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Prediction of Airport Noise Using CadnaA Model and GIS: Case Study of IKIA Airport

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Background: The issue of airport noise pollution is of paramount importance to communities in the vicinity of airports.

Materials and Methods: The potential effects of aircraft noise at the Imam Khomeini International Airport (Iran) was investigated by employing remote sensing and the geographic information system (GIS) in conjunction with an optimization algorithm integrated with CadnaA software. CadnaA is a computer model used to develop noise exposure maps (NEMs) to determine how noise affects a specific area. The results of aircraft noise modeling with this software for three scenarios (in 2015, 2025 and 2035) are provided in the NEMs. A georeferenced GIS database was built in Envi software comprising topography and land use data, the results of the CadnaA model and project data. These maps were overlaid. Face-to-face interviews were carried out by canvassing door-to-door in the permitted survey sites near IKIA and by structural modeling of the questionnaire estimates using AMOS.7 software.

Results: The results showed that the CadnaA model well simulated and predicted noise changes in different scenarios. The results of the map overlay indicate the compatibility of existing land use around the IKIA airport with noise levels and provided alerts against the development of residential areas in the near future.

Conclusions: The results of the questionnaires indicate a high L_{DEN} correlation coefficient and irritation levels from aircraft noise. Urban development around the airport as well as an increase in the number of flights and runways at IKIA should be carefully studied.

Keywords: Airport noise pollution, Cadna A, Geographic information system

1. Background

Different aspects of noise can be surveyed using various methods and sources, such as was done in one study on prediction of noise levels using a back propagation algorithm (1). Exposure to airport noise can have identifiable impacts on health that range from behavioural effects to annoyance (2), to high blood pressure (3). A general understanding of how sound affects the people around an airport requires measurement methods to assess aircraft noise (4). The current study was undertaken to examine environmental noise pollution and noise from Imam Khomeini International Airport (IKIA) in Tehran, Iran. This study also surveyed land use assessment around the airport by employing CadnaA, an aircraft noise simulation model. In order to supply the required information for both local and global action plans, noise mapping is important (5, 6). INM and CadnaA are widely-used software programs for prediction of airport noise and CadnaA was used for analysis in the current study. The noise modeling performed in this study was completed in accordance with the Standard Method of Computing Noise Contours around Civil Airports (7,8). In this report, CadnaA was used to estimate noise and the L_{DEN} metric as the noise descriptor for analysis of noise exposure areas.

2. Objective

The current study addresses noise exposure that results from aircraft operations at Imam Khomeini International Airport, 30 km southwest of Tehran (9), which is the busiest international air passenger gateway to Iran. The map of standard instrument departures (SIDs) and standard terminal arrival routes (STARs) of IKIA was overlaid with a 1:50,000 topographic map. The study area and noise sampling stations were then determined according to the flight paths and interference in residential areas.

3. Material and Methods

The methodology of this study on aircraft noise was carried out as part of the Standard Method of Computing Noise Contours around Civil Airports (ECAC.CEAC, Doc 29, 2-3 July, 1997). CadnaA software was used to ensure that the study incorporated the most recent European and international standards, methodologies, ISOs and a relevant data base (10).

A strategic noise map (SNM) was designed to identify IKIA's present and future noise models as well as land use which is not compatible with the noise models. The SNM serves as a standard reference with regard to irritation and proposes sensitive development in the vicinity of the airport. The existing conditions SNM reflects airport operating conditions in 2015, the 10-year and 20-year SNMs reflect anticipated operation and development at IKIA in 2025 and 2035. Different runway layouts were used in each scenario.

CadnaA uses as input information about the airfield configuration, flight track locations, aircraft fleet mix, analytic aircraft traffic data per day/runway/flight path, aircraft climb and descent profiles, runway utilization, distribution of aircraft types in categories of day/hour/runway/flight paths in the three periods of the day, evening and night and the number of daily operations (Table 2). At IKIA, 60% of the landing and take-off procedures operate from the west on runways 29L/R and 30L/R.

Table 1 Scenarios showing characteristics in airport noise modeling

Scenario 1 (In 2015)			Scenario 2 (In 2025)			Scenario 3 (In 2035)		
Runway	Annual Passenger Traffic	Average Daily Aircraft Movements	Runway	Annual Passenger Traffic	Average Daily Aircraft Movements	Runway	Annual Passenger Traffic	Average Daily Aircraft Movements
11 / 29	13 Mpax	295 movements	11L / 29R 11R / 29L	28 Mpax	590 movements	11L / 29R 11R / 29L 12L / 30R 12R / 30L	93 Mpax	1756 movements

R: Right L: Left

Table 2 Percentage of Aircraft Operations PER Period of the Day

Time Period	Existing	Mid-Term	Long-Term
Day	65%	66%	70%
Evening	15%	17%	15%
Night	20%	17%	15%

Being a leading software for assessment and prediction of environmental noise, CadnaA can handle noise calculation and noise mapping projects of any size. A model was set using CadnaA and remote sensing (RS) software to further the aims of the study. The exit radials in CadnaA for the present study were the flight tracks by the various aircraft accommodated at IKIA. A georeferenced GIS database was built in Envi (RS software) comprising topography data, land use, the results of the model and project data. The results were used to develop a weighted overlay map of land use and CadnaA output. The following software and instruments were used for satellite data processing and GIS analysis: Envi for image analysis and mapping, ArcGIS for database creation, analysis and map composition and a hand-held GPS for ground verification. The work was carried out by visual image interpretation. This method was done using 47 classes in order to establish a good representation of the various land-use classes in a continuous overlay of NEM and the land use map.

The parameter of noise used was L_{DEN}, which is commonly used in valid research (11). Face-to-face interviews were carried out by canvassing door-to-door in the permitted survey sites near IKIA. To calculate the number of questionnaires required, locations that were more exposed to aircraft noise during landing and takeoff were studied and homes in these areas were randomly selected for the questionnaire. Five experienced interviewers who were trained to fully understand and administer the questionnaire visited approximately 300 houses from 7 March 2015 to 8 February 2015. The effective sample size was 281 volunteer participants aged 18 to 68 years. The questionnaire comprised six sections. General noise perceptions occurred on a daily basis and were addressed in sections 1 and 5. The questions were designed based on previous aircraft noise studies and real situations at IKIA. Twenty questionnaire items were designed using a 7-point Likert scale. (1: unlikely, 4: neutral and 7: likely) to make it easy for participants to formulate responses (12). Sections 2 to 4 inquired about individual noise tolerance levels around a hypothetical airport. Section 6 obtained personal information, including the individual's income and age. The information on general noise awareness was used (e.g. irritation from road, rail and air traffic), the general noise sensitivity from Sections 1 and 5 and the personal information from Section 6. After screening the information, the data were validated for further analysis (2).

L_{DEN}, as a contextual variable, is expected to have a positive effect on irritation caused by aircraft noise. This relates to the hypothesis that an individual will become more irritated as they are exposed to higher levels of aircraft noise [13, 14].

3. Results

Noise contours are lines overlaid on a land use map that connect points of equal sound levels. For instance, a 60 dB_A contour is drawn by connecting all points on a grid with L_{DEN} values of 60 dB_A. Generally, noise contours are plotted at 5 dB_A intervals, beginning with the noise compatibility L_{DEN} threshold of 65 dB_A. Part 150 of the Land Use Compatibility Guidelines define noise sensitive land use above a DNL of 65 dB to be incompatible for airports and noise-sensitive uses below DNL 65 dB are considered to be compatible "without restrictions". The results of the aircraft noise modeling in CadnaA for all scenarios are given in the noise exposure maps in Figures 1 to 3.

In Scenario 2015, the contours extend west and east because of the high percentage of airport operations arriving on Runway 29R, departing from Runway 29R and departing from Runway 11. The 65 dB_A L_{DEN} contour extends beyond the airport boundary into local neighborhoods in these two directions.

Figure 2 shows the NEM for scenario 2025 at IKIA airport. As for scenario 2015, the contours extend to the west and east. The 65 dB L_{DEN} contour extends beyond the airport boundary and into neighborhoods in these two directions. The 2025 NEM shows that highest percentage of airport operations arriving at runways 29R and 11R.

Figure 3 shows the NEM for scenario 2035 at the IKIA airport. As for scenarios 2015 and 2025, the contours extend to the west and east. The 2035 NEM shows that the highest percentage of airport operations arriving at Runways 29R and 30R.

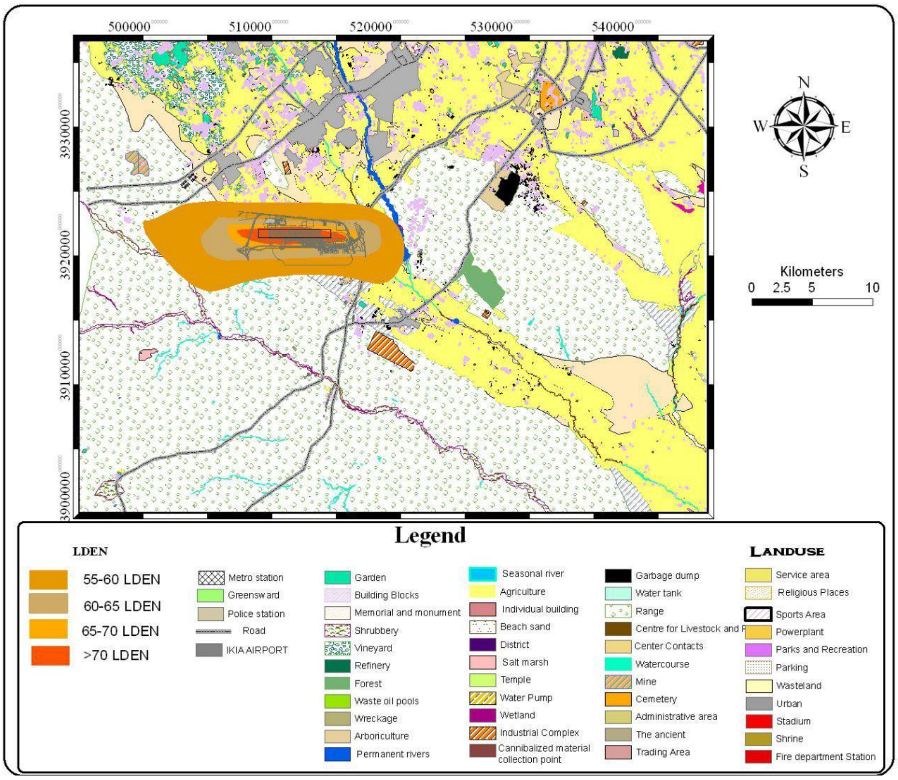

Figure 1 IKIA Airport NEM 2015, noise index L_{DEN} (Modeling by CadnaA)

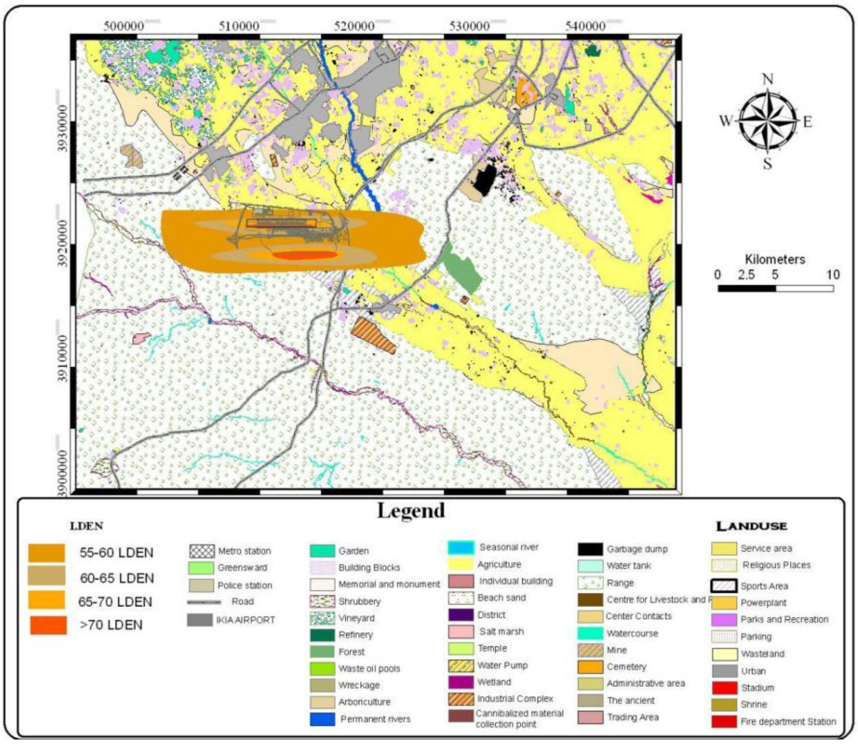

Figure 2 IKIA Airport NEM 2025, noise index L_{DEN} (Modeling by CadnaA)

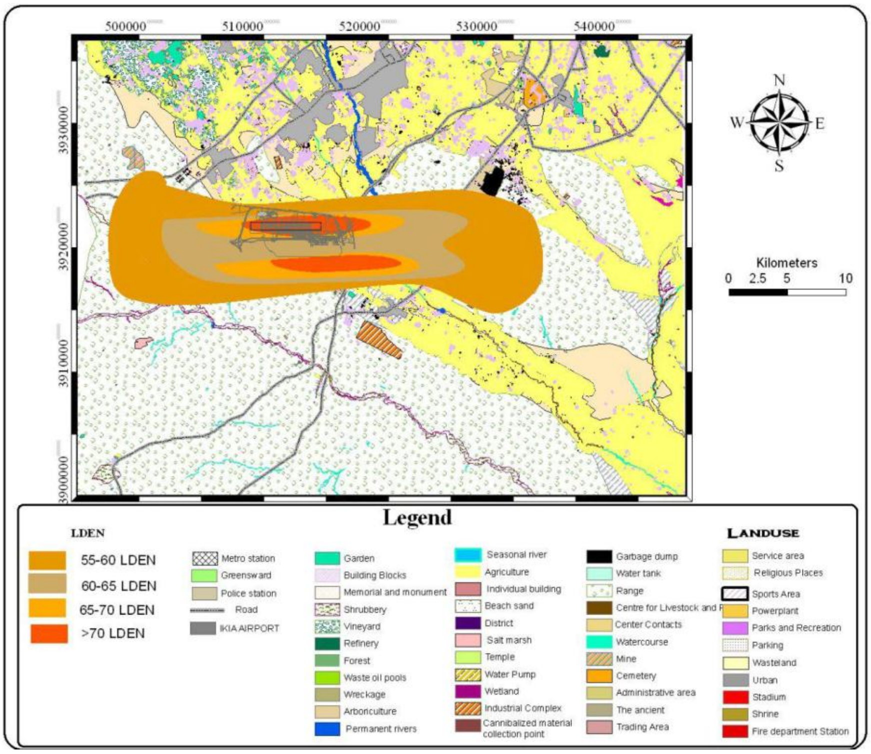

Figure 3 IKIA Airport NEM 2035, noise index L_{DEN} (Modeling by CadnaA)

Conflicts with the existing and future communities in the vicinity as well as providing sufficient flexibility for development of the airport must be considered by urban development management in the area surrounding IKIA airport.

Structural modeling of the questionnaire was estimated using AMOS.7. There were four hypotheses to be analyzed:

- H1: Aircraft noise irritation
- H2: Noise sensitivity
- H3: Affluent status
- H4: Irritation by other sources

4. Discussion

The result showed that the noise sensitivity construct had a highly significant effect on aircraft noise irritation (H1; $p< 0.01$), which was consistent with that of Taylor's (15). A positive effect for noise sensitivity from other noise sources was also significant (H2; $p< 0.01$). This finding is consistent with the findings of Horonjeff (16) and Girvin (17). The result showed that affluence had a positively significant effect on aircraft noise irritation (H3; $p< 0.01$), which was in correspondence with another study that found the people living in the area of the greatest affluence were significantly more irritated by aircraft noise (18). Affluence had an insignificant effect on irritation caused by other noise sources (H4: $p = 0.441$), which was consistent with other studies (15, 19).

The results of the overlaying of land use maps, satellite images and outputs from CadnaA showed that with increase in runways and development of the airport, the regions that are affected by airport noise pollution will increase. Simulation of airport noise in three scenarios by CandaA indicated that in 2015, residential areas were not affected by airport noise, but in 2025, parts of Robat Karim will be affected by 55-60 dB noise. In 2035, the residential areas affected by noise will increase and parts of Robat Karim and Islamshahr will be exposed to 60 to 65 dB of noise. The results show that urban development will approach IKIA and, in the future, the increase in flights will cause high dissatisfaction among residents around the airport. Previous research carried out using the INM model in the same study area confirms the results of the present research (9). The results of the questionnaires indicate that the level of irritation from the airport noise is high. The results of the irritation questionnaire were in correspondence with earlier studies [15, 16, 17, 18, 19].

5. Conclusion

The responses of residents exposed to aircraft noise around IKIA were quantified using the CadnaA model and Arc GIS software. The results show that CadnaA was able to simulate and predict noise changes in different scenarios. The results indicate that if urban development around IKIA in the 2025 and 2035 scenarios materializes, residents of these urban areas will encounter with high levels of aircraft noise. Urban development around the airport as well as increases in the number of flights and runways at IKIA should be carefully studied. The results of the questionnaires indicate a high correlation coefficient for L_{DEN} values and irritation levels from aircraft noise.

Conflicting of Interests

There are no conflicts of interest with respect to the Islamic Azad University Hamedan.

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Authors' Contributions

The author contributed to the development of the paper.

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پیش‌بینی صدای فرودگاه با استفاده از مدل CadnaA و GIS (مطالعه موردی: فرودگاه امام خمینی)

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مقدمه: مسئله آلودگی صدای فرودگاه برای جوامع اطراف فرودگاه دارای اهمیت زیادی می‌باشد.

مواد و روش‌ها: این مطالعه به پیش‌بینی صدای فرودگاه با کاربرد سنجش از دور، سیستم اطلاعات جغرافیایی و تلفیق با نرم افزار CadnaA، برای تخمین اثرات بالقوه و عواقب ناشی از صدای هواپیما در محدوده مطالعاتی می‌پردازد. فرودگاه مورد مطالعه، فرودگاه امام خمینی در ایران (که به عنوان فرودگاه بزرگ در نظر گرفته شده) می‌باشد. CadnaA یک مدل کامپیوتری می‌باشد که برای تهیه نقشه‌های در معرض صدا برای تخمین مناطق تحت تاثیر صدا مورد استفاده قرار گرفته است. نتایج مدل‌سازی صدای هواپیما با استفاده از نرم افزار CadnaA برای سه سناریو (سناریوی ۱ (۲۰۱۵)، سناریوی ۲ (۲۰۲۵)، سناریوی ۳ (۲۰۳۵))، تحت عنوان نقشه‌های NEM (نقشه‌های مناطق در معرض صدا) ارائه شده است. یک پایگاه داده‌ی جغرافیایی زمین مرجع شده در نرم افزار ENVI متشکل از داده-های توپوگرافی، کاربری اراضی، نتایج مدل CadnaA و داده‌های پروژه تشکیل شد و همه‌ی نقشه‌ها روی هم‌گذاری شدند. هم‌چنین یک مصاحبه‌ی چهره به چهره در سایت‌های مورد مطالعه‌ی نزدیک فرودگاه امام خمینی (ره) انجام شد و مدل ساختاری پرسشنامه با استفاده از نرم افزار AMOS.7 ساخته شد.

نتایج: نتایج نشان داد که مدل CadnaA به خوبی می‌تواند تغییرات صدای فرودگاه را در سناریوهای مختلف پرواز شبیه‌سازی و پیش-بینی نماید. نتایج روی هم‌گذاری نقشه‌ها نشان‌دهنده‌ی سازگاری کاربری‌های موجود اطراف فرودگاه امام با سطوح صدای فعلی فرودگاه و هشدار برای توسعه مناطق مسکونی نزدیک فرودگاه در آینده می‌باشد.

بحث و نتیجه‌گیری: نتایج پرسشنامه نشان‌دهنده‌ی ضریب همبستگی بالای بین LDEN و آزردگی ناشی از سطوح صدای هواپیما بود. توسعه فرودگاه‌ها در اطراف شهرها و افزایش تعداد پروازها در فرودگاه امام خمینی باید با دقت بیش‌تری مطالعه شود.

کلمات کلیدی: CadnaA، آلودگی صدای فرودگاه، سیستم اطلاعات جغرافیایی، فرودگاه امام خمینی