

TRANSDISCIPLINARY FRAMEWORK: CHALLENGES IN MODELLING THE SUSTAINABLE CITY

PAPER 280

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1 INTRODUCTION

Researchers and practitioners of urban modelling have created a global social sub-system. The cities analysed contain "wicked" problems and the interaction of economic, environmental and social forces demands that we apply new and creative ways of thinking that can rise to the challenges of greater complexity. A trans-disciplinary mode of thinking about cities (and urban modelling) aims to create the richest possible identification of problems and issues and how they may be addressed, including the role of models in the policy formulation and implementation phase.

In 1965, the Special Edition of *the Journal of American Planners* opened the eyes to planners on operational urban modelling possibilities in a profession where land-use plans had been inspired more by the "artist's brush" than

rigorous analysis (Blunden, 1971). Hitherto, highway and traffic engineers, had largely dominated the modelling field. The diversity of disciplinary backgrounds lead to the formation of multi-disciplinary teams, especially in the comprehensive land-use and transport planning studies that themselves became institutionalised and global in their reach. An overview of the key model developments of the past 40 years in Section 2 (optimization approaches, aggregate four-step forecasting, individual choice models, and integrated land-use and transport models) that often engaged discipline experts maintaining rigid boundaries of ownership allows us to contrast traditional practice with that required in a trans-disciplinary framework (Section 3). To be more specific on abstract concepts we locate two examples from our research and illustrate connections with medical science in the formation of trans-disciplinary teams researching quality of urban life issues. Modelling the impact of aircraft noise on environmental health (Section 4), and quality of life adjusted years concepts to evaluate residential locations and their “chance of liveability” under conditions of planned retreat and re-concentration (Section 5) are selected as illustrative examples of emerging trans-disciplinary thinking.

The challenges are great and the territory vast so we hope the philosophy of the trans-disciplinary approach will be adopted, even mutating into higher-order approaches when the 50th Anniversary of the Special Edition is celebrated. These new directions are under constant development through our leaderships of the Botany Bay Studies Unit (<http://www.bbsu.unsw.edu.au>) and the Laboratory for Sustainable Transport and Spatial Development. ([http://www. ??????](http://www.??????)), respectively. We trust that readers find the arguments persuasive enough without resort to full scholarly referencing conventions in the pages that follow, but a bibliography in electronic format is available by contacting the authors.

2 THEMES IN LAND USE, TRANSPORT AND ENVIRONMENTAL MODELS

In the new profession of traffic engineering – it was understandable of a desire to protect the secrets of “signs, signals and markings”. Rapid motorisation in the USA in the 1940s and 1950s spawned traffic engineers but, initially, they were largely excluded from the University discipline of civil engineering. They made great strides in modelling using concepts from operations research and queuing theory. One “high priest” was Alan Voorhees, who was instrumental in 1955 in introducing the gravity model into practice¹.

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1. In the 1880s, German railway engineers applied an unconstrained gravity model to estimate passenger traffic for planned inter-city routes. A production constrained gravity model was applied in an urban transport study in Stockholm in the late 1940s.

Previously, the master plans for highways were based on traffic counts and an extrapolation of demand into the future made by highway engineers (who were part of the Civil Engineering fraternity) that, in essence, produced ring-radial freeway solutions to a fixed future land-use plan.

The urban transport planning process that emerged from the Detroit and Chicago comprehensive land-use and transportation studies of the 1950s recognised that planning for transport required a systematic understanding of land-use patterns from which travel patterns are derived (Mitchell and Rapkin, 1954; Oi and Schuldiner, 1956). The aggregate, four-step models of traffic demand and transport supply required exogenous inputs of land use. It was six years after the publication of the Special Issue that these modelling techniques were consolidated into books (Creighton, 1970; Blunden, 1971; Bruton, 1971) whose markets were predominantly engineers and planners.

In a period of rapid urban growth spatial restructuring the preparation of future land-use plans and socio-economic forecasts proved vexatious issues. Two distinctly different modelling approaches emerged in the 1960s to overcome the deficiencies exposed in the four-step modelling process: optimisation models and integrated land-use and transport modelling (Lowry-type models and derivatives). The United Nations Urban Renewal Plan for Singapore applied linear programming to determine the best spatial distribution of land uses. Lowry models limited exogenous inputs to the geographical locations of “basic” employment in zones (implicitly within the powers of the planning authority to implement) and then, in iterative loops, the model generated service employment locations based on accessibility concepts finally converging to a stable amount of total zonal employment.

Public transport investment was largely ignored in the US transport studies with their emphasis on highway solutions and the aggregate models of modal split were somewhat superficially applied. However, important research into individual choice emerged in the late 1960s (Lisco in the USA; and Quarmby and Stopher in the UK) that later paved the way for the development of logit and multi-nomial logit models of mode choice that are now firmly embedded into urban transport planning practice. Importantly, these models contained attributes of the different transport modes – such as in-vehicle time, waiting time and costs – and were able to demonstrate how investment in public transport service frequency and route coverage as well as pricing policies would alter mode choice. The development of individual (discrete) choice models in the 1970s paralleled a change in highway investment policy from “predict and provide” to transport system management (TSM) – or getting more out of the existing facilities – and, later, travel demand management (TDM).

Environmental legislation, introduced in the USA in 1969, and in other countries, required the environmental impacts of projects to undertaken in the form of environmental impact statements (EIS). The modelling requirements were different to that of travel demand estimation: the framework contained issues such as: what is the magnitude of the impact (with the project)? what is the size of the population exposed to that impact? how can adverse impacts best be mitigated and managed? A suite of environmental and social impact models have been developed for areas such as vehicle emissions, transport

noise, traffic accident risk, visual intrusion of infrastructure, and social exclusion. Dose-response relationships (see Section 4) are important models for social and health impact assessment.

Decision makers today evaluate transport plans, projects and policies on sustainability criteria: the “triple bottom line” of economic, social and environmental impacts. Sustainability constraints are important political drivers of any contemporary transport investigation. The Australian Government’s Ecologically Sustainable Development (ESD) Transport Working Group of 1991 provided the first consolidated set of recommendations on how to achieve a more sustainable transport sector in Australia, although appropriate analytical techniques were not addressed (Black, 1996). Suitable models for analysing the properties of the sustainable city remain a research challenge that we think is best addressed through a trans-disciplinary thinking.

3 TRANS-DISCIPLINARY APPROACHES

“Transdisciplinary thinking is primarily a process of assembling and mapping the possible interconnections of disciplinary knowledge about any given health problem until the fullest possible understanding of the problem emerges” (Albrecht *et al*, 2001, p.75).

The aim is to understand process and change and to create the richest possible description of the context within which modelling land use, transport and a sustainable environment (in the specific application discussed in this essay) are situated.

Table 1 compares and contrasts the character of trans-disciplinary approaches to urban modelling problems with that of single, multiple and inter-disciplinary approaches. In the single discipline approach there is a strong tendency to maintain rigid boundaries around some part of the problem. Multi-disciplinary research is characterised by sharply defined disciplinary boundaries, with results pieced together at the conclusion of the process. Inter-disciplinary approaches encourage different disciplines to actively pursue the inter-connected aspects of the problem that is defined within the boundaries of the interacting disciplines, but, of course, it ignores those disciplinary perspectives not invited to the research.

The trans-disciplinary approach transcends boundaries so that research is committed to exploring fully the boundaries of the specific problem under investigation by promoting cooperation and coordination between all relevant disciplines. The common conceptual framework sought is a new and significant way of understanding a problem that now unifies all previously disconnected fields of knowledge and the outcome may help dissolve the previous boundaries around fields of knowledge with the creation of a trans-disciplinary explanation. Trans-disciplinary thinking will inevitably challenge the intellect because a problem may entail diverse theories of modern thought from positivism to post-modernism. All of this requires epistemological tolerance, mutual respect for different disciplines, an ethics of inclusion, and

recognition that the community may have specialised knowledge that can be brought to bear on the research problem.

Table 1: Approaches to Urban Modelling Phenomena

Approach	Problem & Boundary	Conceptual Framework - Role
Single discipline	What a single discipline thinks it is	Arises from single discipline
Multi-disciplinary	What several disciplines working independently think it to be; hard disciplinary boundaries placed around problem components	Mutually exclusive conceptualisations juxtaposed
Inter-disciplinary	What several disciplines working together agree it may be, but aspects of problem from excluded disciplines ignored; soft boundaries	Isolated explanations of a problem from limited number of disciplines assembled and connected
Trans-disciplinary	Part of open, dynamic system operating on many levels where problem expands to be inclusive of all relevant disciplinary insights	Common conceptual framework usable by any discipline

(Source: based on Albrecht, et. al., 2001, Table 4.1, p. 72)

Albrecht (et. al., 2001, pp. 80 – 81) have identified seven key stages when conducting trans-disciplinary research, much along the process of the systems approach familiar to urban modellers – aims and objectives, data collection, understanding through models, forecasting, alternative solutions, evaluation and appraisal, and recommendations for implementation. Systems analysis has been extensively applied in urban transport. Advances in computing have allowed massive amounts of data on land use activities, travel patterns and transport supply characteristics to be stored, manipulated and plotted graphically with the aid of geographical information systems. The systems approach remains relevant to the needs of contemporary practice at the beginning of the 21st Century and still forms the framework around which transport studies at the national, regional, sub-regional, and local scales are designed. In addition to the technological revolution in computing hardware and software the most significant developments have been a broader set of (sustainability) goals and objectives and a wider set of performance indicators on each alternative at the evaluation and appraisal phase.

With this broad context in mind, the general stages in conducting trans-disciplinary research are as follows.

1. Problem identification.
2. Assemble a group (or network) of researchers with the necessary skills to offer a perspective on the problem.

3. Extensive literature review on the problem area to exhaust all disciplinary and inter-disciplinary conceptualisations and explanations of the problem.
4. Design research enquiry from research gaps identified in 3.
5. Implement research enquiry.
6. Review conceptual understandings and synthesise data sets, including the search for a common conceptual framework that illuminates the problem and provides maximum explanatory power.
7. Specify types of intervention (often with a network of local stakeholders) to resolve the problem.

If the problem is identified as modelling the sustainable city there are great challenges ahead into largely unknown territory. As a first step, we offer our observations from experience gained with two research projects, both focusing on quality of life issues in the city.

4 AIRCRAFT NOISE AND ENVIRONMENTAL HEALTH

Before describing the trans-disciplinary insights into our research into environmental health and quality of life, let us consider current practice in airport planning (see, Horonjeff and McKelvey, 1994) and the problem of noise, where there are two important models: that of aircraft noise, and that of community response to those noise levels. These models are used in environmental impact assessment of airport development proposals. Civil engineers, acoustical engineers, and land-use planners (dose-response relationships are used in practice to identify land-use compatibility around airports) dominate this technical field, largely to the exclusion of other disciplines. Embodied in professional practice and statutory requirements is a problem identification (simplified to its essence) along the lines of: "If the airport expands and the number of aircraft increase (by type and size) what are the best operational arrangements (runway usage, flight paths, jet engine power settings) that will minimise the impact of aircraft noise on the surrounding land uses?"

In undertaking an EIS the lead consultant is often a company that can supply multi-disciplinary teams, and sub-consult work to appropriate disciplinary experts. The existing knowledge base is searched, but literature review reports are rarely couched in a critical way, and little original research is undertaken to warrant the design of a research inquiry. For example, demand models are part of forecasting future requirements but airport EIS studies often resort to forecasts synthesised from other studies. The two key models are applied that estimate the future sound pressure levels experienced on the ground for given operational regimes – the Integrated Noise Model (Gulding, et. al., 1999) – and the dose-response model (Schultz, 1978) – to calculate the number of people adversely affected (annoyed) by aircraft noise within different contours of noise level descriptors. Typically, a noise management plan would be formulated as step seven of the trans-disciplinary approach to mitigate or minimise impacts, but drawing on measures approved by the International Civil Aviation Authority (ICAO, 1993).

If this problem of aircraft noise and the community were recast within a trans-disciplinary framework then more disciplinary perspectives would be included in problem definition. Such an approach was taken as part of the Government of New South Wales Botany Bay Strategy a stakeholder workshop (<http://www.bbsu.usw.edu.au/>) involving 120 people from state and local government, NGOs, the private sector, community representatives and academia, scoped research needs, that included one recommendation on a better understanding of the impacts of aircraft noise on the community (the runways of Sydney Airport extend southwards into Botany Bay).

Secondly, a small research group was established. The research was undertaken by a doctoral student (Issarayangyun, 2005), supervised from the Medical and Engineering Faculties of UNSW and supported by translators from South Sydney Area Health Services. Studying impacts of aircraft noise on environmental health and well-being requires an understanding of the medical literature – which is extensive on aircraft noise and individual health – as well as perspectives from epidemiology, social survey methods, acoustical properties of noise, and multivariate statistics (step 3). The literature reviewed showed that environmental noise disturbs community daily activities (for example, watching TV, listening radio, sleeping, conversation, or studying). The reactions of people to those disturbances are different. Most people are annoyed by those disturbances. Some of them can habituate (or get use to it), or even avoid it (by moving residence), or modify their activities in these noisy places. In susceptible people, noise intrusion into their home makes them angry and stressful. Suffering from chronic stress can lead to health problems that can be either physiological or psychological.

Fourthly, from the research gaps in the literature, the group formulated two research questions (*“Is health related quality of life worse in communities chronically exposed to aircraft noise than in communities not exposed?”* and *“Does long-term aircraft noise exposure associate with adult high blood pressure level via noise stress as a mediating factor?”*). Epidemiological research design strategies were followed (Hennekens *et al*, 1987). Basically, epidemiology compares the effects of exposure of an exposed group with a matched control group (this was our research design), or assesses the changes in exposed individuals over time.

The fifth phase involves implementation of the research – data collection and multivariate statistical analysis. A self-administered questionnaire was designed, building on standard questions from the Harvard University SF-36 health status (Ware, 2000; Ware *et. al.*). A description of the pilot and main survey of people in South Penrith (control) – some 55km west of the airport - and around Sydney airport are described elsewhere (Issarayangyun, *et. al.*, In press). In a quasi-experimental design, the hypothesis for testing one of the four standard scales on the SF-36 questionnaire (Ware and Sherbourne, 1992), that we formulated (for general health), and aircraft noise exposure is.

H₀: *There is no difference in the population mean General Health score for aircraft noise exposure group and population mean General Health score for the control group (or $\alpha_1 = \alpha_2$).*

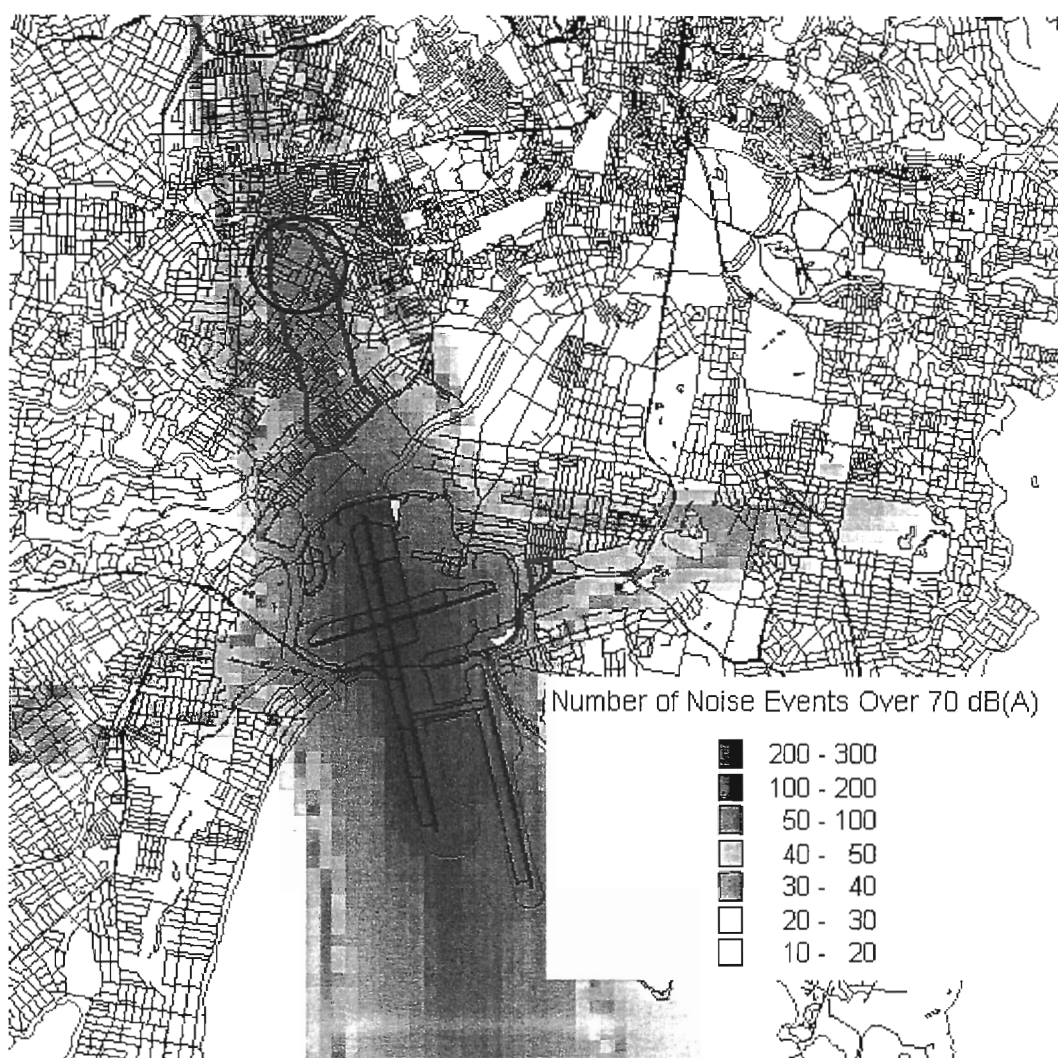


Figure 1: Daily Average Number of Aircraft Noise Events Louder than 70 dB(A) at Sydney Airport During 1 January – 31 December 2003 and Study Population of Aircraft Noise Exposure Area (Circle)

(Source: Airservices Australia, 2004, attachment F)

H_a: There is a difference in the population mean General Health score for aircraft noise exposure group and population mean General Health score for the control group (or $\alpha_1 \neq \alpha_2$).

The mean difference of the SF-36 scale between study groups was investigated using the analysis of covariance (ANCOVA) technique. From the scatter plot of **CVs** and General Health, a suitable **CV** was the age variable. The prevalence of hypertension (**HY**), high cholesterol status (**CHOL**), exercise activity levels (**EXER**), smoking status (**SMK**), alcohol consumption (**ALC**) and body mass index (**BMI**) were selected as candidates for the secondary **IV** and were assessed for significance. Any secondary **IV** that provided **p-value** less than 0.05 were discarded from the analysis as marked by the 'X' symbol in Appendix, Table A1.

The first trial factorial ANCOVA was carried out by SPSS. Any secondary IV that was not significant in this model would be excluded. The first trial of factorial ANCOVA found that the smoking status variable ($F_{(2, 427)} = 2.867$, **p-value** = 0.058) and body mass index variable ($F_{(3, 427)} = 2.34$, **p-value** = 0.073) were not significant. After excluding these two variables from the model, the second trial of factorial ANCOVA was undertaken Appendix, Table A2).

There is significant interaction among prevalence of hypertension, exercise activity level, and aircraft noise exposure in the model. This interaction explained 1.7 percent of variance in the adjusted General Health score. The *Levene's test* found no significant difference of variance between groups. Moreover, an additional analysis of CV performed by SPSS using Type III sum of squares revealed that age variable was a significant CV ($F_{(1, 615)} = 33.647$, **p-value** < 0.001) of this model. The null hypothesis that there is no effect from CV (slope of the regression line (β) between the DV and the CV equals to zero) was therefore rejected.

Adjusted mean scores of General Health were 63.41 for the control group and 60.24 for noise exposure group. This leads to the conclusion that after removing the linear effects of age on General Health, and controlling for significant effects of secondary variables, which are prevalence of hypertension and exercise activity levels, the difference in mean scores of general health was due to the effects of long-term aircraft noise exposure. The study rejects the null hypothesis, and concludes that health related quality of life in term of general health of the subject from the aircraft noise exposure group was worse than the subject from the matched control group. Nevertheless, the strength of association is weak ($\eta^2 = 1.1\%$), implying that there is only 1.1 percent of the variance in the adjusted General Health score that was associated with aircraft noise exposure level.

The sixth stage of the trans-disciplinary approach is the review of conceptual understandings. There are some preliminary and tentative conceptualisations (Issarayangyun, 2005) but this phase is yet to be completed. Finally, comments about interventions are warranted because that is the ultimate purpose of such research. The primary stakeholders (in Australia) are the Commonwealth (AirServices Australia) and the State Government of New South Wales, the airport owners (Sydney Airport Corporation) and the airlines.

Sydney airport, along with many commercial airports of the world, implement environmental management plans but our survey of airport websites has found no mention of the health impacts of aircraft noise. A follow-up stakeholder workshop is planned for later in 2005.

5 THE COMPACT CITY IN JAPAN

In the near future, Japan will experience a dramatic decline in population with an associated regression in the economy. Given this change in socio-economic structure, the idea is to reduce built-up areas in the suburbs and so save on infrastructure and maintenance costs over the long term. These savings can be used to subsidise the return of households to the central areas of cities – the concept of planned urban regeneration (Hayashi and Sugiyama,

2003). In order to demonstrate this concept in a convincing manner a methodology was developed to measure quality of life (as derived from the medical literature) based on the satisfaction of an individual based on five components:

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The five components that make up total quality of life are economic opportunities, service opportunities, residential amenity, safety and security, and environmental burden. The goals of urban regeneration can be set up in a model of future quality of life.

6 CONCLUSIONS

There are a number of points that arise from this analysis that warrant further

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APPENDIX A

Table A1 : Assessing the Significance of Secondary **IVs** for General Health

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
HY	10630.26	1	10630.26	24.070	0.000
GROUP	1741.50	1	1741.50	3.943	0.047
CHOL	1564.34	1	1564.34	3.443	0.064
GROUP	1527.73	1	1527.73	3.393	0.066
EXER	8225.55	3	2741.85	6.092	0.000
GROUP	3238.73	1	3238.73	7.196	0.007
SMK	9717.82	2	4858.91	10.800	0.000
GROUP	1785.59	1	1785.59	3.969	0.047
ALC	2568.28	2	1284.14	2.769	0.064
GROUP	1600.14	1	1600.14	3.450	0.064
BMI	5991.64	3	1997.22	4.470	0.004
GROUP	2089.92	1	2089.92	4.677	0.031

Table A2: Factorial ANCOVA of General Health and Aircraft Noise Exposure

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	60390.98	16	3774.44	8.827	0.000	0.187
Intercept	2685703.27	1	2685703.27	6280.604	0.000	0.911
AGE	32227.14	1	32227.14	75.364	0.000	0.109
HY	11053.16	1	11053.16	25.848	0.000	0.040
EXER	7510.84	3	2503.61	5.855	0.001	0.028
GROUP	2820.52	1	2820.52	6.596	0.010	0.011
HY * EXER	1341.83	3	447.28	1.046	0.372	0.005
HY * GROUP	37.62	1	37.62	0.088	0.767	0.000
EXER * GROUP	828.52	3	276.17	0.646	0.586	0.003
HY * EXER * GROUP	4571.35	3	1523.79	3.563	0.014	0.017
Error	262985.46	615	427.62			
Total	3009079.72	632				
Corrected Total	323376.44	631				

Levene's Test of Equality of Error Variances

Dependent Variable: GH

F	df1	df2	Sig.
1.195	15	616	0.270

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5 CONCLUSIONS

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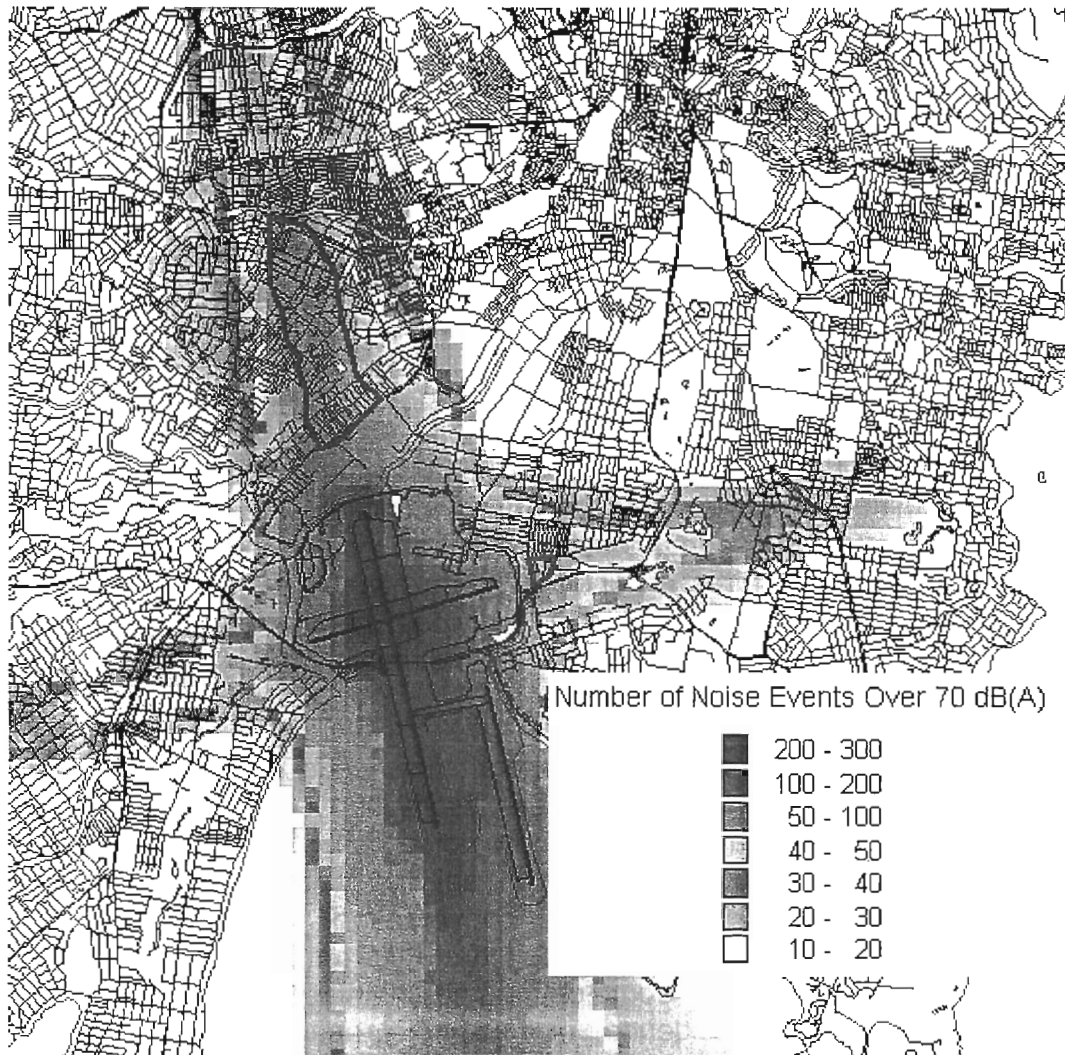


Figure 2: Daily Average Number of Aircraft Noise Events Louder than 70 dB(A) at Sydney Airport During 1 January – 31 December 2003 and Study Population of Aircraft Noise Exposure Area.

(source: Airservices Australia, 2004, attachment F)

Embodied in professional practice and statutory requirements is a problem statement (simplified to its essence) along the lines of: "If the airport expands and the number of aircraft increase (by type and size) what are the best operational arrangements (runway usage, flight paths, jet engine power settings) that will minimize the impact of aircraft noise on the surrounding land uses?" Demand models are part of forecasting future requirements but the two key models estimate the future sound pressure levels experienced on the ground for given operational regimes – the Integrated Noise Model

(Nelson, 1987; Gulding, et. al., 1999) – and the dose-response model (Schultz, 1978; Hede and Bullen, 1982)¹ – to calculate the number of people adversely affected (annoyed) by aircraft noise within different contours of noise level descriptors. Typically, a noise management plan would be formulated to mitigate or minimize impacts drawing on measured approved by the International Civil Aviation Authority (ICAO, 1993). Civil engineers, acoustical engineers, and land-use planners (dose-response relationships are used in practice to identify land-use compatibility around airports) dominate this technical field, largely to the exclusion of other disciplines.

If this problem of aircraft noise and the community were recast within a trans-disciplinary framework then more disciplinary perspectives would be included in problem definition, hypotheses to test, data collection, statistical analysis and model building. Studying impacts of aircraft noise on environmental health and well-being requires an understanding of the medical literature – which is extensive on aircraft noise and individual health² - epidemiology, social surveys, acoustical properties of noise, and multivariate statistics.

Such a team might scope problem on aircraft noise and community health and well-being with previous research (see, Issarayangyun, 2005) classified as in Figure ?? . The diagram indicates how noise can affect human health Environmental noise disturbs community daily activities (for example, watching TV, listening radio, sleeping, conversation, or studying). The reactions of people to those disturbances are different. Most people are annoyed by those disturbances. Some of them can habituate (or get use to it), or even avoid it (by moving residence), or modify their activities in these noisy places. In susceptible people, noise intrusion into their home makes them angry and stressful. Suffering from chronic stress can lead to health problems that can be either physiological or psychological. Our research team formulated two research questions based on gaps in previous research (*"Is health related quality of life worse in communities chronically exposed to aircraft noise than in communities not exposed?"* and *"Does long-term aircraft noise exposure associate with adult high blood pressure level via noise stress as a mediating factor?"*).

environmental impacts. Sustainability constraints are important political drivers of any contemporary transport investigation. The Australian Government's Ecologically Sustainable Development (ESD) Transport Working Group of 1991 provided the first consolidated set of recommendations on how to achieve a more sustainable transport sector in Australia, although appropriate analytical techniques were not addressed (Black, 1996). Suitable models for analysing the properties of the sustainable city remain a research challenge that we now attempt to address through the trans-disciplinary approach.

3 SYSTEMS ANALYSIS AND TRANS-DISCIPLINARY APPROACHES

Systems analysis has been extensively applied in urban transport. Advances in computing allowed massive amounts of data on land use activities, travel patterns and transport supply characteristics to be stored and manipulated. Models were derived from analogies from the physical and social sciences. The systems approach remains relevant to the needs of contemporary practice at the beginning of the 21st Century and still forms the framework around which transport studies at the national, regional, sub-regional, and local scales are designed. Books formalising the systems planning or the systems engineering process appeared after the publication of the Special Issue (McLoughlin, 1969; Wilson, *et. al.*, 1969; Chadwick, 1971)

4 AIRCRAFT NOISE AND PUBLIC HEALTH

"Transdisciplinary thinking is primarily a process of assembling and mapping the possible interconnections of disciplinary knowledge about any given health problem until the fullest possible understanding of the problem emerges" (Higginbotham *et al*, 2001, p.75). Applying this definition to our locus of interest is straightforward by substituting the word "transport" for "health". Of course, modelling is but a part of a larger understanding of any given problem but for the purposes of this paper on modeling challenges it is convenient to contrast traditional modeling approaches within a systems planning and engineering framework with those requirements under trans-disciplinary approach. First, let us consider current practice in airport planning (see, Horonjeff and McKelvey, 1994) and the problem of noise, where there are two important models: that of aircraft noise, and that of community response to that noise that are applicable in environmental impact assessment of airport development proposals.

techniques were consolidated into books (Creighton, 1970; Blunden, 1971; Bruton, 1971) whose markets were predominantly engineers and planners.

In a period of rapid urban growth spatial restructuring the preparation of future land-use plans and socio-economic forecasts proved vexatious issues. Two distinctly different modelling approaches emerged in the 1960s to overcome the deficiencies exposed in the four-step modelling process: optimisation models and integrated land-use and transport modelling (Lowry-type models and derivatives). The United Nations Urban Renewal Plan for Singapore applied linear programming to determine the best spatial distribution of land uses. Lowry models limited exogenous inputs to the geographical locations of “basic” employment in zones (implicitly within the powers of the planning authority to implement) and then, in iterative loops, the model generated service employment locations based on accessibility concepts finally converging to a stable amount of total zonal employment.

Public transport investment was largely ignored in the US transport studies with their emphasis on highway solutions and the aggregate models of modal split were somewhat superficially applied. However, important research into individual choice emerged in the late 1960s (Lisco in the USA; and Quarmby and Stopher in the UK) that later paved the way for the development of logit and multi-nomial logit models of mode choice that are now firmly embedded into urban transport planning practice. Importantly, these models contained attributes of the different transport modes – such as in-vehicle time, waiting time and costs – and were able to demonstrate how investment in public transport service frequency and route coverage as well as pricing policies would alter mode choice. The development of individual (discrete) choice models in the 1970s paralleled a change in highway investment policy from “predict and provide” to transport system management (TSM) – or getting more out of the existing facilities – and, later, travel demand management (TDM).

3 ENVIRONMENTAL MODELS AND SUSTAINABILITY CRITERION

Environmental legislation, introduced in the USA in 1969, and in other countries, required the environmental impacts of projects to undertaken in the form of environmental impact statements (EIS). The modelling requirements were different to that of travel demand estimation: the framework contained issues such as what is the magnitude of the impact (with the project)? what is the size of the population exposed to that impact? And, how can adverse impacts best be mitigated and managed? A suite of environmental and social impact models have been developed for areas such as vehicle emissions, transport noise, traffic accident risk, visual intrusion of infrastructure, and social exclusion. Dose-response relationships (see Section ?) are important models for social and health impact assessment.

Decision makers evaluate transport plans, projects and policies on sustainability criteria: the “triple bottom line” of economic, social and

In addressing these challenges in a complex system we suggest that the analysis and modelling of a “sustainable city” are best arranged within a transdisciplinary framework, and show the results of examples of our research drawing on medical science concepts that has involved multi-disciplinary teams. Specifically, we examine major airport developments and the impact of aircraft noise on community health, and quality of life adjusted years concepts to evaluate residential locations and their “chance of livability” under conditions of planned retreat and reconcentration (Hayashi and ??).. Thus, the modelling paradigm has shifted to embrace land use, transport and the environment – where the latter clearly means the social (and health), economic and natural environments. Finally, we speculate on the type of land use, transport and environmental models that may be required in the coming decade.

2 LAND USE AND TRANSPORT MODELLING THEMES

The Special Edition of the Journal of American Planners opened the eyes to planners on operational urban modelling possibilities in a profession where land-use plans were inspired more by the “artist’s brush” than rigorous analysis (Blunden, 1971). Hitherto, the engineers, especially the highway and traffic engineers had largely dominated the field. Rapid motorisation in the USA in the 1940s and 1950s spawned a new profession of traffic engineers, typified by Alan Voorhees who was instrumental in 1955 in introducing the gravity model into practice¹. Previously, the master plans for highways were based on traffic counts and an extrapolation of demand into the future that essentially produced a ring radial freeway solution to a fixed future land-use plan.

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1. In the 1880s, German railway engineers applied an unconstrained gravity model to estimate passenger traffic for planned inter-city routes. A production constrained gravity model was applied in an urban transport study in Stockholm in the late 1940s.
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The urban transport planning process that emerged from the Detroit and Chicago comprehensive land-use and transportation studies of the 1950s recognised that planning for transport required a systematic understanding of land-use patterns from which travel patterns are derived (Mitchell and Rapkin, 1954; Oi and Schuldiner, 1956). The aggregate, four-step models of traffic demand and transport supply required exogenous inputs of land use. It was six years after the publication of the Special Issue that these modelling

**PAPER 280 A TRANSDISCIPLINARY FRAMEWORK:
CHALLENGES IN MODELLING THE SUSTAINABLE CITY**

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1 INTRODUCTION (VERY DRAFT)

We locate this research into a transdisciplinary framework (Higginbotham, *et. al.*, 2001) and illustrate connections with medical science in the formation of multidisciplinary teams researching quality of urban life issues.

First, we review briefly the mainstreams of modelling in transport during the past 40 years – optimization approaches, aggregate four-step forecasting, individual choice models, and integrated land use and transport models. We note the importance of the systems approach as an organising framework for research and practice (Black, 1981, Chapter 1) and the early connection between transport and “land use”. We use this systems framework to articulate the dominant goals and values of a sustainable approach to urban transport under aging societies in developed countries and growing societies in developing society both of which under a tight financial and time constraints.