# APPLICATION OF GIS TO SIMULATION OF THE AIR TRAFFIC POLLUTION IN NAKHON RATCHASIMA, THAILAND

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**ABSTRACT:** The purpose of the study is to generate traffic air pollution map using mathematical model and geographic information system (GIS). The pollutants analyzed were CO, and NOx which can be harmful to people living in the area. The 3 steps of mapping process were performed under the GIS environment using the existing vehicle emission rates and pollutant dispersion model. First, traffic volume, road network, and the emission rates of road segments varying with types of vehicle were collected from existing data. Second, the pollutant concentrations were calculated by use of Caline4, a tool with Gaussian dispersion model. The model parameters include emission rate, wind directions and speeds, ambient temperature and observed pollutant concentration, and atmospheric stability during all seasons from the 1$^{st}$ January 2010 to 31$^{st}$ May 2011.This resulted in concentrations at many receptor points along links of the road network. Third, distributions of pollution concentrations were generated by means of the spatial interpolation of those from receptors. The results can be used as helpful basic data for efficient traffic and transportation planning.

## 1. INTRODUCTION

NakhonRatchasima has been long known as the large province and big gateway to the northeastern part of Thailand. Increasing of traffic activities in NakhonRatchasima municipality has led to an increase in the consumption of fossil fuels and subsequent air pollution. This causes air quality and human health deterioration in this municipality. Air pollutants can cause a variety of health problems such as breathing difficulty, lung damage, bronchitis, cancer, and nervous system damage. Air quality is necessary to be simulated from air traffic pollution map in order to reduce pollution to levels which minimize harmful effects on human health and the environment. The main objective of the study is to generate the representative spatial distributions of air pollution (CO and NOx) in the study area using worst case wind angle of Caline4 model.

## 2. RELEVANT DATA IN THE STUDY AREA

### 2.1 Study Area

The study area is the municipality of NakhonRatchasima province, Thailand, commonly referred to as Korat. The province is located on the southwest rim of the Khorat Plateau. The municipality covers an area of 37.2 $km^2$ and its population density is 7496 persons/$km^2$. A map of municipality area is displayed in Figure1.

### 2.2 Traffic Data

The traffic volume data, a number of vehicles per hours (V/H), of major and minor roads were derived from records collected by traffic counts on 34 main intersections, Five categories of vehicles are private light duty gasoline vehicles (PLDGV), light duty, diesel trucks (LDDT), heavy duty diesel trucks (HDDT), bus (BUS), motorcycles (MC). The pollutants to be investigated are CO and NOx. Most road segments were processed as line sources and the vehicle fleet of the local city roads was classified in accordance with Figure 1.

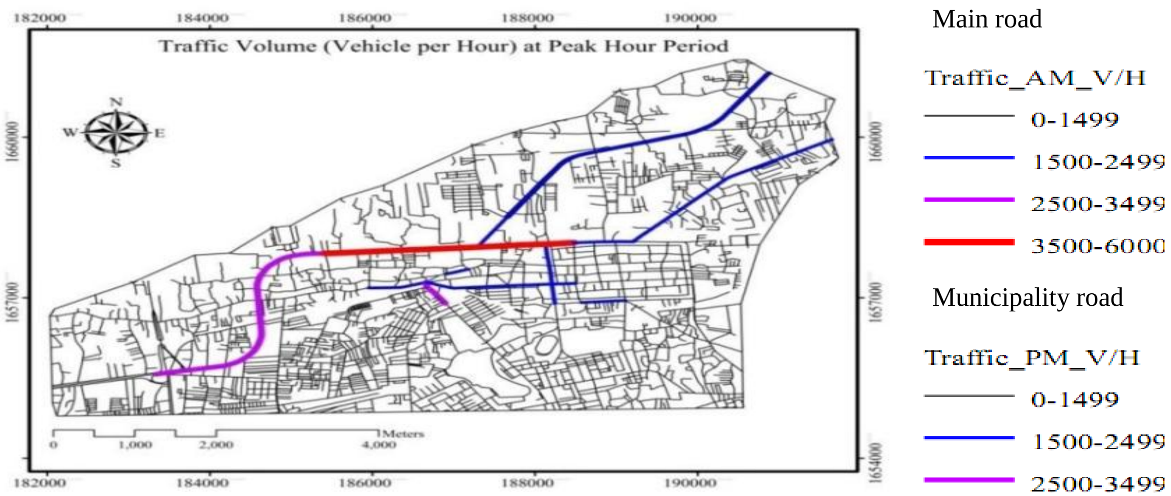


Figure 1 Traffic volumes on road network in the study area at 07.00 - 08.00 am and 16.00 - 17.00 pm collected between1 - 20 February 2007.

The increase of vehicles in NakhonRatchasima is not proportionate to the increase of roads and has caused traffic congestion and delay in transportation. Traffic speed surveyed in 2007 showed that during the rush hour, average speed was 10-12 km/hour in the inner area, whereas it was 19-21 km/hour in the outer area. These large numbers of vehicles and traffic congestion have put severe impact on air quality of NakhonRatchasima. The percentage of emission from different mobile sources which are the major emitters of NOx (80%), CO (75%) and PM10 (54%).

### 2.3 Meteorological Data

Wind speed and wind direction are meteorological factors that vary significantly and cause variation of pollutant distribution in the atmosphere. Figure2 shows the wind rose diagram of all season when traffic data were collected in March 2007. Wind speed and directions change markedly in different months, which impose some uncertainty on the pollution distribution. This study employs hourly data of all dates from 1 January 2010 to 31 May 2011 recorded by the Thai Meteorological Department (TMD). These data are also utilized to assess the efficiency of the planned monitoring network based on simulation results. The Gaussian distribution model parameters include emission rate, wind directions and speeds, ambient temperature, and observed pollutant concentration, and atmospheric stability during the whole observed period.

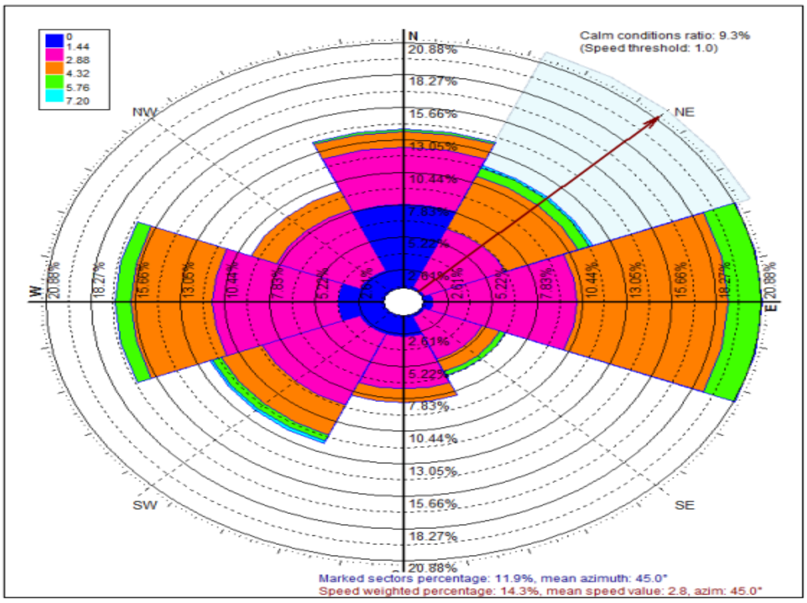


Figure 2 An example of wind rose diagram of average mean speed and the 45º direction of NakhonRatchasima municipality during 1 January 2010 to 31 May 2011 at 16.00 pm.

## 3. RESEARCH PROCEDURE

The procedure framework in this study is illustrated in Figure 3. It includes data acquisition, model of dispersion, and GIS processes of time-series pollution.

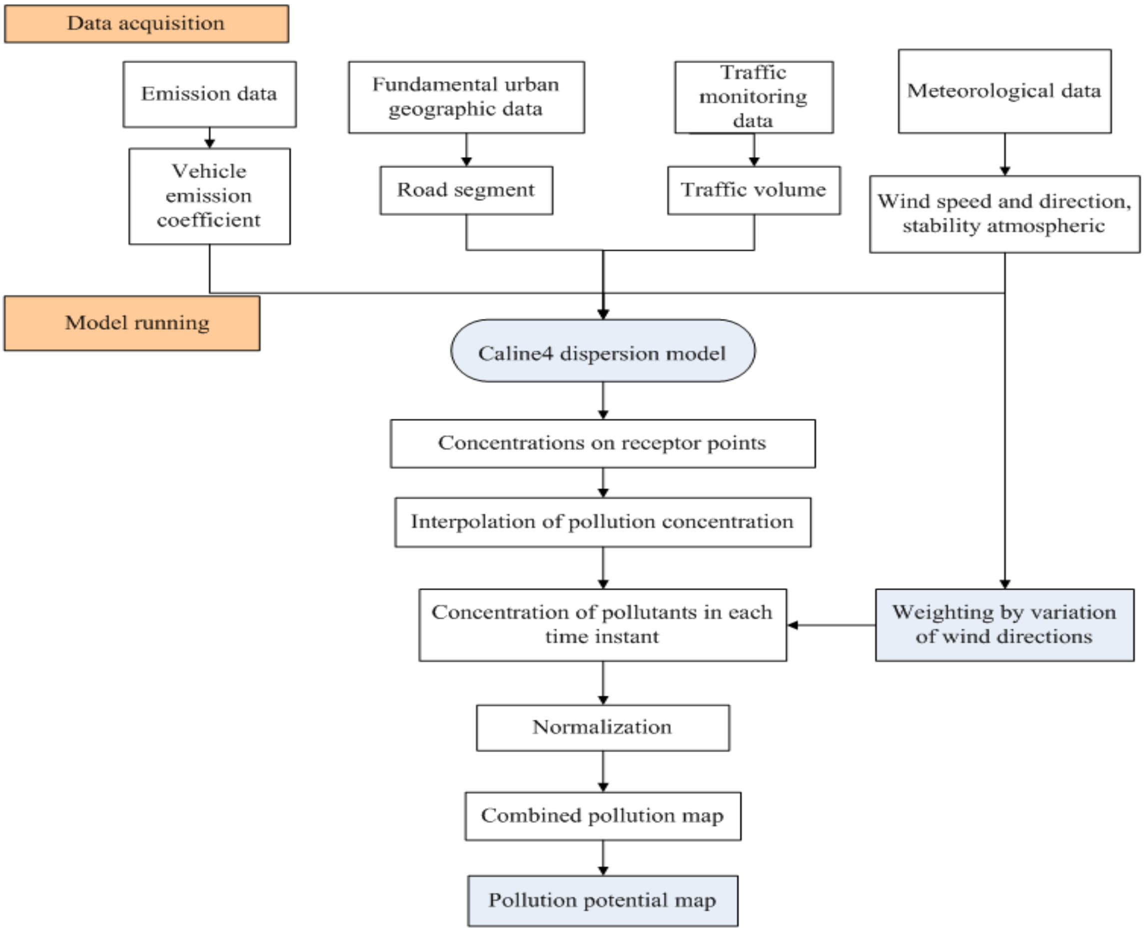


Figure 3 Procedure framework of the study.

### 3.1 Traffic and Emission Coefficient Data

The emission of the entire vehicle fleet was calculated on the basis of emission coefficients (g/km/vehicle), traffic volume (vehicles/hour), and road segment length (kilometer). The traffic volume was estimated using the SYNCRO which is a traffic optimization software package. The average speed from field observation and traffic volume of each link were then input to estimate CO, and NOx of each link.The set of the emission coefficients with respect to different types of vehicles and speeds was developed and updated by the Pollution Control Department (PCD) of Thailand. Table 1 shows examples of the emission coefficients of CO determined in 2007. Other emissions coefficients such as NOx in 2007 are also available.

Table 1 Examples of emission coefficients of CO with respect to different types of vehicle and speeds (PCD, 2007).

| Speed (km/hr) | PLDGV | BLDGV | LDGT | LDDT | HDDT | HDGV | BUS | MC2 | MC4 |
|---|---|---|---|---|---|---|---|---|---|
| Emission coefficient of CO (g/km/v) | | | | | | | | | |
| 5 | 95.24 | 72.82 | 84.60 | 4.93 | 23.47 | 19.10 | 27.01 | 35.69 | 22.86 |
| 10 | 52.27 | 40.46 | 43.37 | 3.85 | 18.34 | 14.92 | 21.1 | 19.52 | 12.47 |
| 15 | 35.47 | 29.12 | 28.45 | 3.06 | 14.58 | 11.86 | 16.77 | 12.77 | 8.14 |
| 20 | 27.32 | 23.57 | 21.16 | 2.48 | 11.79 | 9.59 | 13.57 | 9.46 | 6.01 |
| 25 | 22.73 | 20.34 | 16.95 | 2.04 | 9.71 | 7.90 | 11.17 | 7.60 | 4.83 |
| 30 | 19.79 | 18.22 | 14.21 | 1.71 | 8.14 | 6.62 | 9.36 | 6.43 | 4.06 |
| 40 | 15.17 | 13.33 | 11.69 | 1.26 | 6.02 | 4.90 | 6.93 | 4.93 | 3.10 |

### 3.2 Dispersion Using Caline4 Model

Caline4 is a computer-based line source Gaussian dispersion model works as expressed in equation (1). It was developed to calculate CO concentrations and it can be used to predict the concentrations of various other pollutants (NOx, inert gases and particulates) in a variety of road networks (Marmur, A, 2003). The input parameters required for the model involve roadway geometry, meteorological parameters and measured traffic flow. The emission factors used for computation are considered in grams per kilometer for each vehicle (Gramotnev, G, 2003).

$$C = \frac{q}{\sqrt{2\pi u \sigma_z}} \left\{ \exp\left[ \frac{-(z-H)^2}{2\sigma_z^2} \right] + \exp\left[ \frac{-(z+H)^2}{2\sigma_z^2} \right] \right\} \quad (1)$$

Where C is nth receptor concentration (g/m$^3$), $q$ is the lineal source strength (g/mi/s), $u$ is wind speed (m/s), $H$ is source height (m), $\sigma_z$ is vertical dispersion parameters. To obtain $\sigma_z$. The experiment of Turner (1970) has been widely accepted and applied in this study.

### 3.3 Spatial Pollution Interpolation

The predicted CO and Nox concentrations varying with wind directions and time instants from Caline4 in the receptors along the road network were interpolated to predict the raster-based concentrations over the study area. Inverse Distance Weighting (IDW) method was chosen to express more local influence. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell and can be expressed as equation (2). A general form of finding an interpolated value $u$ data given at point $x$ based on samples $u_i = u(x_i)$ for i = 0,1,..., N using IDW as an interpolating function:

$$u(x) = \sum_{i=0}^{N} \frac{w_i(x) u_i}{\sum_{j=0}^{N} w_j(x)} \quad (2)$$

Where

$$w_i(x) = \frac{1}{d(x, x_i)^p} \quad (3)$$

is a simple IDW weighting function, $x$ denotes an interpolated point, $x_i$ is an interpolating (known) point, $d$ is a given distance from the known point $x_i$ to the unknown point $x$, $N$ is the total number of known points used in interpolation and $p$ is a positive real number, called the power parameter.

### 3.4 Combined Pollution Map

All types of pollution concentrations were weighted by percentage of all wind directions and combined to be the map of pollution intensity. This intensity was normalized. The potential pollution intensity at any grid cell is the sum of pollution of each type of pollutants, vehicles, and time instants as expressed in equation (4).

$$\text{Potential pollution map} = \left( \sum_{t=1}^{T} \sum_{v=1}^{V} \sum_{i=1}^{I} C_{jivt} \right) / T_o \quad (4)$$

Where $C_{jivt}$ is the concentration at cell $j$ of pollutant $i$ of traffic volume of vehicle type $v$ according to time instant $t$. $T_o$ is the total number of time instants.

## 4. RESULT AND DISCUSSION

The pollution levels were simulated to evaluate the air traffic quality of the municipality of Korat. The result of the analysis shows that there is a trend of increasing air pollution (CO and, NOx) in high traffic volume road network. The resulting distribution maps of CO and, NOx, as integrating spatial variations of traffic volume, types of vehicle, wind directions and speeds at different time instants (peak hour periods: 07:00 – 08:00 am and 16:00 – 17:00 pm), are displayed in Figures 4 and 5. It was assumed that all vehicles moved at the speed up to 20 km/h. The maximum distribution areas of these pollutants at two time instants are overlapped. This corresponds to the high traffic volume always available in the main roads falling into this area at those time instants.

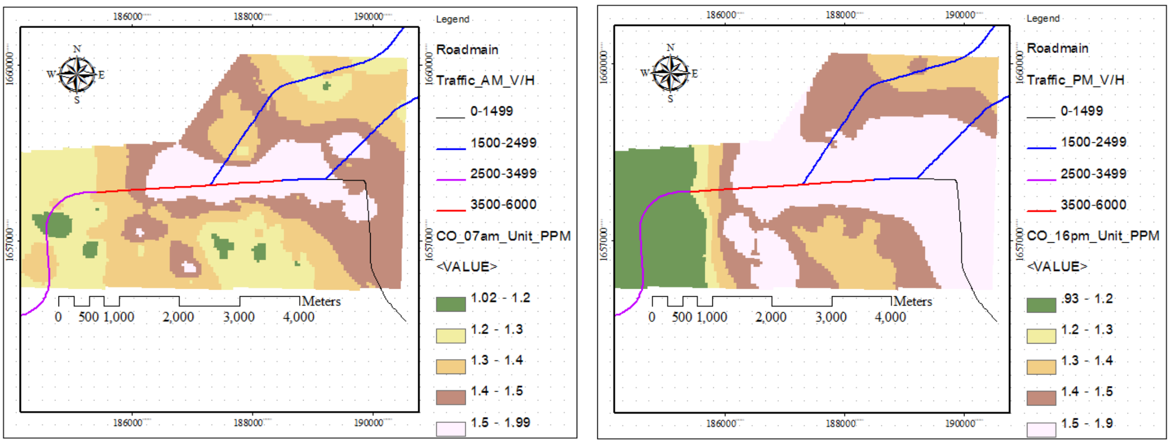


Figure 4 Traffic volume and concentration of CO ( ppm) at 07:00 am (left) and 16:00 pm (right).

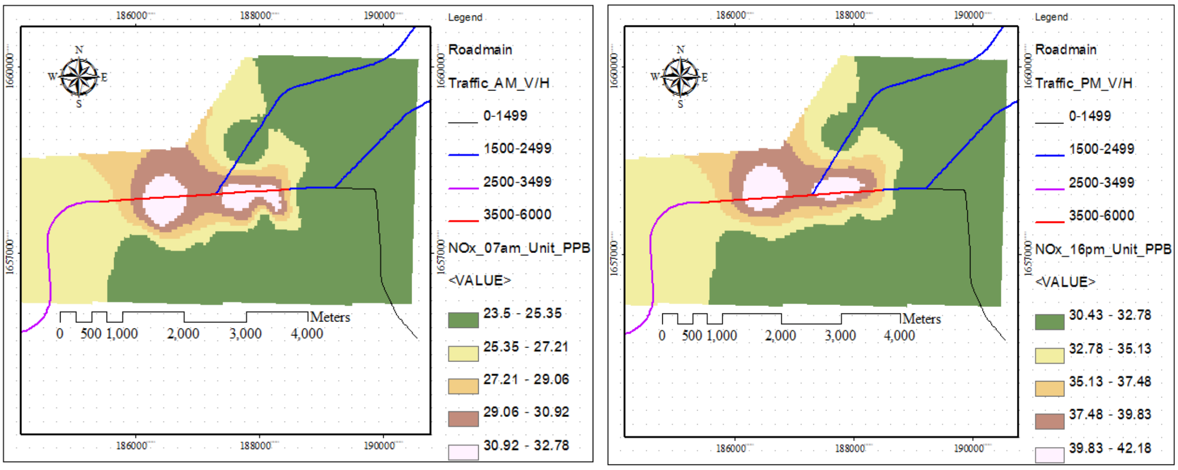


Figure 5 Traffic volume and concentration of NOx (ppb) at 07:00 am (left) and 16:00 pm (right).

To consider the overview of the distribution of these pollutants at the peak time instant, normalized attributes of maps in the Figures 4 and 5 were integrated with equal weight using equation (4) and resulting in the potential air pollution map as displayed in Figure 6. The integrated normalized attributes were expressed as the indexes related to the concentration of the total pollution (CO and NOx) distributed in the area. The higher the index comparatively indicates the higher pollutions. The obviously maximum pollution patch can be observed in the upper middle part of the study area. The commercial complex and local famous schools including several road intersections are situated in the patch. This spot and the surroundings have well known as the worst traffic of the municipality.

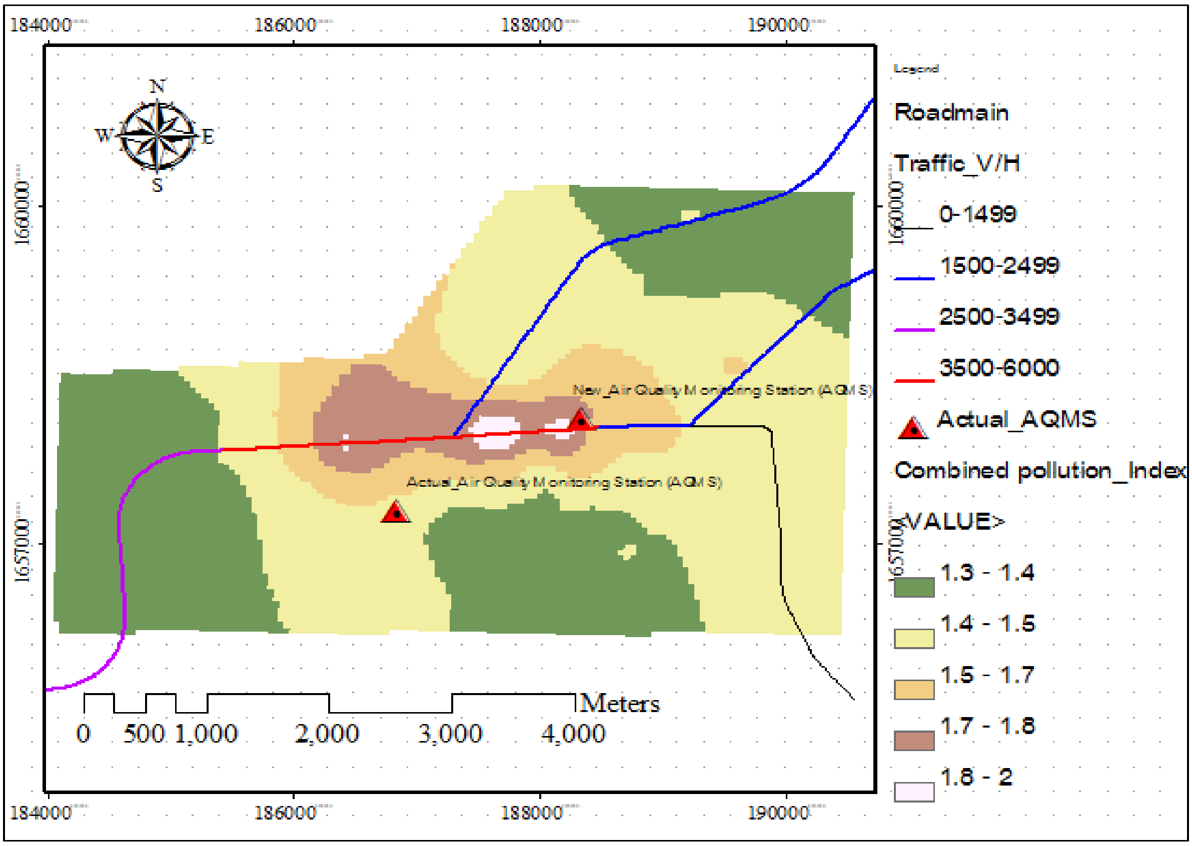


Figure 6 the normalized concentration of CO and NOx into combined pollution map.

## 5. CONCLUSION

The study confirmed that the pollution dispersion model and GIS can be incorporated successfully in simulating spatial distribution of traffic air pollution in the municipality of Korat. When simulation model was used, GIS can increase efficiency in area mapping and improve geographic precision. GIS visualization and display through graphic interface can increase the understanding ability of the simulation model. Spatial distribution maps of CO and NOx and their integration were generated via GIS interpolation with enhancing local effect. Their high concentration distribution is well associated with the high populated land marks such as the shopping mall, commercial complex, and schools.

This information can be effectively used for several aspects in transportation planning. For example, proper position of an Air Quality Monitoring Station (AQMS) can be located efficiently when spatially integrates this information with people exposure impact, frequency of pollution violence, and effective service area using optimization multi-objective decision analysis.

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