, in which an attempt has been made to interpret the subjective perception by individuals of these phenomena, using cardinal scales ranging from 'tolerable' to 'intolerable', etc. In effect the ranking model is an attempt to derive a *linear utility model* based on transformation of objective units into cardinal utility scales as proposed by Stanley (1974).

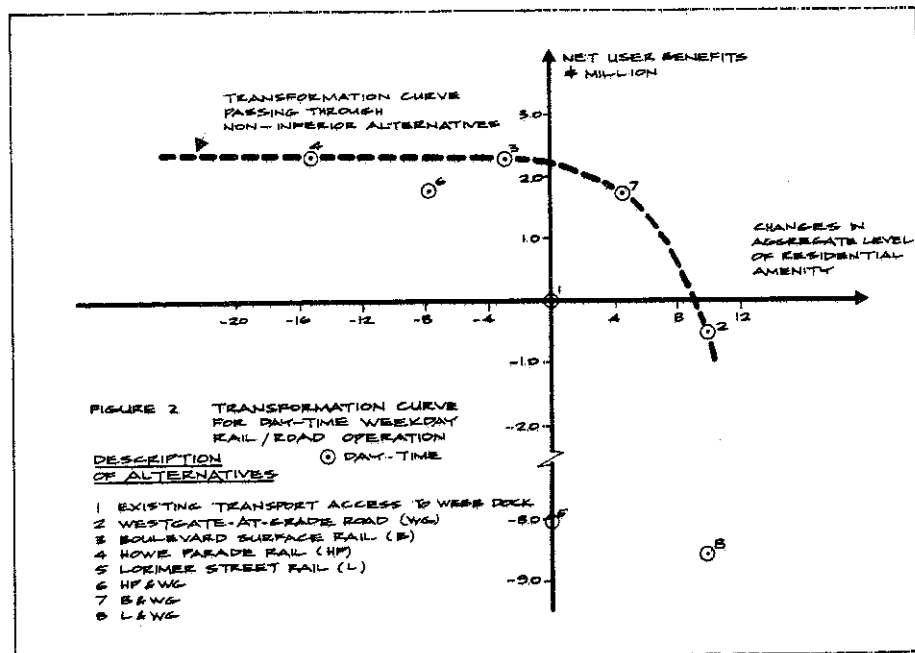
The scalings of these components were based on behavioural standards (e.g. noise standards) and attitudes. The linear *combination* of these components into a single 'utility' index of residential amenity required the derivation of a further set of parameter co-efficients ( $\alpha, \beta$  and  $\gamma$ ) which represents the relative importance of each of these subjective factors, such as tolerability of noise, visual intrusion, etc. In this way the index converts separate tolerability scales into a utility index for residential amenity.

#### 6. TRANSFORMATION CURVE

The final stage of Multiple-objective Planning analysis produces a *transformation curve* which is derived by plotting values of *net user benefits* against *changes* in aggregated residential amenity for daytime weekday operation of port road and rail traffic, for each project.

The transformation curve *envelopes* all the proposed alternatives and *passes through the non-inferior projects* thus, recalling that an alternative is inferior if there exists another alternative which *scores better in both objectives*, the transformation curve screens out inferior projects which do not warrant further consideration.

Figure 2 shows there are only three non-inferior projects from which final project selection must be made.



## 7. CONCLUSION

The purpose of this paper has been to outline the study content and methodology. The outcome of the multi-objective planning approach to this problem has been to screen some 30 potential projects down to a final set of three projects. This final set includes alternatives which may be termed 'environmental', 'economic' and 'compromise' solutions, reflecting their major contribution towards the objectives of environmental quality and/or economic efficiency. In presenting this result it is argued that (objective) analysis can go no further'. The final selection of a *preferred alternative* depends upon society's relative valuation of each objective as specific for this problem. Such assessments are properly the role of governments (through elected representatives). But having stated that final project selection is the responsibility of elected government and not planners the question still arises as to how far planners should go in advising governments on project or plan selection. In the port study, the further step of recommending a final project was undertaken, although clearly stating the value judgements involved. The alternative approach would be to limit advice to the presentation of the final set of non-inferior alternatives, and the trade-offs involved in selecting *any* one of the alternatives. Instead a single project was recommended which - in the opinion of the study team - best meets community values. Whilst this is more controversial, it provides the decision-makers with another informed opinion (to which they are not in any case bound), and should help focus and stimulate public debate and provide a useful input to the process of public participation and government review.

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