AUTOMATED CARTOGRAPHY AS AN AID TO DECREE PROTECTION AREAS AGAINST AIR TRAFFIC NOISE

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I. Introduction

The fast and enormous industrial development which characterizes our 20th century has undoubtedly brought tremendous technical and economical achievements to the human being. However this development has had some negative effects on mankind: threat to the oecological balance and to the human health by pollution in its manifold manifestations. Some of these negative effects are the several sources of noise of modern industrial production and traffic. Years ago physicians already warned and stated that noise of higher than a certain level affects human health and deteriorates man's ability to work creatively and his ability to recreate effectively in his leisure time. Although these implications of noise have been well known, reconstruction and development of the heavily devastated industries and infrastructure after World War II got utmost priority.

Such fast economic growth meanwhile caused industrial and traffic noise of a level which is intolerable to a number of inhabitants already superior to some millions. That's the fact especially in a country like Germany with a generally dense population - the concentration of which is still higher in urban and industrialized areas - and with heavily loaded communication lines.

The Health and Safety Directorate of the European Communities

estimates that today nearly 10 million people out of West Germany's total population of 61 millions suffer at daytime from outdoor noise of a level of more than 65 dB(A)*) which equals being only 50 m off a much frequented road.Reason for this burden of outdoor noise are mainly the several types of traffic connections: roads, railways and airline routes.

With regard to the above mentioned results of medical research it's obviously necessary to take measures to fight traffic noise and especially aircraft noise - the peaks of noise level caused by an aircraft in its landing and take-off phase (between 85 dB(A) and 105 dB(A)) are comparable to those caused by an express train passing at 160 km/h at a distance of not more than 25 m.

II. The German Law for Protection against Aircraft Noise of 1971

On the area of West Germany comprising only 250 000 km^2 there are situated 430 airfields, namely:

a) 11 international airports with more than 1 million landings and take-offs per year
b) 260 minor civil airfields with nearly 3.5 million landings and take-offs per year
c) more than 100 military airports.

Realizing the enormous high peaks of air traffic noise and its concentration at a limited number of airports German legislation passed a law in 1971 trying to balance two conflicting demands:
first,the legitimate demand by industry, business and the public for an efficient air-traffic-system,
second,the understandable and by no means less legitimate claims of the affected people for protection and compensation.

This law regulates the establishment of so.called "Lärmschutzzonen" - protection areas against aircraft noise - for all 11 international airports and for those 34 military airports used for jet aircraft. The law authorizes the Federal Department of the Interior to decree protection areas for each of those mentioned airports with approval by the "Bundesrat", the representation of the German Federal States.

Each protection area is divided into two zones:
zone 1, the inner zone, with an equivalent level of noise (äquivalenter Dauerschallpegel) of more than 75 dB(A)
zone 2, the outer zone, where the level of noise is between 67 dB(A) and 75 dB(A).

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*) The figures quoted in this paper in dB(A) refer to absolute sound pressure level.

1. Legal Consequences

The following legal consequences are decreed for these distinct zones:

Restrictions:

In zone 1 no new human residences are allowed to be constructed
in zone 2 new houses may be built providing they comply with specific sound-insulation requirements established by governmental decree
in both, zone 1 and zone 2, such sensitive buildings requiring special protection like schools, hospitals and homes for the aged are not allowed.

Legal Claims:

In zone 1 the proprietor of a home already existing before the law of 1971 came into force can get refunding of his expenditure for improved insulation - up to 130 DM (circa 80 US $) per square metre living area of his flat.

The refund limit is unrelated to whether the proprietor insulates only one window of one room or all the windows of his home. The main tendency is to allow the proprietor getting his indoor living area more quiet in the way he prefers.

The law makes provision for such financial claims by a landowner against airport authorities or against the federal government in case of military airports. It is stated by the law that all real estate parcels or buildings which lie only partly in those zones are to be treated as if they lie totally within the zones.

To clarify that geometric relationship between real estate and noise protection area a precise definition and graphical representation of the borders of the protection areas are necessary. This makes clear how much stress lies in the computation and visualization of these borders.

2. Determination of the Protection Areas

It was decided not to base the limits of the areas on actual measurements in the environs of the airports for two reasons: First,such registration over how long a period they might be carried out give only a more or less arbitrary result and can never be reproduced within sufficient accuracy,
second,not only the actual activity of the airport should be considered but also the approved future increase in air traffic within the next ten years.

Therefore all known details as to the flights at present and in the future are collected according to procedures agreed to by a

number of experts and decreed by federal statutory regulations. The data as to the flights in the six busiest months of the year - number and type of the aircraft, engine characteristics, approach-and take-off procedures, flight-paths and different weights of day- and night-flights respectively - and the relevant data as to the further extension result in a mathematical system which definitely describes lines of equal noise level.

From this complex mathematical model the zone borders are computed by iteration as sets of points (between 10 m to 150 m apart of each other) which deviate not more than 0.001 dB(A) from the precise borders with their theoretical noise levels of 75 dB(A) and 67 dB(A) respectively.

3. Legal Definition of the Protection Areas

According to the law's intentions every citizen must have the possibility to recognize easily whether his property is affected by these noise areas or with other words to learn whether he is entitled to a claim or whether he is obliged by legal restrictions.

At this moment the cartographer was needed in order to help visualize the legal consequences. There was no doubt about the fact that the noise areas should be depicted in topographic maps. But the question was long and intensely discussed which accuracy to be applied or with other words which scale to be taken. First the jurists demanded a map at a scale of at least 1:1 000 in order to have graphically a comparable precision of lines and points by field surveys. Most jurists suspected that a map smaller than 1:1 000 could not sufficiently clarify uncertain relationship between the positions of the air noise area and the real estate and because of this uncertainty an incalculable number of lawsuits was feared.

Depending on cadastral maps 1:1 000 as a base for drawing and printing the protection areas would have involved a tremendous workload: for a medium size protection area (3 km by 20 km) nearly 150 sheets would have been necessary to show the whole border. Furthermore a lot of these cadastral maps are still based on different local co-ordinate systems, a fact which would have demanded disproportionately much expense by several different transformations of the protection areas.

Apart from such mere economic reasons mathematicians, physicists and surveyors on the other hand argued that the underlying precision of all data-collection, computation and representation did not imply that exaggerated accuracy (better than $\pm$ 0,1 m) demanded for by the law. Finally the jurists fell back from

demanding a map 1:1 000, but in order to have nevertheless the possibility to rely on an utmost precise threshold a mere legal definition of the protection area's borders was chosen:
The co-ordinates of the border points togehter with a polynomial interpolation (like those implemented on most drawing machines) were declared the constitutionally relevant border line. - A solution comparable to the fact that just by legal definition a point of time is declared the threshold between being qualified to get a driving licence or not. -

4. Visualization and Publication of the Protection Areas

After having consented on such a legal definition it was agreed to take the German Base Map 1:5 000 - which is our smallest map showing property borders - as the large scale map to publish graphically the protection area. However as this base map series is not yet totally completed in some German Federal States, in one of these states orthophotomaps 1:5 000 and in two states cadastral maps 1:5 000 and 1:2 500 (reduced to 1:5 000) are taken. Between 10 and 50 sheets of this base map series cover the whole protection area of one airport. These map sheets are bound to form an atlas of which copies are proclaimed in up to 10 municipalities around the airport where the public finds out whether someone's property is affected by the law and the appertaining decree.

In order to represent the whole protection area on a single sheet a second map of smaller scale is prepared based on the topographical map series 1:50 000. The format of this sheet - up to circa 1 m by 1 m - depends on the size of the protection area and can comprise parts of four adjoining regular sheets of the original map series. A 1:50 000 sheet is attached as a prefix to each atlas. Furthermore these map sheets are used in the legislation process where each member of the "Bundesrat" and of the relevant committee gets a draft decree together with such a map. After the decree being in force such a 1:50 000 map can be requested by every interested person.

For legal reasons it was decided that together with the publication of the decree in the federal journal a graphical representation of the protection area has to be published. For economic reasons the map sheet 1:50 000 could not be taken as its format exceeds in some cases up to 4 times that of the journal. A smaller scale was needed. Therefore a third edition, varying in scale between 1:100 000 and 1:300 000 is produced.

5. Data Processing and Cartography

Data collection is done by the airport authorities under federal supervision.

Location and orientation of the runways and flight-paths on the spheroid are computed in the Institute for Applied Geodesy (IfAG).

The local and plane co-ordinates of the borders of the protection area are computed by experts commissioned by the Federal Department of the Interior.

Transformation from plane to spheroidal co-ordinates of the relevant German transverse mercator system is done in the IfAG. The computer-lists of the spheroidal co-ordinates of the border points are directly taken for reproduction in the federal official journal in order to avoid any typesetting mistake.

Data conversion onto a magnetic tape for drawing machines is done in the IfAG.

The automatic drawing of the protection area for the 1:50 000 scale edition and the smaller scale is done in the IfAG, while afterwards the Land Surveying Offices do the drawing for the large scale edition (1:5 000).

As these large scale maps constitute the graphical means to let the public realize whether someone's property is affected distortions of the 1:5 000 map sheets are checked in order to adjust the scale in x and y on the drawing machine for an optimal fit between protection area and base map.

The borders of the two zones of the protection area are engraved with 0.2 mm lines which are emphasized on the one-colour edition by a 3 mm wide screen band parallel to the border. This parallel is engraved using the original control-tape and the PARALLEL-command implemented on drawing machines. In anticipation of a possible lawsuit - with the necessity to indicate parts of the border on the ground - every tenth point is marked by its number copied into the screen band but without marking the point itself.

All three map types showing the protection area are prepared as one-colour edition in order to minimize costs. For the two smaller scales only the colour-separations planimetry, waters and lettering are used as these maps are mainly for rough orientation purposes. As only a small number of the 1:5 000 scale atlases (some 20) is required for each protection area,reproduction is

done in most cases just by blue-prints while only the orthophoto-maps are reproduced photographically. The comparatively higher editions of the 1:50 000 scale map (some 5 000) and of the smaller map (some 20 000) are printed.

After all maps for a protection area have been edited part of the base material - map-combinations, frames etc. - have to be preserved as after substantial changes in actual flight activities or after substantial modification of the airport's development plans a new protection area will be computed, drawn and decreed.

6. Some Numerical Data

Since the enforcement of the German law against aircraft noise of 1971 it took nearly three years to establish the first of a total of 45 noise areas. From then to 1979 - i.e. in 5 years - 34 noise areas (75%) could be decreed.

The costs involved should be considered separately

1. administrative costs which comprise data collection, data computation, cartographic representation and publication amount roughly up to 0.5 million DM (0.3 million US $) per year.
2. estimated total costs for compensation amount to 74 million DM (41 million US $) for the 11 international airports and 158 million DM (88 million US $) for the 34 military airports used for operation of jet aircraft.

III. Conclusion

In this first 5-year-period of practical experience with the law for protection against aircraft noise it appeared that exclusively all decisions whether a real estate lies - totally or as a part - within the protection area were made relying only on the cartographic representation on the 1:5 000 map. This shall not negate the juridical demand for a mere legal definition, for a precise threshold, but it clarifies the importance of the cartographic publication and justifies the considerable attention and efforts cartographers paid to the large scale representation.

The main outcome of this law has been a first tendency to oblige the originator of aircraft noise (through the airport authorities) to payments for better insulation and to prevent municipalities from allowing house constructions too near to noise sources and to force proprietors to cope with stricter regulations.

Having the airports burdened with the responsibility for compensations and having already declared higher landing taxes for louder

aircraft these beginnings will show effects like urging air companies to switch to aircraft types emitting less noise.

These steps, though they might seem small, will entail further steps. It is already discussed whether there could be granted also compensations for better insulations in the outer zone 2 (67 dB(A)) and whether there might be enforced further restrictions as to town planning in a third zone (down to 62 dB(A)) round the airport. And for sure this will cause another involvement of cartography into noise abatement activities.

Cartography as an aid to a healthier environment !

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