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THE ROLE OF TRANSIT BELT-ROADS IN URBAN TRAFFIC NOISE REGIME

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Abstract: Road traffic is a main source of urban noise. Therefore, reducing traffic flow in cities stands as a common noise management practice. This research was conducted in the city of Caransebeş, Romania, from 2012 to 2014. The sample consists of three sets of L_{Aeq} noise values measured in 170 monitoring point stations along roads. The goal of this research is assessing noise level changes between two distinct situations: with and without traffic flow through the city. Thus, 2040 data values were statistical analyzed. We used interpolation tools for spatial modeling and correlation testing. The results highlight that noise pollution scale down for more than 50% of urban space when transit traffic uses the belt road. However, high noise levels persist in some edge zones. Thus marginal areas claim enhancement solutions.

Keywords: urban traffic noise, GIS, L_{Aeq},, statistical analysis.

1. INTRODUCTION

Noise pollution has been well recognized as an environmental growing problem (Farcaș & Sivertun, 2009; Swain & Goswami, 2013; Mehdi et al., 2011; Piccolo et al., 2005). Many studies indicate that noise affects the quality of life worldwide: North America (QiGan et al., 2012; Zuo et al., 2014), South America (Suárez & Barros, 2014), Asia (Hunashal & Patil, 2012; Swain & Goswami, 2013; Mehdi et al., 2011), Europe (Weber et al., 2014; Méline et al., 2013; Piccolo et al., 2005). Recent research revealed the strong relationship between noise, annoyance in humans (Garg & Maji, 2014; Paunović, 2013; Méline et al., 2013; Mehdi et al., 2011) and human health (Banerjee, 2013; Weber et al., 2014; Hunashal & Patil, 2012; Babisch, 2014, Tiesler et al., 2013). World Health Organisation (WHO, 2012) considers noise one of the strongest inequality indicators at subregional and national levels. In the recent times noise assessment became a concerned social, health or geospatial research theme.

Urban areas are exposed to noise because they lodge various sources of unwanted sound intensity and unwanted frequencies: industry, transportation, commercial areas, schools etc. The predominant source of noise in European urban areas is the busy road traffic (Swain & Goswami, 2013). European authorities have estimated that 12.5 % of European population is exposed to excess noise due to road traffic (European Commission, 2011). In order to develop action plans for reducing noise, the 2002/49/EC Noise Directive has claimed all Member States to develop the strategic noise maps for urban areas and major transport infrastructures. Reducing traffic flow in cities is the principal measure to reduce urban traffic noise (Piccolo et al., 2005). Thus, the deviation of transit circulation on belt roads could be a good solution.

In Romania, noise pollution is recognized by the authorities as a general environmental problem of urban areas. A recent study on noise pollution using field measurements and geographical information systems (GIS) modeling has been done in Cluj-Napoca city by Popescu et al., 2011.

This study undertook three years of field measurements across Caransebeș city, Romania. We collected real-time noise datasets from 170 noise monitoring point stations along roads in different time periods. Additionally, we compare the noise level due to transit traffic flow through the city with the noise level of local road traffic flow. The GIS tools were used to map noise, analyze noise pollution indices and evaluate changes. The results justify the rationality of constructing city belt roads and highlight the town benefits from urban noise pollution standpoint.

2. DATA & METHODS

Caransebeș is a city about 25000 inhabitants, with a stable socio-demographic structure and mixed type of urban land use consisting of roads, industries, commerce, leisure and dwellings. Due to the rising number of cars and increasing (personal and commercial) vehicle traffic, the main actual urban environmental problems are noise and air pollution. A local solution was to construct a belt road transport infrastructure for taking over the transit traffic flow, including heavy vehicles.

Noise mapping is one of the best ways of understanding environmental noise (Tsai et al., 2009; Weber et al., 2014; Garg & Maji, 2014; Mehdi et al., 2011). Based on three time sets of field data measurements, GIS modeling and geostatistical analysis, the present paper evaluate the spatial distribution of noise due to transit traffic flow in the city of Caransebeș.

This study established 170 temporary noise monitoring stations along roads in Caransebeș urban area (Fig. 1). To select the spatial distribution of the monitoring point stations, the urban area was divided into 250 x 250 m standard side grids. At least one measurement point station was set within each grid cell. The maximum number of points in one cell was 3. The shortest Euclidean distance between two nearest points is 41 m and the longest is 212.5 m.

The noise level measurements were performed manually using calibrated precision 2250 Brüel&Kjær sound level meter, with 90mm windscreen prepolarized free-field 1/2" microphone type 4950, held 1.5 m above the ground surface and minimum 2 m away from reflecting surface, if any (STAS 6161/3/89).

According Gaja et al., 2003, a measurement period of 2 weeks can be sufficient representative for longer term noise variations and reduce the uncertainty associated to noise measurements. Thus, we monitored separately working-days and weekend noise levels during morning (8-10 h) and evening (20-22 h) in three field campaigns (C1-2012, C2-2013 and C3-2014). In C1 and C2 cases the belt road was closed for overhauling, causing a busy urban road traffic flow and high traffic noise values. Thus, C1 and C2 measurements were registered for similar road traffic conditions. The C3 measurements were registered in a different situation (without transit traffic flow through the city) and were used for quantifying the noise changes. All measurements were done in good climatic conditions (no rain, no significant winds).

The sound meter was set to record noise statistics every 30 seconds using the A weighting filter, which offer the best correspondence with human auditory spectrum. The logged parameters are: L_{Aeq} for C1, C2, C3 and LAFmax, LAFmin, LCpeak for C2, C3. A total of 6120 noise data were collected. We used in this study only the 30 seconds average A-weighted equivalent continuous noise descriptor (L_{Aeq}), a total of 2040 values.

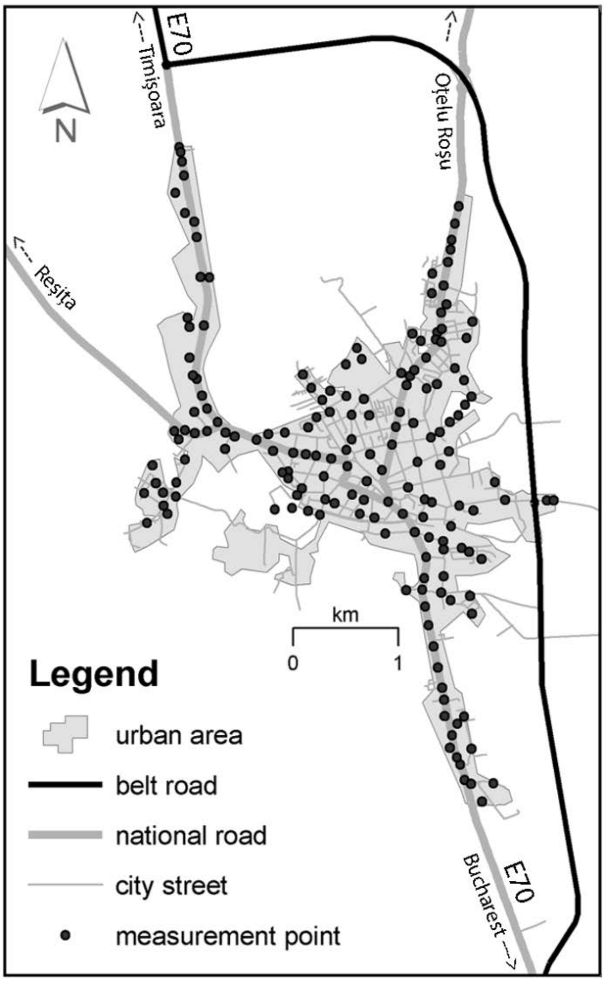

Figure 1. Spatial distribution of noise measurement stations

A variety of traffic noise prediction models including source modeling and source propagation algorithms (FHWA, CoRTN, RIS 90, Harmonoise, CNOSSOS) integrated with GIS interface (Garg & Maji, 2014) for a less time consuming approach have been developed in recent times. They are based on field measurements, highway noise descriptors and traffic noise parameters (Kumar et al., 2014). Because similar studies perform longer point measurement time for such big scale noise maps, we statistically tested the validity of applied 30 seconds time per point measurement for C1 and C2 L_{Aeq} datasets using Pearson's and Spearman's rank correlation analyses (Ross et al., 2011, Chowdhury et al., 2015, Fernandez-Somoano et al., 2015).

GIS techniques were then used to integrate field measurements with spatial information and to construct noise maps. We perform ordinary Kriging for spatial interpolation, which is recognized as the most widely used geostatistical interpolation method (Tsai et al., 2009).

3. RESULTS AND DISCUSSIONS

This study adopted L_{Aeq} as a standard parameter for analyzing environmental noise, known as one of the quantities that show the best correspondence with human auditory sensation (Kumar et al., 2014, Maruyama et al., 2013, Tsai et al., 2009). The A-curve weighted noise is largely used for quantifying traffic road noise indicators and annoyance in urban communities (Banerjee, 2013, Swain & Goswami, 2013, Kumar et al., 2014), sometime in association with air pollution (QiGan et al., 2012; Weber et al., 2014).

Previous studies used different specific short-term noise exposure sampling time for calculating L_{Aeq} point measurements: 5 min (QiGan et al., 2012), 15 min (Suárez & Barros 2014; Paunović, 2013; Piccolo et al., 2005), 30 min (Zuo et al., 2014), 1 h (Kumar et al., 2014). In the present case study we perform 30 seconds time measurement per point. Thus, the 1st step of our analysis was to demonstrate de validity of registered datasets. We hypothesized that similar field conditions must be reflected by quasi-similar noise values in 30 seconds time measurement per point. We use Pearson's and Spearman's rank correlation analyses to test the statistic similarity between C1 and C2 noise measurements (specific time periods with transit traffic flow through the city).

Figure 2 (A) depicts the Pearson's correlation charts for C1 L_{Aeq} and C2 L_{Aeq} working-mornings (wm) spatial datasets. The score of 0.64 for morning time prove a good relationship between data. The Pearson's point cloud distribution also suggests a bimodal association of values. The black dots highlight the 4th quartile values of both parameters (C1wm, C2wm). These selected values are hatched in the frequency histograms (Figure 2: B and C). This bimodal distribution is specific to all C1and C2 paired datasets and will be investigated in future studies.

The Spearman's rank correlation analysis results strength aforementioned association between C1 and C2 geodatasets. The best Spearman index values are obtained for morning time (working-days 0.79, weekend-days 0.63). The evening Spearman's values (working-days 0.59, weekend-days 0.45) are smaller because of local noise events related to residential sources.

Therefore, the 2nd step of analysis was to compare C2 and C3 recorded noise levels: C2 – July 2013, with transit traffic flow through the city (including heavy vehicles); C3 – February 2014, without local traffic flow through the city.

Noise maps were calculated for a 15 x 15 m grid using ArcGIS tools (ArcGIS; ESRI, Redlands, CA, USA) for eight time intervals: C2 and C3 morning and evening working-days and weekend-days. Noise level contours show the spatial distribution of noise during each time interval (Fig. 3).

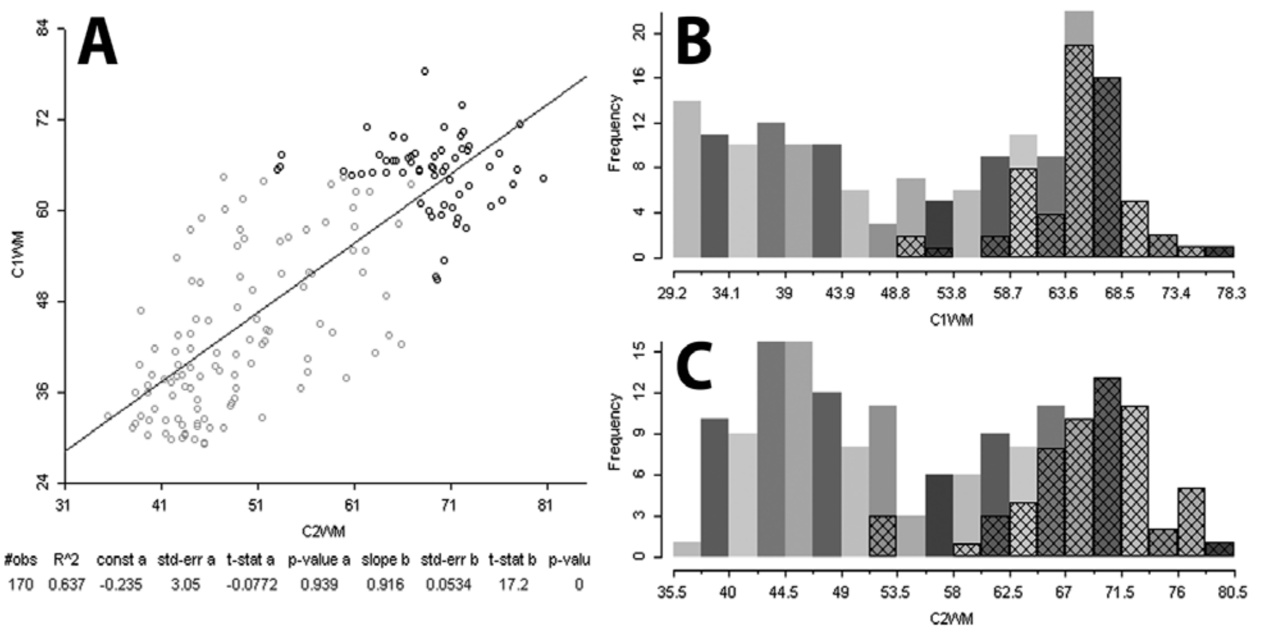

Figure 2. Pearson's correlation chart (A) and frequency histograms for C1 (B) and C2 (C) L_{Aeq} working-mornings (wm) registered values

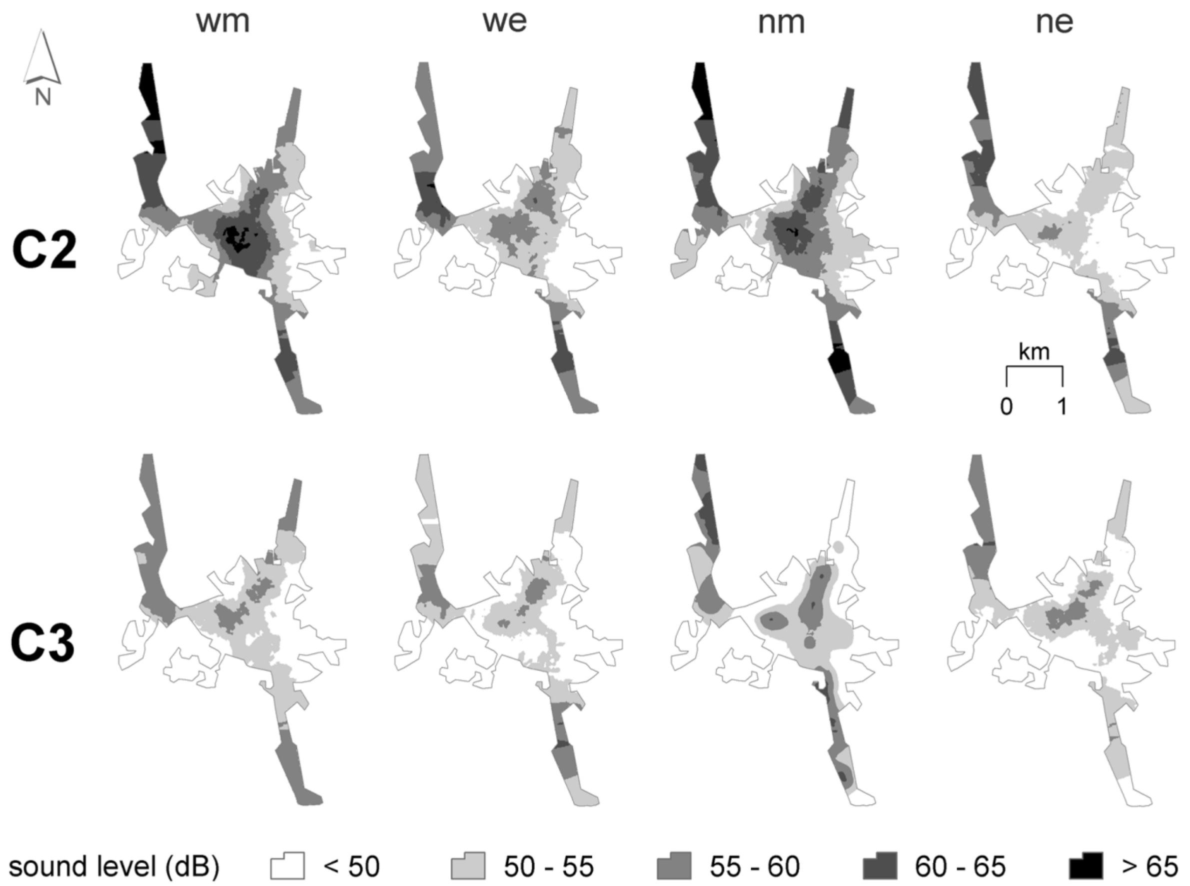

Figure 3. Classes of noise distribution: working-day morning (wm), working-day evening (we), weekend morning (nm), weekend evening (ne)

According European Directive about Environmental Noise 2002/49/EC (EU Directive 2002/49/EC, 2002), the noise levels equal to or above 55dB(A) corresponding to the day time limit recommended by the WHO for urban centers, could have an impact on human health. Romanian Law recommends noise levels lower than 50dB(A) during day-time (6:00-22:00) and lower than 40dB(A) during night-time (22:00-6:00) (OMS 536/1997).

The highest exposure to noise occurs in C2 morning working-days (C2wm), revealing not significant differences from morning weekend-days. This situation suggests an intense heavy traffic flow in C2 morning all the time. In the weekend, even if local traffic increases due to the rising number of passenger cars and their traffic speed, the evening noise levels (C2ne) are lower because the heavy trucks are stationed.

The C3 noise levels are characterized by spatial general stability with local intensity variations due to point sources. Due to broken roads and inadequate traffic management, the registered sound level is still high on network axes (city access roads). These edge areas correspond to industrial and commercial zones. The noise pollution in city center is due to services density (business, banks, offices, schools etc.). The residential areas have substantial lower noise levels.

The C2-C3 comparative analysis indicates that 27% of urban area registers 5-15dB lower noise level values in the morning working-days (wm), when the transit road traffic uses the city belt road. A 7% area of the entire city is affected by more than 15dB intensity changes.

The changes registered in the evening working-days (we) covered more than half city area (59%) including more than 15dB significant changes (11%). This result is explained by intense heavy vehicles transit road traffic in C2 and no heavy vehicles transit road traffic in C3.

In the weekend-days the urban areas affected by changes are smaller (21% - nm, 5% - ne). There are some constant high (principal access roads, city center) and constant low noise areas (residential), which result no changes.

All these results indicate lower noise levels using the belt road infrastructure. However, the remaining “noisy” urban areas still need stake-holders attention for specific management.

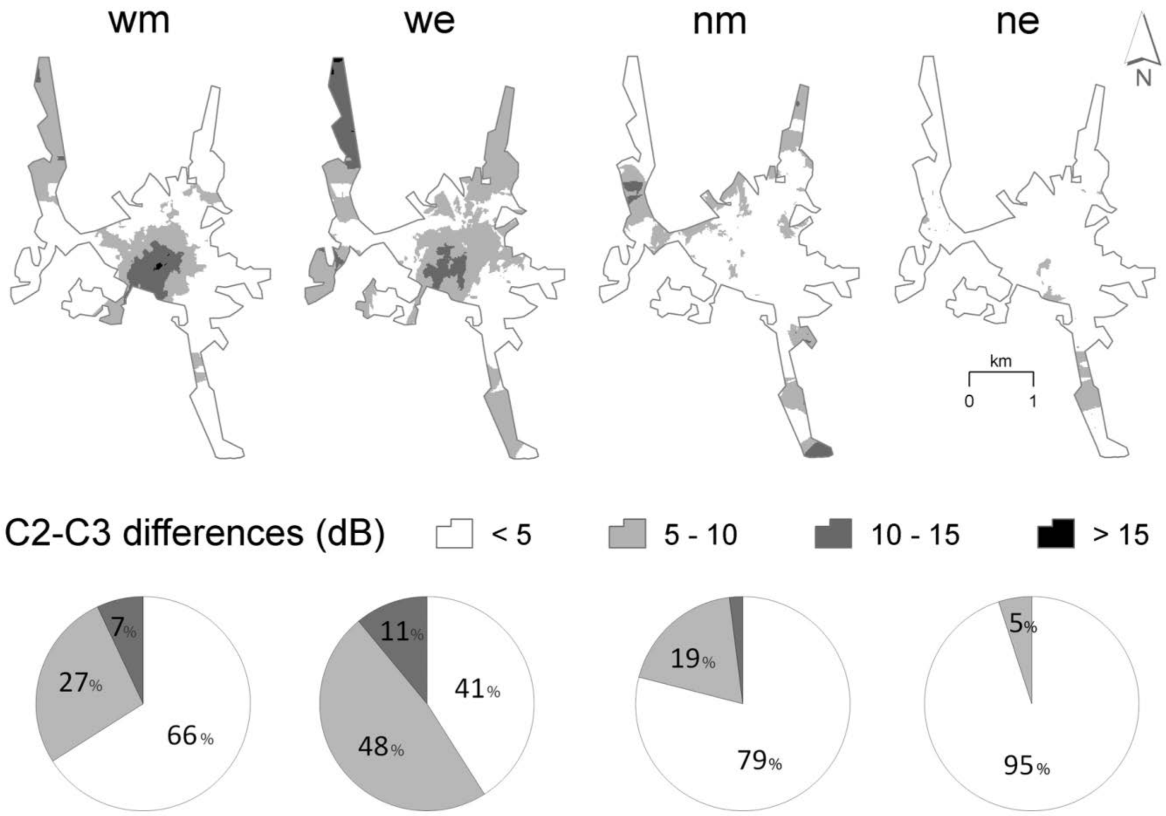

Figure 4. Classes of noise values changes between C2 and C3 datasets: surface distribution and percent analysis

4. CONCLUSIONS

This research evaluates urban noise levels in Caransebeș to demonstrate the noise benefits of constructing city belt roads. The results revealed lower noise levels from 5% up to 59% of urban area. The use of belt road also diminishes urban L_{Aeq} noise descriptor values up to 15dB. However, there remain some areas with high noise levels and need improvement solution from the urban decision makers.

From a practical point of view, this is a useful method to clearly identify areas with alarming noise pollution levels in Caransebeș. The registered values can be used in the future urban planning as environmental parameter condition. The authorities of Caransebeș should be aware of annoyance and health effects that traffic noise high levels can cause.

The use of traffic volume data and longtime continuous noise measurements can improve the results.

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