TRANS-DISCIPLINARY FRAMEWORK: CHALLENGES IN MODELLING THE SUSTAINABLE CITY

John BLACK
Foundation Professor of Transport Engineering
The University of New South Wales
Sydney, NSW 2052
Australia
Tel: +61 29 385 5018
Fax: +61 29 385 6139
E-mail: j.black@unsw.edu.au

Yoshitsugu HAYASHI
Professor
Graduate School of Environmental Studies
Nagoya University
Chikusaku Furouchou, Nagoya,
464-0814 Japan
Fax: 81-52-789-3837
E-mail: yhayashi@genv.nagoya-u.ac.jp

Abstract: Research challenges for urban modellers are described in a trans-disciplinary framework. 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 – are reviewed and their deficiencies for modelling sustainability issues are exposed. We suggest that analysis and modelling of a “sustainable city” are best arranged within a trans-disciplinary framework, and show the results of two examples of our research that draws on medical science concepts of quality of life. 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 “potential of liveability” under conditions of planned retreat and re-concentration. Finally, we speculate on the type of land use, transport and environmental models that may be required in the coming decade.

Keywords: Trans-disciplinary, transport models, quality of life, compact city

1 INTRODUCTION

Researchers and practitioners of urban modelling have created a global social sub-system. The cities they analyse contain “wicked” problems, where the interaction of economic, environmental and social forces demands that new and creative ways of thinking are applied that can rise to the challenges of greater complexity. Making cities more sustainable is likely to dominate the policy and research agenda for the foreseeable future. A trans-disciplinary mode of thinking about cities (and urban modelling) aims to create the richest possible identification of problems and issues about sustainability and how they may be addressed, including the role of models in the policy formulation, evaluation and implementation phase.

In May 1965, the Special Edition of *the Journal of American Institute of 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 scientific analysis (Blunden, 1971). Hitherto, highway and traffic engineers, had largely dominated the modelling field. The diversity of disciplinary backgrounds lead later 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 (Ben Bouanah and Stein, 1978).

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 draw on two examples from our research and illustrate connections with medical science in the formation of trans-disciplinary teams researching quality of urban life issues. Quality of life adjusted years concepts to evaluate residential locations and their “potential of liveability” under conditions of planned retreat and re-concentration (Section 4), and modelling the impact of aircraft noise on environmental health (Section 5), are selected as illustrative examples of the seven key stages of trans-disciplinary thinking.

The challenges are great, and the territory vast, so we hope the philosophy of the trans-disciplinary approach proposed will be adopted, even mutating into higher-order approaches in modelling when the 50th Anniversary of the Special Edition is celebrated. We apologise for being speculative, but then so too was William Garrison when being invited to write in the Special Edition about future directions for urban transport models ten years down the track (Garrison, 1965). New ways of thinking about discipline integration are under constant development through our leaderships of the Botany Bay Studies Unit and the Laboratory for Sustainable Transport and Spatial Development. We trust that readers will find the arguments persuasive enough for them to advance this trans-disciplinary framework without resort to full scholarly referencing conventions in the pages that follow, but a bibliography is available from the authors.

2 THEMES IN LAND USE, TRANSPORT AND ENVIRONMENTAL MODELS

In the (then) new profession of traffic engineering – there was 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 physics, operations research and queuing theory. One “high priest” was Alan Voorhees, who was instrumental in 1955 in introducing the gravity model into practice. Previously, the master plans for highways had been based on traffic counts and an extrapolation of demand into the future made by highway engineers (who were part of the Civil Engineering fraternity). They designed ring-radial freeway solutions to a fixed future land-use plan.

The urban 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. The aggregate, four-step models of traffic demand and transport supply required exogenous inputs of land use. It was five to six years after the publication of the Special Edition of the *Journal of the American Institute of Planners* that these modelling techniques were consolidated into books whose markets were predominantly engineers and planners.

In a period of rapid urban growth and 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 zone employment.

Public transport investment was largely ignored in the US transport studies with their emphasis on highway solutions. The aggregate models of modal split were somewhat superficially applied. However, important research into individual choice emerged in the1960s (Tom Lisco in the USA; and David Quarmby and Peter Stopher in the UK) that later paved the way for the development of logit and multi-nomial logit models of transport mode choice that are now firmly embedded into urban transport planning software. 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 5) are important models for social and health impact assessment.

Today, decision makers 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 most contemporary transport investigations. For example, 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. Elsewhere, research into goals and objectives and performance indicators for the evaluation of alternative strategies and instruments has greatly advanced. Suitable urban 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 a problem - modelling land use, transport and a sustainable environment. 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 party.

The trans-disciplinary approach transcends boundaries so that research is committed to exploring fully the boundaries (or even stretching them) of the specific problem under investigation. It does this 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 be a challenge 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 will probably have specialised knowledge that can be brought to bear on the research problem if wisely managed.

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, el. al., 2001, Table 4.1, p. 72)

Albrecht (*et. al.,* 2001, pp. 80 – 81) have identified seven key stages when conducting trans-disciplinary research. These follow similar lines as the systems approach – aims and objectives, data collection, understanding through models, forecasting, alternative solutions, evaluation and appraisal, and recommendations for implementation.

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.

3 QUALITY OF LIFE AND MODELLING CHALLENGES

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, as fore shadowed by Garrison (1965). The systems approach remains the foundation 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, other 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. However, the transport models still applied today were developed in an era of growth and development.

Research in this arena from a trans-disciplinary perspective is sufficiently advanced so as to suggest a common conceptual framework (Figure 1), where it should be emphasised the background to the problem involves geography, the natural sciences (climatology) and the social sciences before focusing on the current state of transport and the environment. We suggest this as a common conceptual framework because of its derivation from extensive international collaborative research team and the inevitable compromises that arise when a panel tries to agree on its detailed content (WCTRS and ITPS, *et al*, 2004, for details).

The general goals can be expressed as an action to prepare a set of “policies” to achieve sustainable cities and regions as one of its objectives, through the systematic analysis (modelling) and appraisal of alternative strategies. For sustainable cities and regions, there are alternative planning objectives including efficiency, liveability, equity, safety, economic growth, considering current and future generations, other than environment (Figure 1), as also pointed out by Himanen, (*et. al*., 2005).

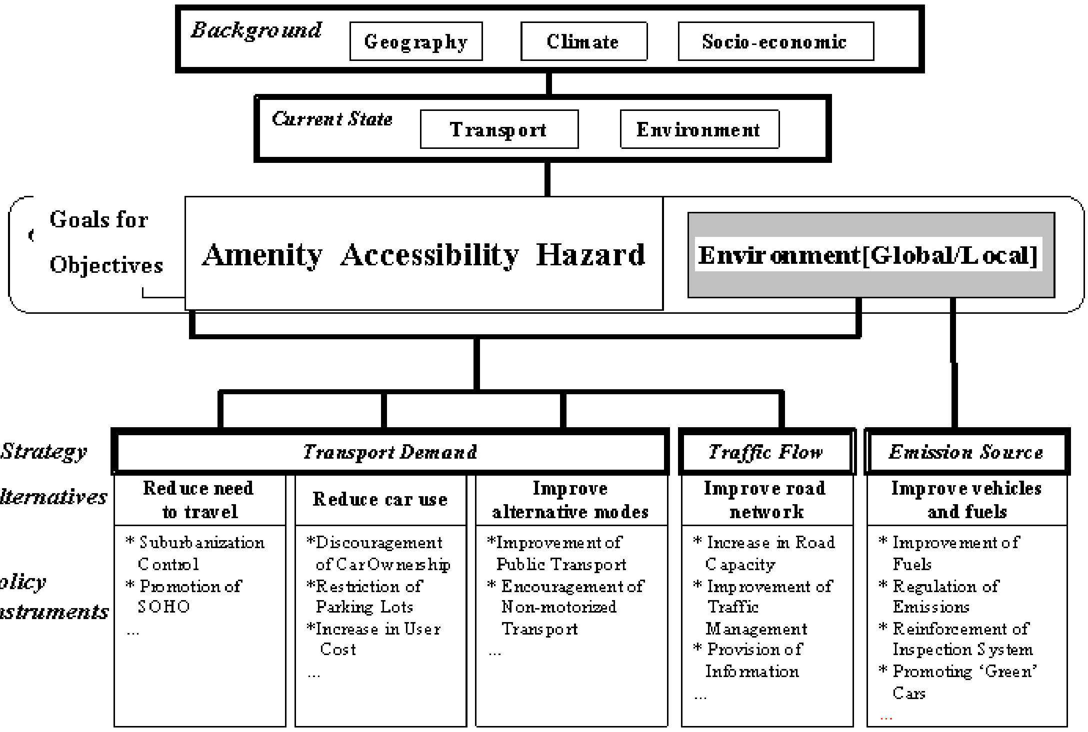

Figure 1 Common Conceptual Framework for QOL Objectives and Alternative Strategies and Policy Interventions

(Source: based on WCTRS and ITPS, *et al*, 2004)

Specifically, when applying this common conceptual framework to Japan, the country will experience a dramatic decline in population with an associated regression in the economy in the near future. Given this national problem of a change in socio-economic structure, the challenge is to reduce built-up areas in the suburbs and so save on infrastructure and maintenance costs over the long term and encourage more compact city living. 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 to key stakeholders and the general public in a convincing manner, and given the inadequacies in existing models identified in Section 2 above, a methodology is being developed to measure quality of life (as derived from the medical literature) based on the satisfaction of an individual based on several components that can be integrated in Quality of Life (QOL) indicators (Hayashi and Sugiyama, 2003).

To achieve sustainable cities and regions, QOL is to be maximised under the constraints of environmental, financial and social sustainability. As income and car ownership has grown, the life style of people changes, with an end result of greater suburbanisation. This can be explained by the shift of weight between the factors determining Quality of Life (QOL), composed of five factors: employment and income opportunity; cultural life opportunity; amenity of life; security and safety; and environmental burden (Figure 2). Chadwick

(1971, p. 259) also pointed out criteria values are likely to change over time with changes in life style.

In the early stage of economic development, peoples' interests are mainly employment and income, as seen in the phenomenon of urbanisation where people migrate from farming regions to cities to seek better employment prospects. But as income grows, people tend to have interest in the other factors such as cultural life, amenity, security and, eventually, environmental sustainability. Such a shift in perception of QOL progresses under the surface physical phenomena of the progression of different urbanisation stages, and this is the real cause for the growing demand for suburban space.

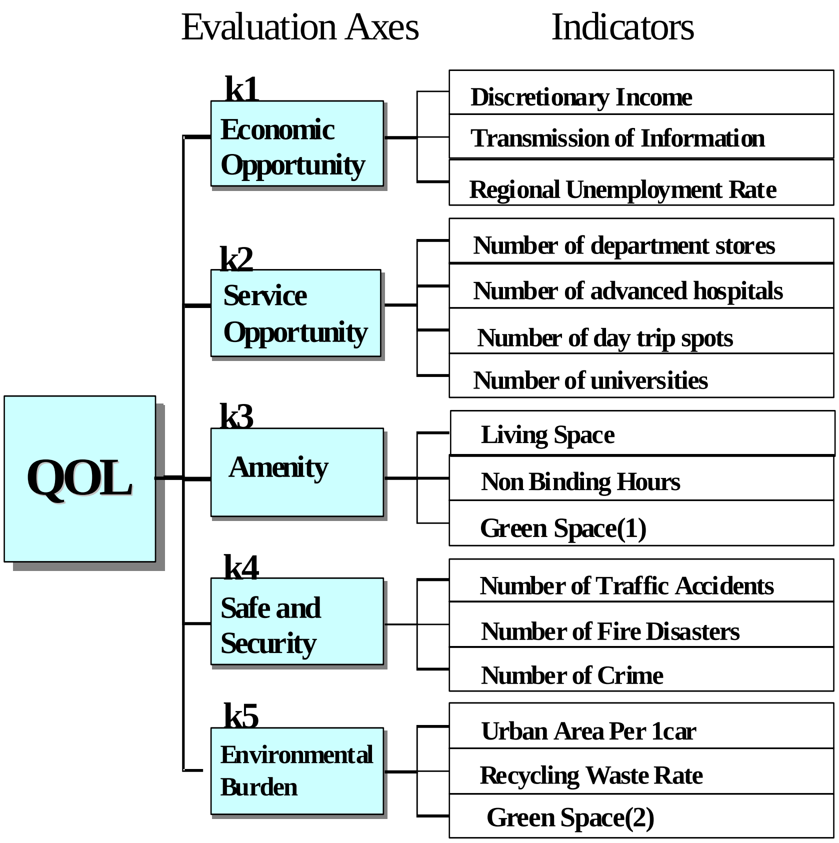

Figure 2 Overall Quality of Life (QOL) Objective and its Component Objectives and their Goal Indicators

The formulation of this concept into an operational model is a key challenge so as to demonstrate to the public and decision makers the trade-offs between suburban and more compact living, including visualisation. The current land-use condition makes it difficult to directly solve the optimisation problem. In Figure 3, Social Value index is not only for solving the optimisation problem for land-use distribution by maximising QALY, but also for evaluating land use to identify planned retreat and re-concentration areas. A QALY (Quality Adjusted Life Year) index is one means to evaluate quality of life in urban locations. The QALY index represents how long each individual lives with the situation of a particular level of quality of life. This 'liveability', includes location attributes (accessibility, amenity, and hazard) in each area, and individual preferences for these location attributes. A Social Value index means an increase in the rate of QALY against an input cost in each zone. The change of quality of life accompanied with a change in land use and transport system context, and with changes in preferences, may be estimated.

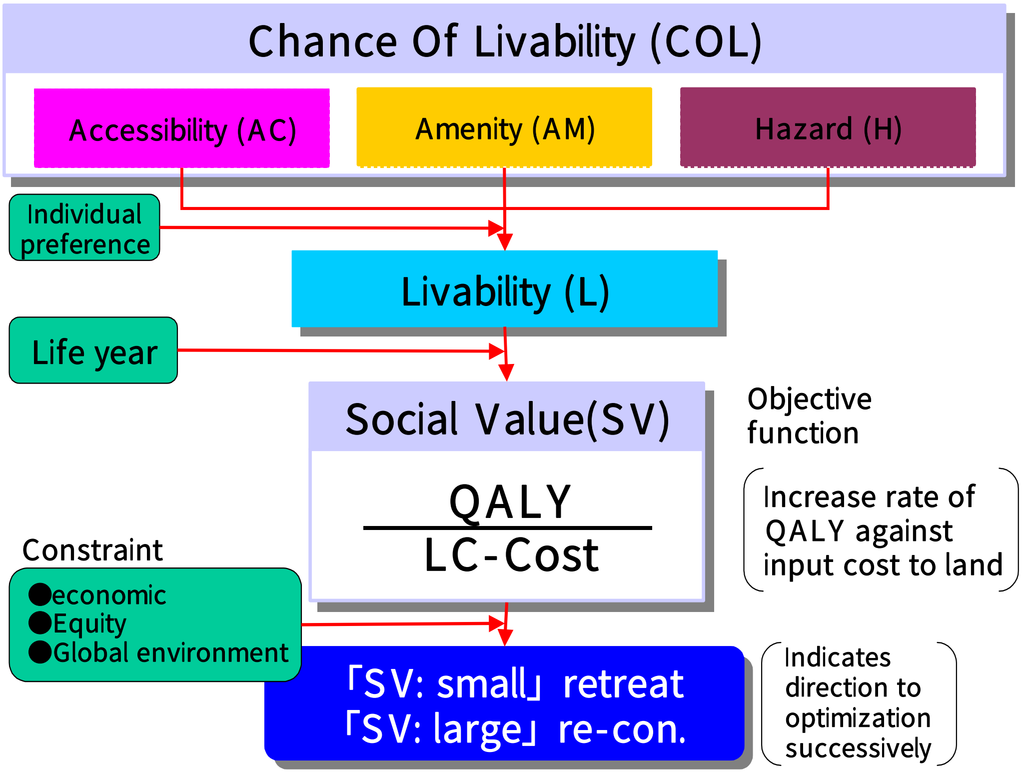

Figure 3 Framework for Target Oriented Modelling for Restructuring Urban Form based on Livability Maximizing Approach

Although location attributes are the same, liveability might be different according to each individual preference – that is, the importance to which individuals attach accessibility, amenity and hazards. First, accessibility is the opportunity to participate in activities in different locations. Thus, accessibility refers the extent to which the land use and transportation system enables groups of individuals or goods to reach activities or destinations by means of a transport mode. Secondly, amenity includes the natural environmental features that exist in the target zone, living comfort, which mainly depends on the condition of each house, townscape, noise and air quality. Thirdly, hazard includes the risk of earthquake, flood, crime, traffic accidents that are expressed by their damage and probability. In particular, the risk of earthquake and flood in Japan depends on the geotechnical conditions and the properties of each building. Individual preference is expressed by weights of three “Potential of Liveability” components which may change over time. A detailed description of this land use, transport and environmental evaluation model as a tool for different urban and suburban development scenarios can be found in Kachi (*et. al.,* 2005).

5 AIRCRAFT NOISE AND ENVIRONMENTAL HEALTH

Whereas the previous section articulated the trans-disciplinary approach with an example of a common conceptual framework and some challenges in making an operational model of quality of life in urban and suburban areas, the aim of this section is to work through, and illustrate, all steps of the process. The second example of research into one of the amenity indicators of Figure 2 – environmental noise - drills down in more detail by illustrating all seven elements of the process when examining health-related quality of life.

Current practice in airport planning (see, Horonjeff and McKelvey, 1994) and the problem of noise, involve two models: that of aircraft noise, and that of community response to those noise levels. 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; Fidell, *et. al*., 1991) – to calculate the number of people adversely affected (annoyed) by aircraft noise within different contours of noise level descriptors.

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. 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. 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 (Tharit Issarayangyun), 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 quality of life requires an understanding of the medical literature – which is extensive on aircraft noise and individual health (see, for example, Kryter, 1994) – 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 research team 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 – data collection and multivariate statistical analysis – and a few selected comments on this phase of the research. A self-administered questionnaire was designed, building on standard questions from the Harvard University SF-36 health status (Ware, 2000; Ware *et. al*. 1993). A description of both the pilot and the 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).

A total of 796 responses were returned, of whom 704 filled in the questionnaire and 92 indicated unwillingness to participate in the survey. The number of responses from subjects in the control group was a little bit lower than from the noise exposure area. The total sample sizes of each group were sufficient to detect the 5-point differences in health measures between groups as required by SF-36's developers at the 5% level of significance with a power of 80%. It is important to note that this research has assumed that long-term aircraft noise has indirect negative community health and well-being impacts. Consequently, subjects who have resided in their existing residence for less than 1 year are excluded from the study. In the total sample, there were 33 (8.9%) of 372 from the noise exposure group and 16 (4.8%) of 332 from the control group who have lived in their existing residence for less than one year. These subjects were, therefore, excluded from the study. Thus, the total sample size becomes 339 for the noise exposure group and 316 for the control group.

Table 2 compares the demographic characteristics and socioeconomic status of both study groups. In the total sample, age ranges from 15 to 87. The distributions of age were considered normal in both groups with no outliers. For example, he mean age of the control group was approximately four years higher than the noise exposure group. From student t-test, it was found that this difference was statistically significant (*p-value* = 0.001). Other statistical comparisons of variables are shown in the table.

Table 2: Demographics and Socioeconomic Status by Study Area, Noise Exposure (Mascot) and Control Group (South Penrith)

Variable	Noise Exposure Group	Control Group	*p-value*
Mean age (year)	46.63 (SD=15.57)	50.85 (SD=15.22)	0.001
Sex (% female)	190 (56.0%)	209 (66.1%)	0.009
Body Mass Index			0.006
Obesity	55 (16.2%)	81 (25.6%)	
Overweight	104 (30.7%)	90 (28.5%)	
Acceptable weight	132 (38.9%)	91 (28.8%)	
Underweight	25 (7.4%)	18 (5.7%)	
Education			<0.001
Bachelor degree or higher	118 (34.8%)	37 (11.7%)	
Certificate - Diploma	106 (31.3%)	144 (45.6%)	
High school or lower	108 (31.9%)	131 (41.5%)	
Employment status			0.003
White collar	167 (49.3%)	118 (37.3%)	
Blue collar	50 (14.7%)	64 (20.3%)	
Unemployed	19 (5.6%)	13 (4.1%)	
Not in labour force	94 (27.7%)	119 (37.7%)	
Marital status			<0.001
Married/De facto	186 (54.9%)	219 (69.3%)	
Widowed/Divorded/Separated	55 (16.2%)	64 (20.3%)	
Never married	93 (27.4%)	29 (9.2%)	
Smoking status			0.014
Current smoker	76 (22.4%)	44 (13.9%)	
Ex-smoker	98 (28.9%)	108 (34.2%)	
Never smoke	149 (44.0%)	153 (48.4%)	
Alcohol consumption			0.623
High	54 (15.9%)	43 (13.6%)	
Low	186 (54.9%)	183 (57.9%)	
None	68 (20.1%)	68 (21.5%)	
Exercise activity level			0.034
High exercise	59 (17.4%)	40 (12.7%)	
Moderate exercise	77 (22.7%)	66 (20.9%)	
Low exercise	134 (39.5%)	122 (38.6%)	
Sedentary	58 (17.1%)	82 (25.9%)	
Household weekly income			0.451
Over AUD$2,000	33 (9.7%)	22 (7.0%)	
AUD$401 - AUD$1,999	225 (66.4%)	214 (67.7%)	
Under AUD$400	68 (20.1%)	66 (20.9%)	
Acoustic Insulation			<0.001
Yes	126 (37.2%)	9 (2.8%)	
No	198 (58.4%)	286 (90.5%)	
Nutrition			0.135
Salty food	54 (15.9%)	65 (20.6%)	
No salty food	277 (81.7%)	246 (77.8%)	

Table 3 compares health and related measures of subjects between study groups. Most of the health measures of the noise exposure group were lower than the control group, implying that the health-related quality of life of residents was worse than the control group. However, without any control for covariates, analysis of variance (ANOVA) found almost all of these differences (except Mental Health Score) were not statistically significant. The proportion of people with hypertension in the control group was slightly higher than in the noise exposure group. However, this difference is not statistically significant (***p-value*** = 0.450). The proportion of hypertensive in parent(s) and high cholesterol level in the noise exposure group was higher than the control group, but these differences were also not statistically significant.

Table 3: Descriptive Statistics of Health and Related Measures by Study Groups

Variable	Noise Exposure Group	Control Group	*p-value*
Mean Physical Functioning Score	79.09	79.23	0.941
Mean General Health Score	64.49	66.08	0.370
Mean Vitality Score	54.58	57.02	0.128
Mean Mental Health Score	68.02	73.53	<0.001
Hypertension	51 (15.0%)	55 (17.4%)	0.450
Hypertension in Parent(s)	154 (45.4%)	132 (41.8%)	0.297
High Cholesterol Level	62 (18.3%)	47 (14.9%)	0.215
Mean Noise Stress Score	6.44 (SD=2.31)	4.25 (SD=1.93)	<0.001
Mean Noise Sensitivity Score	27.76 (SD=7.92)	26.97 (SD=7.38)	0.193
Mean Aircraft Noise Annoyance	6.27 (SD=3.04)	1.03 (SD=2.01)	<0.001
Mean Traffic Noise Annoyance	2.61 (SD=2.57)	1.96 (SD=2.31)	0.001

Residents in the noise exposure group were more sharply annoyed by aircraft noise (*p-value* < 0.001) than the control group. Even though, the level of traffic noise annoyance between both groups was slightly different, it was statistically significant (*p-value* = 0.001). This might reflect the fact that the noise as measured by $L^{B}_{Aeq,(7am\text{-}6pm)}$ of the control group was lower than the noise exposure group. The level of noise sensitivity between both groups was not significantly different (*p-value* = 0.193). Thus, subjects from the noise exposure area have a high level of noise stress (*p-value* < 0.001) than the control area. Apparently, this noise stress is largely due to the exposure of aircraft noise. The mean difference of the SF-36 scale between groups was investigated using the analysis of covariance (ANCOVA) technique (see, Issarayangyun, *et. al*., 2005).

Adjusted mean scores of General Health were 63.4 for the control group and 60.2 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 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. The strength of association is weak (η^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, 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 Ltd.) and the airlines. Sydney airport, along with many commercial airports of the world, implement environmental management plans. Our survey of airport websites has identified gaps as with no mention of the health impacts of aircraft noise.

6 CONCLUSIONS

Urban modellers in the past have been used to working in a multi-disciplinary environment so it should not be a radical departure to locate research and development within a trans-disciplinary framework as outlined in Section 3. A lag would be expected for professional acceptance, as also pointed out by Garrison (1965). For transport policy makers, the common conceptual framework proposed in Figure 1 is sufficiently robust to accommodate the various technical inputs (including models) to meet the challenges of trying to achieve more sustainable development patterns.

Our own view is that the dominant economic planning objective of the past has to be buried in the quest for more universal evaluation criteria, such as being replaced by a higher order social objective, namely quality of life. The urban models of the future will enlighten us on selected dimensions of quality of life. For example, we have partitioned quality of life into five key objectives each with corresponding goal performance indicators (Figure 2), although, clearly such a list may be expanded or contracted to meet the specific modelling context. Because of limitations on data we have modelled accessibility, amenity and hazard. Thus, one modelling challenge is to refine this list, to overcome data constraints, and build operational models. We have started with the city of Iida, (Japan, pop: 100 000) using accessibility, residential amenity and risk of natural disasters (Kachi, *et. al*. 2005).

The illustrations of the trans-disciplinary framework proposed have been drawn from our own research on quality of live of suburbs and of health-related quality of life and aircraft noise, but the globalisation of urban modelling would guarantee that there are better examples elsewhere. We would welcome hearing of that experience. It seems to us that the concrete challenges ahead is to formulate a general model to estimate QOL for different segments of the population, because of the importance of socio-economic structures we have identified (see case study in Section 5). Values change over time, and a challenge is to demonstrate historically how the perceptions and weights associated with each QOL objective has changed, and how such weights might be estimated for future generations and so tackle transitions and inter-generational equity issues.

Trans-disciplinary thinking respects the richness of community input, and future plans require a more community-based approach. To help imagine the future (see, for example, Sugihara and Hayashi, 2005), all of the explanatory variables of relevance and model outputs that need to be forecast require visualisation of some form. This is precisely where, technically, so many important contributions have been made by members of the Conference on Computers in Urban Planning and Management, and will continue to be made. Making cities more sustainable is likely to dominate the policy agenda for the foreseeable future, requiring the application of the most creative minds in urban modelling.

ACKNOWLEDGEMENTS

A large number of colleagues and students, too numerous to list, have helped with the ideas expressed in this paper; they are acknowledged in the publications that underpin this paper. However, special thanks is given to: Associate Professor Deborah Black (Faculty of Medicine, UNSW), Dr Susan Boyd-Irvine (Health Matters, Sydney), Professor Kenji Doi (Kanagawa University), Mr Tharit Issarayangyun (Doctoral Candidate, UNSW), Mr Noriyasu Kachi (Nagoya University), Associate Professor Hirokazu Kato (Nagoya University), Professor Hideo Nakamura (President, Musashi Institute of Technology), Professor Tony May (Leeds University), Professor Kazuaki Miyamoto (Musashi Institute of Technology), Dr Stephen Samuels (Faculty of Engineering, UNSW), Professor Kenichi Sugihara (Gifu - Keizai University), Dr Ikuo Sugiyama (Nikken Sekkei Civil Engineering Ltd.), and Professor Yasuo Tomita (Kobe University).

REFERENCES

a) Books and Books chapters

Albrecht G., Higginbotham, N. and Freeman, S. (2001) Transdisciplinary thinking in health social science research: Definition, rationale, and procedures. In N. Higginbotham, G. Albrecht, and L. Connor, (eds.) **Health Social Science: A Transdisciplinary and Complexity Perspective**. Oxford University Press, Melbourne.

Blunden, W. R. (1971) **The Land-Use/Transport System: Analysis and Synthesis**, Pergamon Press, Oxford.

Chadwick, G. (1971) **A Systems View of Planning: Towards a Theory of Urban and Regional Planning Process**, Pergamon Press, London.

Hennekens, C. H., Buring, J. E., and Mayrent, S. L. (1987). **Epidemiology in Medicine**, Little, Brown, and Co, Boston, MA.

Horonjeff, R., and McKelvey, F. (1994). **Planning & Design of Airports**, **4th ed.**, McGraw-Hill, International Editions, New York.

Kryter, K. D. (1994). **Handbook of Hearing and the Effects of Noise Physiology, Psychology, and Public Health**, Academic Press, San Diego.

WCTRS and ITPS, Nakamura, H., Hayashi, Y. and May, A. D. (eds.) (2004) **Urban Transport and the Environment – An International Perspective**. Elsevier, Amsterdam.

b) Journal papers

Ben Bouanah, J. and Stein, M. M. (1978) Urban transportation models: A generalized process for international application, **Traffic Quarterly, Vol.**

32, .449 – 470.

Fidell, S., Barber, D. S., and Schultz, T. J. (1991). Updating a dosage-effect relationship for the prevalence of annoyance due to general transportation noise, **Journal of Acoustics Society of America, Vol. 89, No. 1**, 221-233.

Garrison, W. L. (1965) Urban transportation planning models in 1975, **Journal of the American Institute of Planners, Vol. 31, No. 2**, 156 – 157.

Hayashi, Yoshitsugu and Sugiyama, Ikuo（2003）Dual strategies for the environmental and financial goals of sustainable cities: De-suburbanization and social capitalization, **Built Environment, Vol. 29, No.1**, 8-15.

Himanen, V. Lee-Gosselin, M. and Perrels, A. (2005) Sustainability and the nteractions between external effects of transport, **Journal of Transport Geography Issue 13**, 23-28.

Kachi, N., Kato, H., Hayashi, Y. and Black, J. (2005) Making cities more compact by improving transport and amenity and reducing hazard risk, **Journal of the East Asian Society for Transport**, **Vol. 6** (In Press).

Schultz, T. J. (1978). Synthesis of social surveys on noise annoyance, **Journal of Acoustics Society of America, Vol. 64, No. 2**, 377 – 405.

Ware, J. E. (2000). SF-36 Health Survey update, **SPINE, Vol. 25, No. 24**, 3130-3139.

Ware, J. E., and Sherbourne, S. D. (1992). The MOS 36-Item Short-Form Health Survey (SF-36): I. Conceptual Framework and Item Selection, **Medical Care*,* Vol. 30**, 473-483.

c) Papers presented to conferences

Issarayangyun, T., Black, J., Black, D. and Samuels, S. (2005) Aircraft noise and environmental health: A trans-disciplinary approach, **28th Australasian Transport Research Forum, Sydney, 28 - 30 September 2005.**

Sugihara, K. and Hayashi, Y. (2005) 3-D Building model automatically generated from building contour partitioned, **Conference on Computers in Urban Planning and Management, London, 29 June – 1 July.**

d) Other documents

Gulding, O., Mirsky, B and D’Aprile Gerbi, F. (1999) Integrated Noise Model (INM) version 6.0 user’s guide, Office of Environment and Energy, Final Report 1/97 – 9/99, Federal Aviation Administration, Washington, DC.

ICAO (1993), Environmental Protection, International Standards and Recommended Practices, Annex 16, Vol. 1, Aircraft Noise, 3rd Edition, International Civil Aviation Organization, Montreal.

Ware, J.E., Snow, K.K., Kosinski, M. and Gandex, B. (1993) SF36 Health Survey Manual & Interpretation Guide, The Health Institute, New England Medical Center, Boston.