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Influence calculations for risk assessment in spatiotemporal terms. A new method for mapping risks for a dynamic human population

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Abstract

How is an (always) dynamic human population influenced by a (not always men most frequently) dynamic outside influence? This is the basic question the model of influence calculations seeks to answer. And how can we apply the model for risk analyses? This is the second question to be answered in this short presentation. The basic assumption behind the proposed solution is that the momentary *effect* of influence (EI) is the product of the number of persons influenced by the influence source and the strength of influence that hit them. The *amount* of influence (AI) affecting this population is the product of EI and the duration of it. In order to calculate EI we define periods − here: parts of a day − when *both* the distribution of the population *and* the strength of the influence can be considered as unchanging. Then we devide the whole observations field in so small parts that even the density of the population *and* the strength of influence can be considered as uniform within each part. We calculate EI for all such parcels and translate the results into a map of the momentary influence effect occuring every moment during the period (EI). The product of EI and its duration (= the length of such a part of a day) gives the amount of influence (AI) for all part of the observation field, which can also be depicted in a map. Accumulating AI for all such periods making up a day, result in a map of AI representing the impact of the influence source on the human population in each part of the observation field during a 24-hour period. The risk potential on a human population is considered as an influence source and is treated as such. Mapping EI and AI is only one way of analysing the results. Several other processes of analyses, including different risk analyses are presented to some extent in this brief article.

Keywords: Risk assessment; Spatiotemporal; Risk; Urban population density; Population fluctuation

1. Introduction

Suppose that an explosion occurs in the very centre of a city. If the explosion occurs during the night, the damages may be limited to material destruction, because the centre

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is—more or less—empty of people. But if the explosion takes place at noon, when the centre is full of people, a considerable number of persons might be injured, perhaps killed. The consequences depend of course not only on the point of time—e.g. the number of people around—but also on the strength of the explosion. A minor explosion may cause only limited, perhaps only material damages even in the middle of the day, while a strong explosion could kill a large number of people.

2. Discussion

This somewhat over-dramatised—unfortunately not unrealistic—example gives the two main components of a new model designated as *influence calculations*. The basic idea of the model is that the consequences of an influence—here: an explosion—on a human population depend on two factors:

(a) the spatial distribution of the influenced population,

(b) the spatial distribution of the strength of the influence, (e.g. the risk component).

If the influence is not momentary, meaning that if the time component is not negligible then the term ‘spatial’ must be replaced by the term ‘spatiotemporal’ in both (a) and (b) above.

The core of the model is expressed in two statements:

$$\mathrm{EI} = I \times N$$

where EI is the momentary effect of source influence on a human population, I is the strength of the influence and N is the number of people influenced. Thus we delimit areas, where the influence has uniform strength, measure the size of the population within each of them and then calculate the influence effect (EI) as a product of the influence strength and the number of influenced persons in each area.

The second statement considers the time aspects:

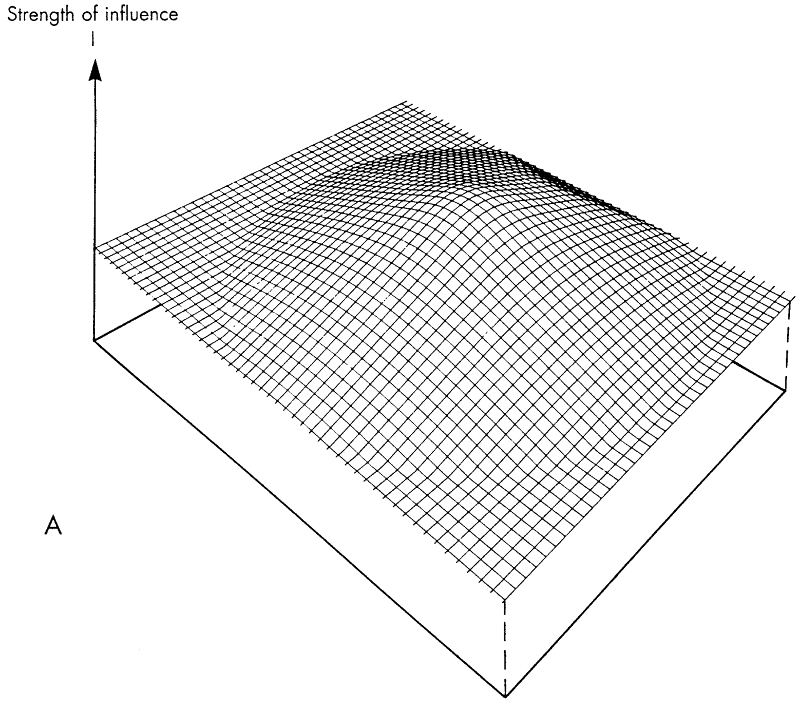
$$\begin{aligned} \mathrm{AI} &= \mathrm{EI} \times T \\ &= I \times N \times T \end{aligned}$$

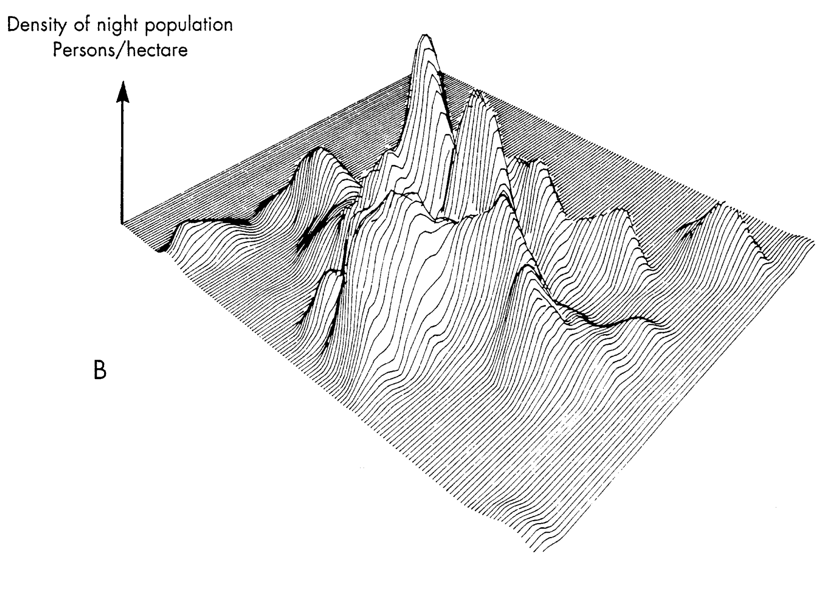
where AI stands for ‘amount of influence’, received by the population during a certain period and T represents the duration of the influence. The amount of influence is thus the through-time accumulated influence effect (the time integral of the influence effect IE).

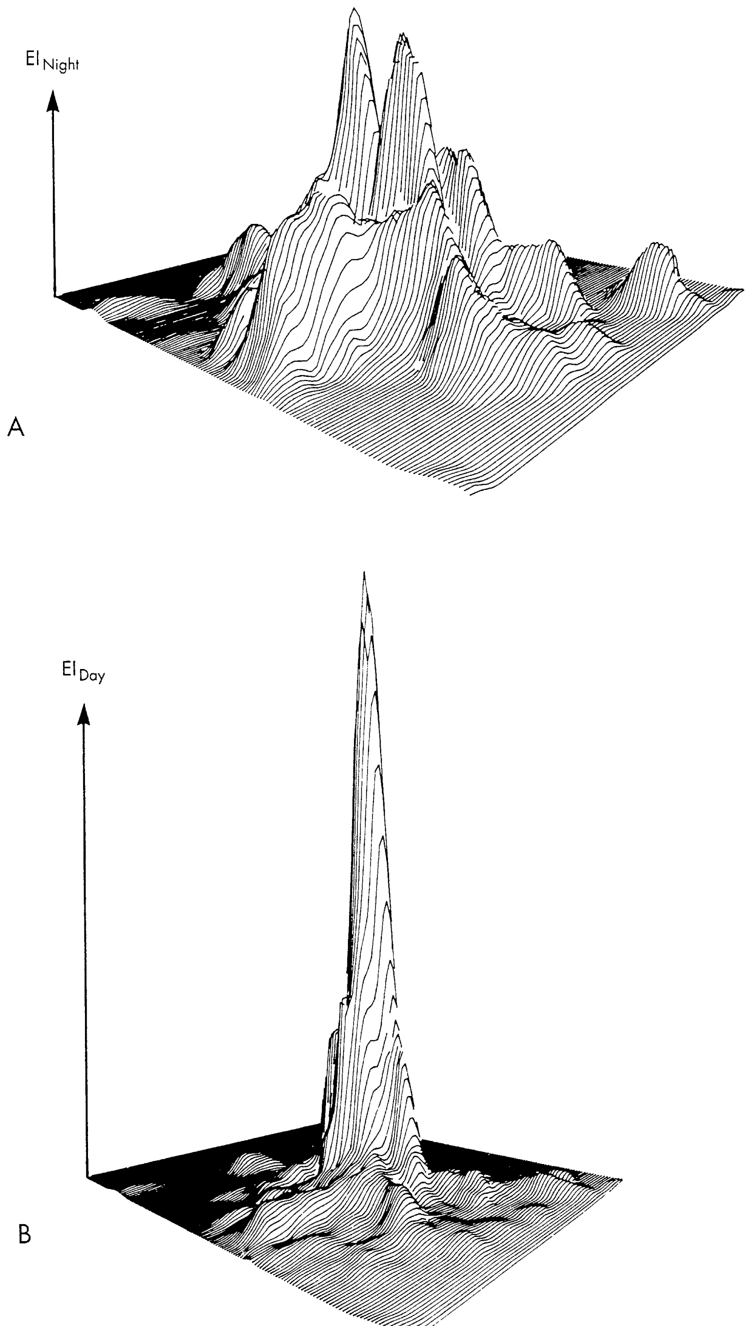
The dominating spatial aspects call for a cartographic treatment of the problem. Hence, the rest of the available space will be used for concreting the principle by means of a cartographic example.

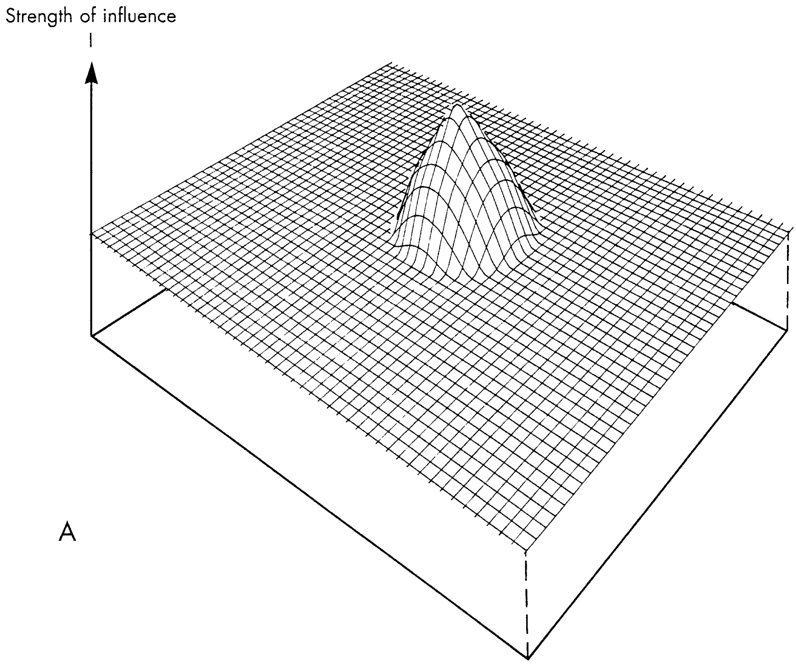
Fig. 1. Influence calculations. Case IV: The night period, Malmö 1980. The strength of the influence is constant throughout the night period, but is greater in the town centre. (A) The strength of the influence. (B) The variations in population density during the night. The elevated parts of the map in (B) rest upon the hidden map of the city of Malmo. The unelevated, horizontal part of the same plane represents the Straits of Öresund outside the shore of Malmo. The same is the case in Figs. 2A, 3A,B and 4.

Fig. 2. Influence calculations. Case IV: The day period, Malmö 1980. The strength of the influence is constant during the day period, but is higher than during the night, particularly in the town centre. (A) The strength of the influence. (B) The variations in population density during the day.

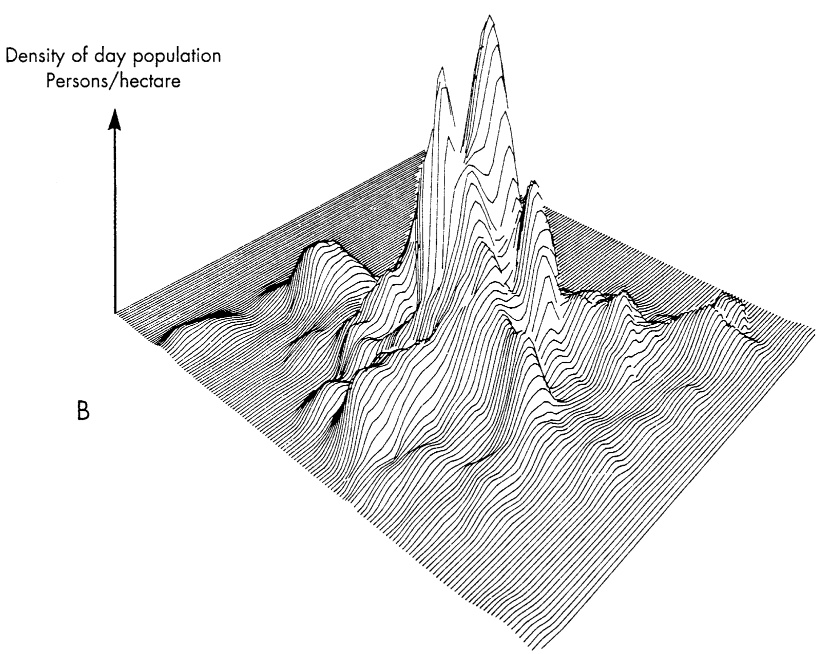

Strength of influence
A


Density of night population
Persons/hectare
B


EI Night
A
EI Day
B


Strength of influence

A


Density of day population
Persons/hectare

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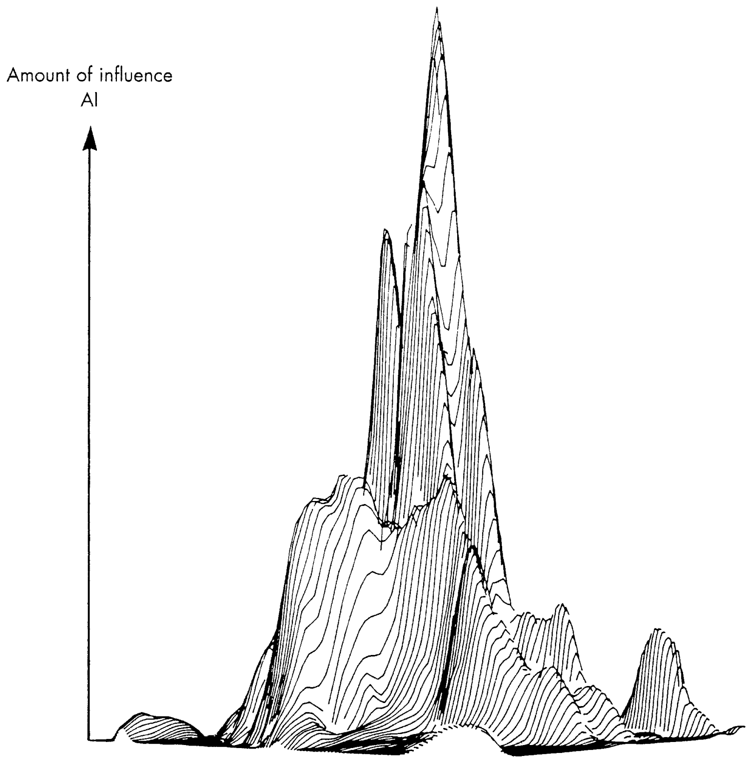

Fig. 4. Influence calculations. Case IV: The amount of influence per unit of area and 24-h period. The extremely high figures for AI in the town centre during the day and its relatively high values during the night, result in a highly centralised pattern of influence amount, with extremely high figures in the actual centre.

Fig. 1B shows the distribution of the population in a city during the night. The height of the model represents the density of population in different parts of the city. The centre is almost empty, represented by a 'hole' in the model, hidden by the higher parts of the model, showing the high density of people during the night in the inner city but outside the centre. The height of Fig. 1A represents the strength of the influence affecting the population in Fig. 1B,—here: the concentration of air pollution—a risk factor of a somewhat different character than an explosion.

The air pollution is supposed to influence the population in every moment. This spatial pattern of the influence effect, $\mathrm{EI} = I \times N$ is shown in Fig. 3A. N represents here the population density, the number of simultaneously present persons per unit of built-up area.

Fig. 3. Influence calculations. Case IV: The effect or impact of the influence at night (A) and during the day (B) in Malmö 1980. The great strength of the influence in the town centre affects the high concentration of the day population there. This results in an extremely high influence effect in the centre (B).

During the morning hours the working people move to their working places. A new pattern of distribution of the population arises, with heavy concentration of people in and around the city centre, and a lower density of persons in the outer zones (Fig. 2B). The concentration of the air pollution changes patterns too, also with rising concentration over the city centre (Fig. 2A). The rising population density and the simultaneously rising strength of influence in the central parts of the city result in a very high momentary influence effect (EI) in these areas (Fig. 3B).

The night period is supposed to last 14 h, the day period 10 h. Hence, the influence amount (AI) in each spot in the city is proportional to 14 times the hight of model in Fig. 3A *plus* 10 times the height of the model in Fig. 3B. This resulting model is shown —after due rescaling—in Fig. 4. Its height represents (number of person hours/unit of area) × unit air pollution. It expresses the exposure of the human population to a slowly acting risk factor during a 24-h period.

We have several types of influence sources around us—punctual, linear, areal—they can occur alone, in groups, acting as singular unit or as parts of a system. They can be active in a very short period—perhaps only a few seconds—but they may exert their influences not only during a day but for years, decades or even longer periods. The area concerned for their influences may be small, a few meters, but it may be a city, a country, a whole continent or the earth in its entirety. The principle shown above can however be applied in each of these different cases.

This short presentation can do no more than give a short glimpse of the method. Its background, theoretical foundation and possibilities for wider applications are however presented in Ref. [1] along with a discussion of the method's limitations.

References

[1] J. Szegö, Mapping Hidden Dimensions of the Urban Scene, Swedish Council for Building Research, Stockholm ISBN 91 540-5651-99, 1994.