TRANSDISCIPLINARY FRAMEWORK FOR TRANSPORT RESEARCH: AIRCRAFT NOISE AND ENVIRONMENTAL HEALTH

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Abstract: Annoyance, in the form of dose-response relationships, is the basis of compatible land-use planning around airports throughout the world. This method is inadequate in the fuller understanding of the community impacts of aircraft noise. A trans-disciplinary research design to a study of aircraft noise and environmental health is applied using Sydney Airport as a case study. A postal, self-administered, questionnaire on individual health and well-being was implemented in noisy areas surrounding Sydney Airport and in a control area of South Penrith. The total sample size was 1,500 with a 47% response rate. This paper describes the trans-disciplinary approach taken, and gives an overview of the methods, key findings and policy implications of this social survey research. The areas covered are: (1) the review of the disciplinary knowledge about epidemiology, social surveys, characteristics of environmental noise (especially aircraft noise), and the effects of environmental noise on community; (2) an overview of practices of aircraft noise management strategies in major commercial airports; (3) the development of a comprehensive health survey instrument for the evaluation of community health and well-being impacts by aircraft noise that draws on the international health self-assessment form, SF-36; (4) the development of a 'new' noise index to describe and assess aircraft noise that is easily understood by a layperson, and fully reflects community responses toward aircraft noise; and (5) statistical methods to explore two core 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?"*).

Keywords: Trans-disciplinary Approach, Aircraft Noise, Environmental Health

1 Introduction

The Australasian Transport Research Forum (ATRF) has, from its inception thirty years ago, attracted studies of transport from a variety of disciplines. Professional practice on large, complex transport projects involves multidisciplinary teams. Nevertheless, the scope of investigations needs broadening to a societal context that embraces land use, transport, a sustainable environment (social, economic, physical) and environmental health. Transport research therefore should be located within a framework of transdisciplinary thinking. Such a framework is introduced here, and its main steps are illustrated with particular reference to a research study completed on aircraft noise and environmental health.

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2 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) p75). Acquiring knowledge about a substantial transport problem requires a trans-disciplinary mode of thinking. Our aim in applying this framework to transport is to understand process and change (infrastructure expansion and increased aircraft traffic) and to create the richest possible description of the context within which the problem – in our case that of aircraft noise - occurs.

Table 1 compares and contrasts the character of trans-disciplinary approaches to transport 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.

Table 1 Approaches to the Analysis of Transport Phenomena (source: Albrecht *et al* (2001) Table 4.1 p 72)

Approach	Problem & Boundary	Conceptual Framework - Role
Single discipline	What a single discipline thinks it is	Arises from single discipline
Multidisciplinary	What several disciplines working independently think it to be; hard disciplinary boundaries placed around problem components	Mutually exclusive conceptualisations juxtaposed
Interdisciplinary	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
Transdisciplinary	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

A trans-disciplinary approach is committed to fully exploring the boundaries of a transport problem by drawing upon disciplinary-specific theories, concepts and approaches. It promotes cooperation amongst disciplines, and encourages teamwork in an open-ended collaboration. All disciplinary insights are assembled to define (and re-define) a complex problem and to discover a common element in apparently disparate components.

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.

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 widely employed by engineers – aims and objectives, data collection, understanding through models, forecasting, alternative solutions, evaluation and appraisal, and recommendations for implementation. In the next section we illustrate the following trans-disciplinary steps with particular reference to aircraft noise and environmental health.

1) Problem identification.
2) Assemble a group (or network) of researchers with the necessary skills to offer a perspective on the problem.
3) Review existing knowledge on the problem area to exhaust all disciplinary and interdisciplinary 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 Aircraft Noise and Environmental Health

This section works through, and illustrates, all steps of the trans-disciplinary process.

3.1 Problem Identification

First, it is necessary to outline the conventional approach to the study of aircraft noise and the community. 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 that are applied to estimate the future sound pressure levels experienced on the ground for given operational regimes are the Integrated Noise Model (Gulding *et al* (1999)), and the dose-response model (Schultz (1978) and 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) much 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 name 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 transdisciplinary approach to mitigate, or minimise impacts, but drawing on measures approved by the International Civil Aviation Authority (ICAO (1993)), and rarely introducing innovation.

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 to research scoping was undertaken in 2004 as part of the Government of New South Wales Botany Bay Strategy development with a stakeholder workshop (http://www.bbsu.unsw.edu.au) involving 120 people from state and local government, NGOs, the private sector, community representatives and academia. One recommendation from this workshop was a better understanding of the impacts of aircraft noise on the community.

3.2 Assemble a Group (or Network) of Researchers

Secondly, a small research group was established. Research was undertaken by a doctoral student (the lead author of this paper), supervised from the Medical and Engineering Faculties of UNSW, and supported by translators from South Sydney Area Health Services. As Sydney is a multi-cultural city, the survey instrument was translated into the most common languages spoken in the home in the study areas. This core research team did not work in isolation from others as the standard, peer-review committees established in the School of Civil Engineering for doctoral candidate progress made suggestions on the research proposal (including formally encouraging the involvement by the Faculty of Medicine), and Faculty Ethics and Occupational Health and Safety Committees approved of details of the survey instrument as delegated responsibilities on behalf of the University of New South Wales.

3.3 Extensive Literature Review

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). This research has extensively reviewed the up-to-date literature on a variety of relevant disciplines as shown in Table 2. 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.

Table 2 Area of Literature Review on Impacts of Aircraft Noise on Environmental Health

Area of Literature	Number	Percent
a. Social Survey	17	10%
b. Acoustical engineering	11	6%
c. Medical General, Epidemiology	12	7%
d. Aircraft Noise Measurements	18	11%
e. Aircraft Noise and Health	51	30%
f. Statistics	11	6%
g. Policy, Aircraft Noise Management Strategies	20	12%
h. Transportation Engineering	10	6%
i. Other Areas	21	12%
Total Citations	**171**	**100%**

3.4 Design Research Enquiry

Fourthly, from the research gaps in the literature (see Table 2), 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 control group (this was our research design), or assesses the changes in exposed individuals over time.

3.5 Implement Research Enquiry

The fifth phase involves implementation – data collection and multivariate statistical analysis – and a few selected comments on this phase of the research are warranted. A self-administered questionnaire was designed, building on standard questions from the Harvard University SF-36 health status (Ware (2000) and Ware *et al* (1993)) – which is regarded as the "gold standard" questionnaire for this kind of research. A description of both the pilot and the main survey of people in aircraft noise exposure area and the control area are described elsewhere (Issarayangyun *et al* (2005)).

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 were 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.

3.6 Review Conceptual Understandings and Search for a Common Conceptual Framework

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 finalised in a form suitable for peer review and critique.

3.7 Types of Intervention

Finally, comments about interventions are warranted because that is the ultimate purpose of our research, yet beyond the scope of this paper. 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.), the community, and the airlines. Sydney airport, along with many commercial airports of the world, implement environmental management plans. The primary environmental legislation that applies to environmental management at Sydney Airport is the *Airports (Environment Protection) Regulations (1997).* Sydney Airport has developed a five-year Environment Strategy (2005 - 2010). The Strategy outlines management plans for specific environmental issues, and contains individual actions designed to improve the overall environmental management of our operations.

Our survey of airport official websites for major international airports has found no mention of the health impacts of aircraft noise. Work in progress aims to take the findings from our research and formulate appropriate mitigation strategies. As part of such a process it is important to be clear about some of the key findings of the impact of aircraft noise on environmental health before mitigation strategies can be addressed, so the next section summarises some key results.

4 Findings

4.1 Study Population

The areas exposed to aircraft noise from Sydney Airport are widespread around the Sydney region due to the Long Term Operating Plan (LTOP) at the airport (AirServices Australia (1996)). Therefore, only the highly exposed areas where the average annual day of ***N70*** is higher than 50 events per day were selected as the study population for the aircraft noise exposure area. The ***N70*** is the number of aircraft noise events that are louder than 70 dB(A). The threshold level of 70 dB(A) was chosen because, approximately, it will then be 10 dB(A) attenuated by the structure of house (with open windows) and that 60 dB(A), or above, is the indoor sound pressure level of a noise event that is likely to interfere with conversation, or with listening to the radio or the television (DoTARS (2002)). The 2003 daily average ***N70*** contour map around Sydney Airport has been obtained from AirServices Australia, Canberra. The study population for the aircraft noise exposure area has been defined by the blue lines, as shown in Figure 1.

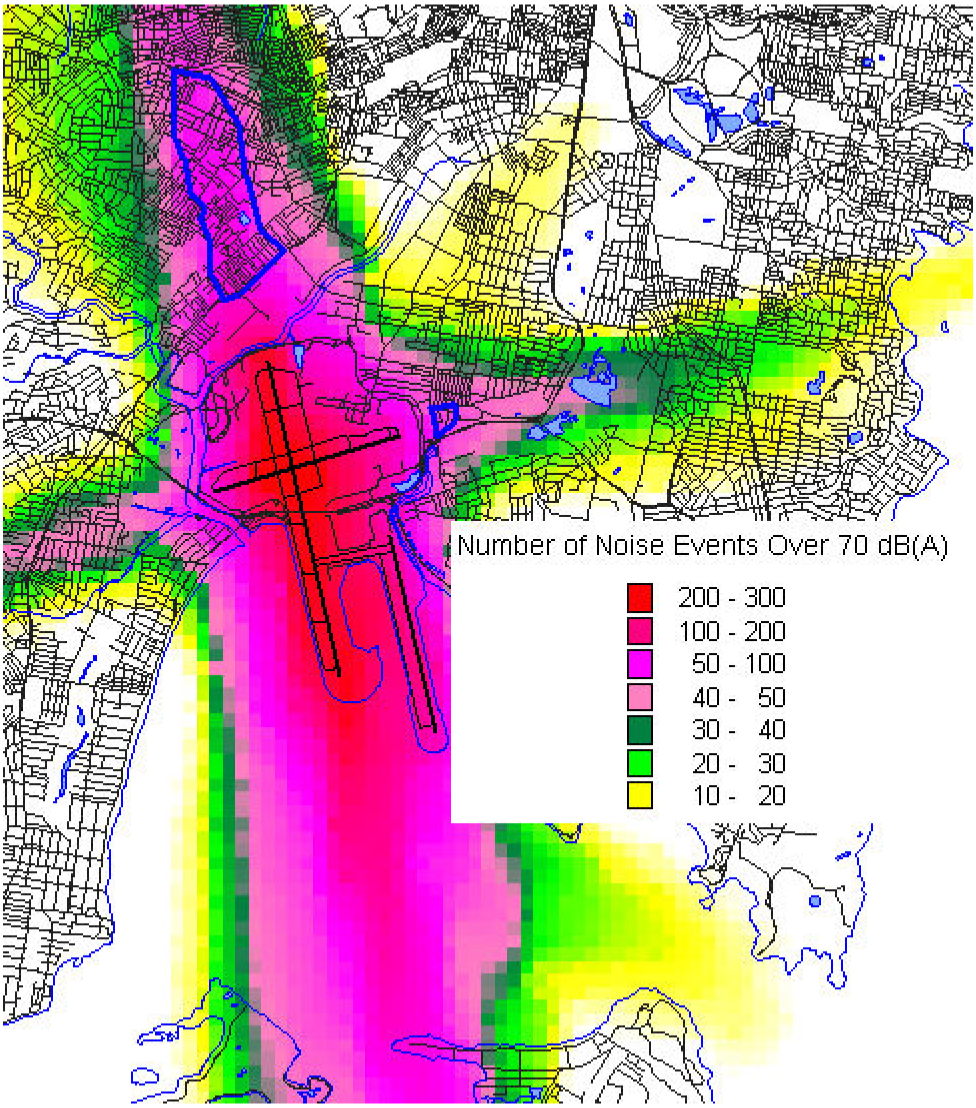

Figure 1 Aircraft Noise Exposure Study Population Defined by the *N70* Contours

The control area is a suburb where the socio-economic status is matched with the exposure area and controlled for noise exposure. Suburbs located outside of the flight paths were selected by visual inspection from Sydney Airport's Track Plots provided by AirServices Australia. Socio-economic indices (called Socio-Economic Indices for Areas, SEIFA) (Trewin (2001)) of these selected suburbs were then compared with the study population of the aircraft noise exposure area by using a nonparametric test (Mann-Whitney U). The suburb of South Penrith, located approximately 55 km to the west of Sydney Airport, was chosen as the control group.

4.2 Noise Gap Index

The Noise Gap Index is a 'new' easier-to-interpret aircraft noise index that has been developed based in this research study on the assumption that "People living in different background environmental noise areas might have different responses to the same aircraft noise level". This index was established so it could distinguish between aircraft noise and background environmental noise in a novel manner.

Data on an annoyance scale for the aircraft noise exposure group were analysed. The aircraft noise annoyance scale is an ordinal variable ranging from zero to ten, where zero means not at all annoyed and ten means highly annoyed by. The ***N70*** value of each respondent was obtained from a large scale ***N70*** contour map generated by AirServices Australia. The ***NGI*** value of each respondent was then calculated based on formulae that we have developed and disseminated (Issarayangyun, Samuels and Black (2004)). Figure 2 illustrates the relationship between aircraft noise annoyance scale and the ***NGI*** stratified by the quartile of points of the respondents.

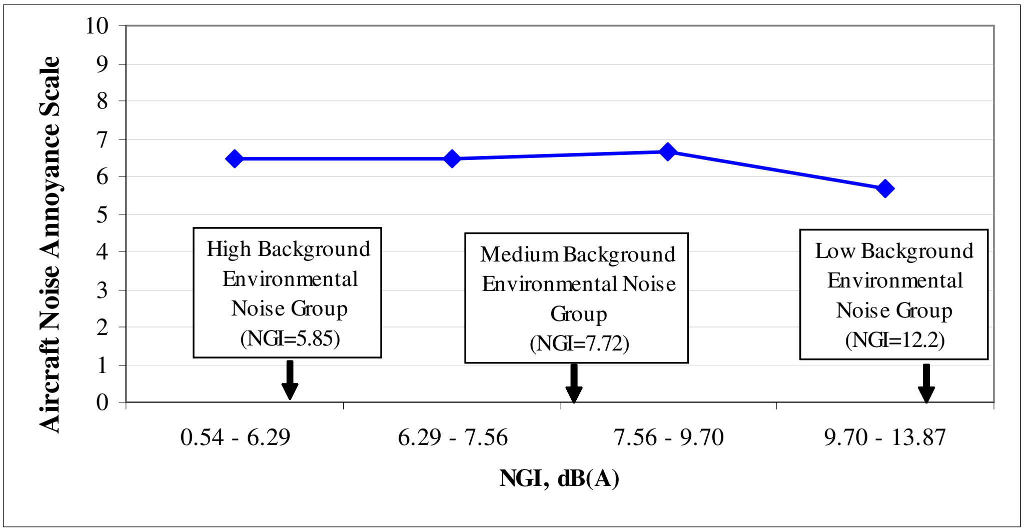

Figure 2 The Relationship between Aircraft Noise Annoyance Scale and *NGI*

For example, 25 percent of respondents were located in areas with ***NGI*** between 6.29 and 7.56 dB(A). The average aircraft noise annoyance score of these areas was 6.5. From this figure, it was found that the average aircraft noise annoyance score of a respondent was quite stable (≈ 6.5) in areas with ***NGI*** less than 9.7 dB(A). Conversely, the average aircraft noise annoyance score dropped to 5.4 in areas with ***NGI*** higher than 9.7 dB(A). It was also found that the average ***NGI*** values of high, medium, and low background environmental noise groups were 5.85, 7.72, and 12.2 dB(A), respectively. People living in high and medium background environmental noise areas are more likely to be annoyed by the same aircraft noise exposure level than people living in low background environmental noise areas. This might reflect the characteristics of people suffering from high level of background environmental noise to be more vulnerable to aircraft noise than people from low background environmental noise areas.

4.3 Research Questionnaire

Subjective health outcomes were measured by a questionnaire. No medical laboratory or experimental tests on people have been undertaken. The questionnaire has been developed from a well-established questionnaire instrument that measures seven major characteristics of each subject: 1) health related quality of life; 2) hypertension condition; 3) noise stress; 4) noise sensitivity; 5) noise annoyance; 6) demographic characteristics; and 7) confounding factors. The details of research questionnaire development are described elsewhere (Issarayangyun *et al* (2005)). The following paragraph briefly explains two set of question in assessing health related quality of life and prevalence of hypertension which were the key health indicators of this research.

Some scales of the medical outcome study (MOS) 36-item short form (SF-36, v.2) (which are Physical Functioning, General Health, Vitality, and Mental Health) have also been added to our research instrument to measure health related quality of life. For each health measure, a summary score in the range of 0 to 100 was obtained with the SF-36 algorithm, with a higher score implying a more positive health status. Table 3 provides the interpretation of the lowest and the highest scores of those selected SF-36 scales.

Table 3 Interpretation of Lowest and Highest Scores of Selected SF-36 Scales (source: Ware and Shebourne (1992) Table 1 p 475)

	Definition	
	Lowest Possible Score	Highest Possible Score
Physical Functioning (PF)	Very limited in performing all physical activities, including bathing or dressing	Performs all types of physical activities including the most vigorous without limitations due to health
General Health (GH)	Evaluates personal health as poor and believes it is likely to get worse	Evaluates personal health as excellent
Vitality (VT)	Feels tired and worn out all of the time	Feels full of pep and energy all of the time
Mental Health (MH)	Feelings of nervousness and depression all of the time	Feels peaceful, happy, and calm all of the time

A set of close-end questions for assessing hypertension has been developed for this research. "*Have you ever been told by a doctor or nurse that **you** have high blood pressure sometimes called hypertension*" (1) Yes (2) Yes, but only temporarily (3) No, and then "*If **YES**, do you currently have high blood pressure?* (1) Yes (2) No. It is evident that the history of hypertension of parent(s) and cholesterol level are related to hypertension. Therefore, to prevent the distortion effects from those variables, this research developed the close-end questions for assessing this history of hypertension of parent(s) and high cholesterol status. *"At any time in the past, have either of **your parents** ever been told by a doctor or nurse that they have high blood pressure sometimes called hypertension?* (1) Yes (2) No (3) Don't know. *"Have you ever been told by a doctor or nurse that **you** have high cholesterol?* (1) Yes, and currently have (2) Yes, but already healed (3) No.

4.4 Exploring Core Research Questions

The most suitable multivariate statistical analysis techniques for the nature of each core research question were carefully selected based on a recommendation provided in Tabachnick and Fidell (2001). For the first core question (*"Is health related quality of life worse in community chronically exposed to aircraft noise than in community not exposed?"*), factorial analysis of covariate was employed to compare the mean scores of the health measures of subjects from aircraft noise exposure group and the control group. In addition, our research applied binary logistic regression analysis to predict an association between aircraft noise and the prevalence of hypertension (*"Does long-term aircraft noise exposure associate with adult high blood pressure level via noise stress as a mediating factor?"*).

For the first core question, the analyses were divided into four sub-sections due to the independence of each health measures (see Table 3). Factorial analysis of covariance revealed that after adjustment by significant covariate variables (for example, age and noise sensitivity) and potential confounding factors (for example, exercise activity, employment status, smoking status, education level, and body mass index), the mean scores of Physical Functioning, General Health, Vitality, and Mental Health of aircraft noise exposure group were significantly lower than the control group. An answer for the first core research question would be: "Health related quality of life, in term of physical functioning, general health, vitality, and mental health, of community chronically exposed to high aircraft noise level were worse than the control area".

For the second core question, the analyses were divided into two sub-sections due to an assumption that "*Aircraft noise has indirect impacts to hypertension, it disturbs daily activities and creates chronic noise stress which becomes a mediating factor for hypertension in the future*". The first sub-section focuses on any association between long-term aircraft noise exposure and chronic noise stress. The second sub-section concentrates on any association between chronic noise stress and prevalence of hypertension in adult. Binary logistic regression analysis revealed that after control for noise sensitivity, traffic noise annoyance, aircraft noise annoyance, and interaction between traffic noise annoyance and aircraft noise annoyance, aircraft noise exposure reliably predicts chronic noise stress. After controlling for high cholesterol status, age, history of hypertension in parent(s), and aircraft noise exposure, chronic noise stress reliably predicts prevalence of hypertension. An answer for the second core research question would be: "Subjects (aged 15 – 87) who have been chronically exposed to high aircraft noise level have the odds of 2.61 of having chronic noise stress compared with the control group. In addition, subjects who suffered from chronic noise stress have the odds of 2.74 of having hypertension compared with those without chronic noise stress".

5 Conclusion

The main contribution of this paper has been the description of the trans-disciplinary research framework applied for a study of community health and well-being impacts by aircraft noise, which is currently rare in Australia, and overseas. Seven key stages for conducting trans-disciplinary research have been identified and illustrated.

The present study aims to assists decision maker(s) to recognise the effects of aircraft noise on community health and well-being. This may lead to improved aircraft noise management strategy in commercial airports. The current practice of aircraft noise management strategies is to minimise, as far as practicable, the total number of people in the community exposed to high levels of noise from overflights and to remedy, as much as possible, the significant aircraft noise exposure in existing noise-sensitive areas. However, the issue of community health and well-being impacts by aircraft noise has not been taken into account by the aircraft noise management strategies. This might reflect the fact that the policies to guide the development of aircraft noise management strategy interpret the meaning of 'health' as just the absence of disease. At present, there is no strong evidence to support causality between aircraft noise and health. Therefore, as it is not required by legislation, none of airport operators have considered the effects of aircraft noise on community health as a major issue.

The contribution of this research is the establishment of robust hypotheses of effects of aircraft noise on community health and well-being for the future experimental study: (1) *"long-term aircraft noise exposure has negative impacts to health related quality of life"* and (2) "*long-term aircraft noise exposure has indirect effects to hypertension via chronic noise stress as a mediating factor"*.

Finally, we recommended that the priority to protect health and well-being from aircraft noise exposure should be given first to the community living in the vicinity of airports before the knowledge from the future experimental study emerges. By encouraging the policy maker(s) to interpret the meaning of 'health' in a broader way (based on Berglund, Lindvall and Schwela (1999) as "health is not only the absence of disease, but also includes a state of complete in physical, mental, and social well-being"), the effects of aircraft noise on community health and well-being should be considered as one issue in developing an aircraft noise management strategy.

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