ACADEMIC LANDSCAPE OF AVIATION AND ENVIRONMENT

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Keywords: *Sustainability, Research on Research, Citation network, Overview map*

Abstract

'Environment' is one of the hottest topics in the aviation future debate. Responding the increase of the world attentions and needs of quick action to the aviation sustainability, the Aviation Environment (AE) research increases the speed of development. Ironically, it leads expansion of knowledge and makes it difficult to follow the latest findings. Furthermore, the term, 'environment' has wide-senses. Such an ambiguity often causes the failure of sustainable debate [1]. In this context, an overview map of the growing academic field is necessary because it can facilitate discussion and decision-making among various stakeholders with different interests. In this paper, we apply a network analysis to academic papers to identify the dominating disciplines in AE; we create a citation network by regarding a paper as a node and citations as links, and then categorize them into clusters, visualize them, and extract the topics of each cluster to provide an overview map. We found that AE consists of 4 different 'environment' domains and 19 clusters.

1 Introduction

ICAS held "Aviation and Environment" workshop in 2009 at Amsterdam. The title of 2010 Inside Aerospace of AIAA was "Aerospace Leadership for Energy and Environmental Challenges". 'Environment' is one of the hottest topics of the aviation industry.

In the academic field, AE research is growing, responding the world attentions. For example, in 2008, about 500 academic papers have been published (Fig. 1). Growing of researches will finally bring the expansion of knowledge.

The expansion of knowledge is occurring these days in many research fields of promise (ex. Nanotechnology; [2], Sustainability; [3], Energy; [4], Water resource management; [5]). As the expansion of knowledge occurs, a research field often faces proliferation of subfields and disciplinary fragmentation so that obtaining a comprehensive overview is very difficult [6]. It cases the delay of right decision of policy makers or the industry managers.

On the other hand, 'environment' is an ambiguous word. At the ICAS 2009 workshop, the center of the interest was what we can do for the climate change. The University of Tokyo held Aviation Environment Workshop on 19th May 2010 with Boeing Noise team. While the ambiguity can be useful for some politicians, it may doom collective action among the various stakeholders with different interests of aviation future to failure. Generally, people often end up with a reluctance to recognize the critical nature of framing issue in the sustainable debate [1].

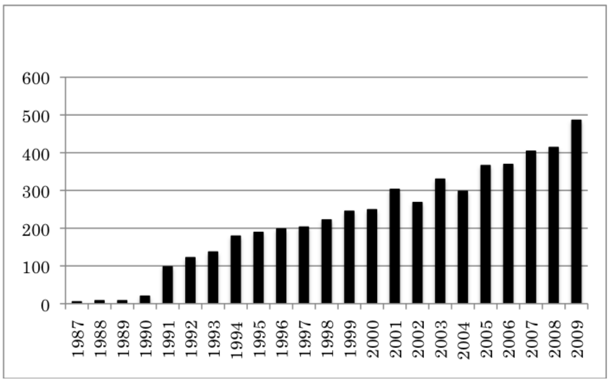

Fig. 1 Growing aviation and environment knowledge

In such contexts, we would like to provide an overview map of the growing AE research. It will help researchers and practitioners to follow the latest findings and to make a right decision in the right time on the aviation sustainability.

A computer-based bibliometric approach using text and citation mining has offered a comprehensive overview and this approach can efficiently work to structure vast amounts of knowledge. A computer-based approach is compatible with the scale of information and can be used to complement the expert-based approach [7] [8]. For example, a citation network analysis, on academic papers which we apply in this paper, creates a citation network in which a paper is represented as a node and citations as links, and they are categorized into clusters which can be visualized. Then the topic of each cluster can be extracted, and the results discussed with experts.

This article is organized as follows; Section 2 explains the data and methodology used in the structuring of AE research. Section 3 discusses the results of academic mapping and the investigation of diversity of 'environment' in AE. Section 4 concludes our findings.

2 Data and Methods

2.1 Data

We collect a set of academic publications which include both an aviation query word and an environment query word in their titles, abstracts, and keywords. We collect citation data for those publications from the Science Citation Index (SCI) and the Social Sciences Citation index (SSCI) compiled by the Institute for Scientific Information (ISI), because SCI and SSCI are two of the best sources of citation data. We use the Web of Science, which is a Web-based user interface for ISI citation databases, and search the papers using the query words in Table 1 as the query, where * represents a wildcard. A total of 5,511 papers were retrieved from 518 different journals (July 2010). The annual published number of AE papers are increasing continuously about 500 papers were published in 2009 (Fig. 1).

Table 1. Aviation and environment query words

	Query words (* as a wildcard)
Aviation	aviation*, aerospac*, aeronautic*, air transport*, airline*, airport*, air travel*, airplane*, aircraft*
Environment	sustainab*, environment*

2.2 Method

Our analyzing procedure is illustrated schematically in Fig. 2. The retrieved data includes both connected components and isolated nodes. We regard papers not citing other papers in the maximum connected component, which currently consists of 658 papers, as digressional from the mainstream of AE and eliminate them from this research. The data are then converted into a non-weighted, non-directed network, and the maximum connected component of the network is extracted. The resulting maximum connected component has 658 nodes. Finally the network is divided into clusters using the topological clustering method [9] [10]. For further information including the modularity of the clustering algorithm, please refer to [3].

For the visualization of the clustered network, we use a large graph layout (LGL) [11]. LGL is based on a spring layout algorithm where links play the role of spring connecting nodes. As a result of this layout, the group of papers citing each other is located in closer positions. In our visualization we hide inter-cluster links and only show the intra-cluster links for each cluster with the same color to clarify the position of each cluster.

After clustering the network, we analyze the characteristics of each cluster by titles and abstracts of papers that are frequently cited by the other papers in the cluster and we also analyze the journals, in which many papers of each cluster were published. Papers in the maximum connected component were published in 250 journals.

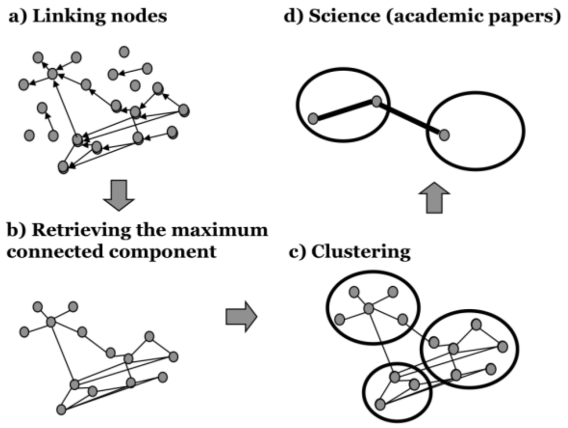

Fig. 2 Schematic diagram of the citation network analysis

3 Results and Discussion

3.1 Results

We present the structure of AE research. The citation network of AE research can be divided into 19 clusters, where the number of nodes in each cluster varies from six (the smallest clusters) to 99 (the biggest cluster, #1). Papers in each cluster are strongly coupled by intra-cluster citations. In the following discussion, we focus on the top 10 clusters.

Cluster #1 is the "Emission impact on the atmosphere" cluster. Not only CO2 but also NOx and Contrails from aircraft emission are considered to have impact on the global warming. In this cluster, the mechanism is discussed and the various model are studied for optimizing the air transport with operational, technological and economic measures. For example, Grewe et al. [12] simulated chemical composition of the atmosphere for a subsonic fleet with the coupled climate-chemistry model E39/C and found a decrease of NOx concentrations at lower cruise altitude. Svensson et al. also concluded that lower flight altitude might reduce global warming effect essentially for the cryoplane with LH2 fuel [13]. CRYOPLANE is a European-sponsored project with two equivalent medium-range aircraft of kerosene and LH2 fuel. The results of the projects are found many in this cluster. Both authors emphasized that lower altitude cruise increases fuel consumption due to the increase of drag and traffic and that further precise model were needed to optimizing the operation. Some researchers discuss "ecological footprint of tourism", the economical benefit and the ecological drawback of tourism. Air transport is the center of the discussion. Gossling et al. [14] added global warming potential of aircraft to the footprint of different fossil energy sources, pointing out that the emission in the upper troposphere and lower stratosphere caused impact on ozone, cloudiness and radiative forcing. Cluster #1 is the biggest and youngest in the top 10 clusters.

Cluster #2 is "Chronic noise exposure effect", in which the relation between noise exposure and physical and mental health effects are discussed often with field studies. One third of papers focus on impact on children health or the school performance. For example, Haines et al (2001) compared the cognitive performance and health of children attending different schools exposed to different levels of aircraft noise [15]. The author concluded that noise exposure was considered to lead noise annoyance and impair reading comprehension but to have little impact on the mental problems.

Cluster #3 represents "Cabin air quality impact", in which relation between cabin air quality and various symptoms of aircrew and passengers are studied. National Academy of Sciences report identified the four areas deserving more attention in future research concerning the aircraft environment; tobacco, ozone, humidity and microbial aerosols [16]. One quarter of this cluster mentioned about effect of environmental tobacco-smoke (ETC) on air quality. For example, Lindgren et al [17] discussed the ETS effect on the fatigue of crews. Cluster #3 is the oldest in the top 10 clusters.

Cluster #4 is "Social cost of air transport", in which researchers discuss pricing methods to estimate the social cost of aircraft movement, especially at airports. Some focus costs of emissions (ex. [18] [19]), and some focus noise (ex. [20]). These researches are useful for airport planning or aviation policy development.

Cluster #5 is the "Galactic cosmic rays effect" cluster. Measuring and modeling aircrew dose are center of interest for the researchers of this cluster. For example, Goldhagen et al. [21]

measured the spectra at different latitude and altitude to reduce the uncertainties in calculation. To limit the occupational galactic cosmic exposure was recommended by International Commission on Radiation Protection (ICRP) due to the cancer risk [22].

Table 2. Characteristics of top clusters of aviation environment research

CL#1 "Emission impact on the atmosphere"	
Age (based on 2009)	# Node
3.34	99
Major Journals	Main Country
Aeronaut J (16) J Air Transp Manag (7) Int J Hydrogen Energ (6)	1. UK (36) 3. Sweden 2. USA (14) 5. Netherl 3. Germany (7)
CL#2 "Chronic noise exposure effect"	
Age (based on 2009)	# Node
5.14	91
Major Journals	Main Country
J Acoust Soc Amer (17) Noise Contr Eng J (7) Appl Acoust (4)	1. USA (25) 4. Germany 2. UK (15) 5. Australia 3. Netherlands (8)
CL#3 "Cabin air quality impact"	
Age (based on 2009)	# Node
7.68	71
Major Journals	Main Country
Aviat Space Envir Med (9) Environ Int (6) Indoor Air (4)	1. USA (33) 4. China 2. Sweden (11) 3. UK (5)
CL#4 "Social cost of air transport"	
Age (based on 2009)	# Node
5.48	64
Major Journals	Main Country
Transp Res PartD Env (12) J Air Transp Manag (9) Atmos Environ/ Energy (3)	1. UK (16) 4. Australia 2. Netherlands (7) 3. USA (6)
CL#5 "Galactic cosmic rays effect"	
Age (based on 2009)	# Node
6.48	62
Major Journals	Main Country
Radiat Prot Dosim (23) IEEE Trans Nucl Sci (14) HealPhys/AdvSpacRes (3)	1. UK (36) 3. Sweden 2. USA (14) 5. Netherl 3. Germany (7)
CL#6 "Chemical-composition and photochemical reactivity of engine emission/ Contrail Formation"	
Age (based on 2009)	# Node
7.00	61
Major Journals	Main Country
J Geop ResSpace Phys (17) Geophys Res Lett (7) Atmos Environ (4)	1. USA (25) 4. Germany 2. UK (15) 5. Australia 3. Netherlands (8)
CL#7 "Detection and Forecast of hazardous weather"	
Age (based on 2009)	# Node
7.11	37
Major Journals	Main Country
J Appl Meteorol (7) Weather Forecast (6) Meteorol Atmos Phys (4)	1. USA (33) 4. China 2. Sweden (11) 3. UK (5)
CL#8 "Aircrew fatigue and crash"	
Age (based on 2009)	# Node
7.15	34
Major Journals	Main Country
Aviat Space Envir Med(17) Hum Factors (7) Int J Aviat Psychol(4)	1. UK (16) 4. Australia 2. Netherlands (7) 3. USA (6)
CL#9 "Diseases of aircrews"	
Age (based on 2009)	# Node
6.29	21
CL#10 "Competition in a deregulated aviation"	
Age (based on 2009)	# Node
7.55	20

3.2 Discussion

In Fig. 3, we show the relative positions of the clusters to summarize the above results. We can use the image as an academic overview map of AE research.

Analyzing the overview map, we can find 4 different types of 'environment' in the current discussion of AE; Climate, Living, Cabin and Business environment. Climate environment discussion has 2 sides, science on climate condition for flight optimization and science on climate change induced by aircraft emission. The latter discussion is growing and often use 'radiative forcing' as a measure. The discussion was also the theme of ICAS Workshop 2009. When we discuss the Living environment, it is mostly about around airports and noise. Cabin environment is important as not only the working condition or health but also against the risk of crash. Business environment discussion was stimulated by deregulation.

Focusing on the Climate and the Living environment discussion, these are connected by CL#4. For example, Janic [23] presented an integrated environmental cost calculation, which considers air pollution, noise, accidents, congestion, water pollution and waste. In this paper, his discussion on air pollution limited to the ground condition, so that the Living environment. Janic [24], however, extended his assessment method to the whole flight operation, to compare air transport and high-speed rail transport later. CL#4 will therefore become more and more important for the balanced development of aviation.

The Business environment discussion is situated near to the Climate discussion. They are connected by the low cost carrier (LCC) topics. LCC is now changing the game of air transport [1]. Graham and Shaw [25] discuss the advantage of LCC, it means the economic development and the disadvantage of LCC, increase of traffic and GHG emission.

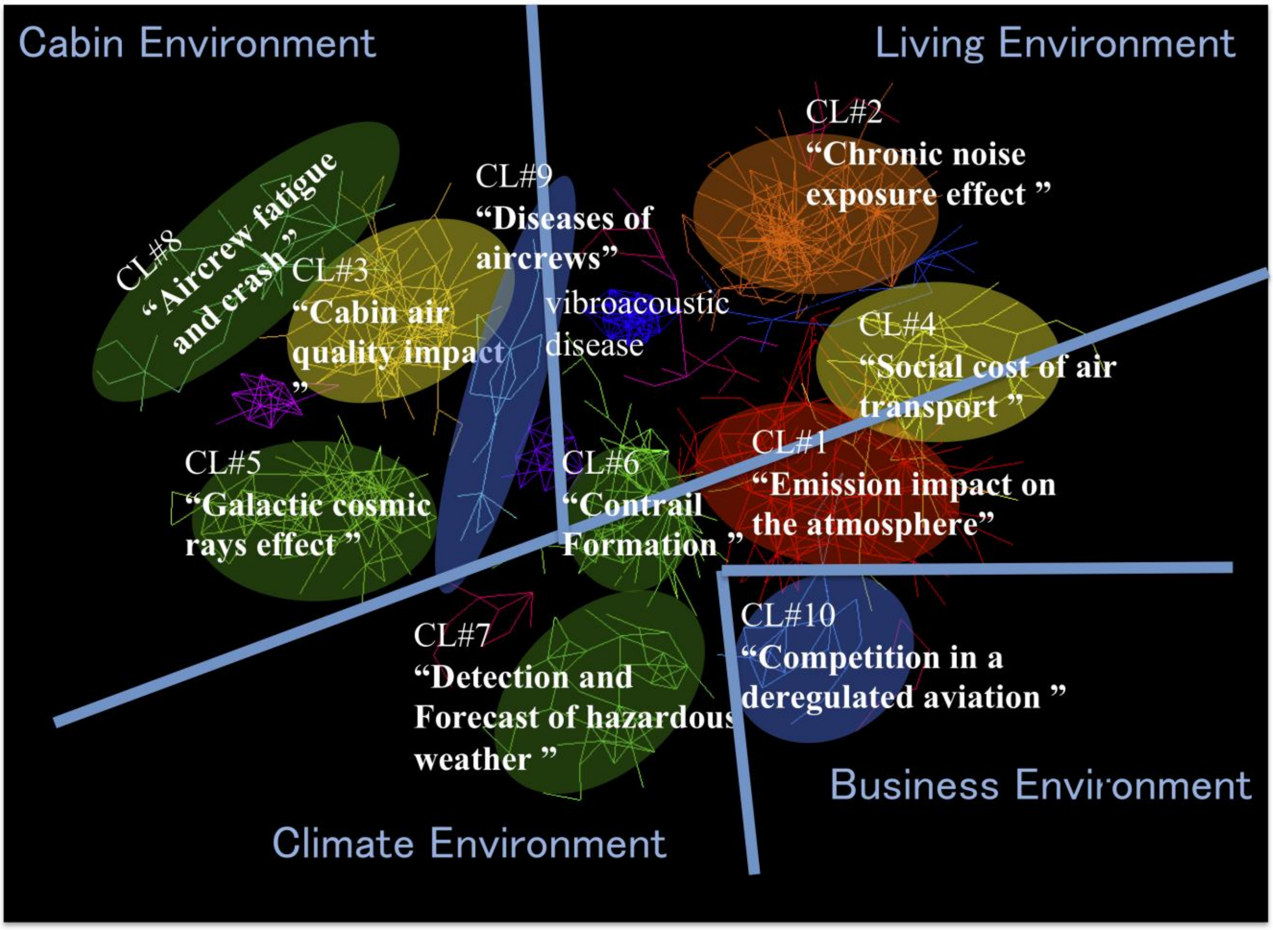

Fig 3. Academic landscape of aviation and environment research

4 Conclusion

Increase attentions have been gathered to the aviation and environment issue. The academic field, responding the world tension, gives rise to the continuous increase of the number of AE papers. The accumulation of knowledge ironically makes it difficult for both researchers and practitioners to follow the latest findings and to seek breakthroughs in AE. Environmental issue has generally another problem. The ambiguity of the term 'environment' often causes the failure of collective actions among people who have different interests. In this paper, we challenged to provide an overview map of the expanding knowledge in order to solve the framing issue and to facilitate right decision in the right time by computing approach.

Our citation analysis extracted 4 main aviation 'environment' domains- Climate, Living, Cabin and Business- and 19 clusters. We also discussed the relation between different 'environments'.

It is often said that balanced approach between greenhouse gas emission and noise are needed because reduction of one may require trade-off of increase of the other. The Climate issue and the Living issue are representing greenhouse gas and noise problems respectively. So the activities of researches of CL#4 "Social cost of air transport", which bridges the two 'environment' can be recommended to follow.

The interesting relation between the Climate and the Business environment was also found in this study. The closer relation than we thought appeared because deregulation in air transport made LCC business models and LCC brought the increase of traffic. It is good for economics but not for climate 'environment'. It shows another causal relation we must consider in a balanced approach.

Overview map we proposed in this cluster is useful to proceed a comprehensive discussion without getting lost in a vast amount of information. Historical analysis of cluster developments and analysis of the rest of the maximum-components will be covered in the next research.

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