Research Paper

Noise Abatement Approach Using Computer Simulation Model for Urban Indian Road of a Tier-2 City

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Noise pollution is a major problem nowadays. In urban context, road traffic is the main source of noise pollution. People directly exposed to road traffic noise suffer from moderate to severe annoyance, headache, stress, feeling of exhaustion, and reduced work performance efficiency. As the sources and severity of noise pollution continue to grow, new approaches are needed to reduce the exposure. In this research, noise abatement has been investigated using a computer simulation model (SoundPLAN essential 4.0). Noise maps were developed using SoundPLAN essential 4.0 software. Noise maps are very beneficial to identify the impact of noise pollution. Data required for mapping are noise data (L_{Aeq}), road inventory data, geometric features of mapping area, category wise traffic counts, category wise vehicle speed, meteorological data such as wind velocity, humidity, temperature, air pressure. L_{Aeq} observed on all locations of the Central zone of Surat city was greater than the prescribed central pollution control board (CPCB) limits during day time and night time. This paper is focused on using acoustic software for the simulation and calculation methods of controlling the traffic noise. According to the characteristics of traffic noise and the techniques of noise reduction, road traffic noise maps were developed using SoundPLAN essential 4.0 software to predict the scope of road traffic noise. On this basis, four reasonable noise control schemes were used to control noise, and the feasibility and application effect of these control schemes can be verified by using the method of simulation modelling. The simulation results show that L_{Aeq} is reduced by up to 5 dB(A). The excess noise can be efficiently reduced by using the corresponding noise reduction methods.

Keywords: noise measurement; noise mapping; noise modelling; noise reduction; simulation.

1. Introduction

Noise pollution consistently ranks high on the list of citizens' concerns (MANOJKUMAR *et al.*, 2019). It is estimated that over half of population in urban areas is exposed to unacceptable noise levels (OGUNTUNDE *et al.*, 2019). Noise from road transport is the major source of this exposure (LAVANYA *et al.*, 2014). Vehicle noise regulation is important, especially in the light of growing traffic volumes and the proximity between transport infrastructure and residential areas (JHANWAR, 2016; PASZKOWSKI, SOBIECH, 2019). Every doubling of transport intensity increases noise levels by 3 dB(A). This research highlights the scale and scope of the traffic noise problem, which affects a very substantial proportion of populace (SONAVIYA, TANDEL, 2019a). Traffic noise becomes severe where residential and commercial areas are built alongside the main stream of traffic to fulfil the housing demands of communities (GOLMOHAMMADI *et al.*, 2007). There are many conventional noise mitigation measures that have been proposed to tackle the road traffic noise problem over the past few decades (PRAJAPATI, DEVANI, 2017).

In this research study, noise maps were developed. Data required for mapping are noise levels (L_{Aeq}), road inventory data, geometric features of mapping area, category wise traffic counts, category wise vehicle speed, meteorological data such as wind velocity, humidity, temperature, air pressure (SONAVIYA, TANDEL, 2019b). The noise maps can be useful at planning stages, or prior evaluation of action plans, or determination of the most polluted areas (Arana *et al.*, 2013). Furthermore, with strategic noise maps developed in this study, an accurate assessment of the number of people exposed to below and above permissible noise standards is possible (Sonaviya, Tandel, 2020). For existing affected areas, hotspots (red color in the noise maps), immediate suitable noise mitigation strategies can be applied using proper traffic planning *viz* making one way lanes, prohibiting the entry of 3-W (auto-rickshaws) or heavy vehicles.

2. Field study and data collection

The area selected for noise mapping is Surat city (tier-II city). The city covers an area of about 326.515 km^2 and has the population of about 6.4 million as per 2016 estimation (Tandel, Macwan, 2017). There are seven zones in Surat city. These seven zones cover diversified activities of business, residence, commerce, and industry. A mixed type of traffic has been observed in these zones. Since the total area of Surat city is very large to map, a small portion of urban arterial road stretches of the Central zone was selected and mapped.

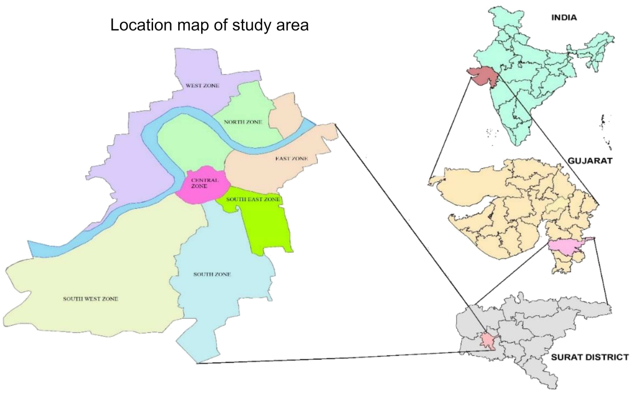

Fig. 1. Location map of Surat city.

Fig. 2. Map of Central zone of Surat city with monitoring locations.

Noise monitoring was done at 3 locations of the Central zone of Surat city's arterial roads, with traffic volume, traffic speed, and meteorological data. Measurements were carried out on Monday through Friday, the working days. Field measurements have been taken by using the KIMO DB 300/2, automatic sound level meter for 24-hour duration. Monitoring was divided in two parts as per CPCB guidelines, day time 6.00 am to 10.00 pm and night time 10.00 pm to 6.00 am. Vehicles were divided into five categories like: 2-wheelers (motorcycle, mopeds), 3-wheelers (auto rickshaw), 4-wheelers (cars), bus, and truck (Central Pollution Control Board, 2000). The counts of number of vehicles that crossed the point of measurement from either direction on the road were recorded by videography. The speeds were monitored with a hand-held radar gun along with noise levels.

Figure 3 depicts the day time L_{Aeq}, of different locations of the Central zone during the working days (Monday to Friday). From Fig. 3, it is clearly seen that the highest L_{Aeq} observed was 74.5 dB(A) at B location. The day time L_{Aeq} observed in all locations of the Central zone was greater than the prescribed CPCB limits during the time, which is 50 dB(A) for the silence zone, 55 dB(A) for the residential area, and 65 dB(A) for the commercial area.

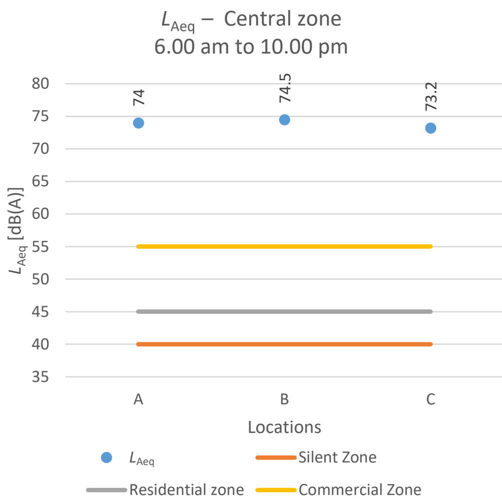

Fig. 3. Central zone – day time L_{Aeq} values at all monitoring locations.

Table 1. Central zone noise level readings.

Locations	Day time L_{Aeq} (6.00 am to 10.00 pm)						Night time L_{Aeq} (10.00 pm to 6.00 am)					
	L_{Aeq}	$L_{\max}$	$L_{\min}$	L_{10}	L_{50}	L_{90}	L_{Aeq}	$L_{\max}$	$L_{\min}$	L_{10}	L_{50}	L_{90}
A	74.0	105.2	44.1	76.4	69.9	65.4	66.6	95.0	37.6	69.1	57.8	41.6
B	74.5	103.7	48.1	75.7	68.7	61.6	62.4	103.4	35.0	63.6	45.6	38.6
C	73.2	113.9	43.5	72.9	67.4	61.8	64.7	101.2	41.0	65.1	49.2	42.5

Table 2. Central zone – day time traffic volume (6.00 am to 10.00 pm).

Locations	No. of vehicles					Total number of vehicles
	2-wheeler	3-wheeler	4-wheeler	Bus	Truck	
A	23 370	6011	5276	246	183	35 086
B	25 567	6981	4902	156	98	37 704
C	29 560	8927	4501	74	45	43 107

Table 3. Central zone – night time traffic volume (10.00 pm to 6.00 am).

Locations	No. of vehicles					Total number of vehicles
	2-wheeler	3-wheeler	4-wheeler	Bus	Truck	
A	3344	349	815	3	2	4513
B	783	97	167	1	2	1050
C	4368	539	1218	18	10	6153

Figure 4 depicts the night time L_{Aeq} of different locations of the Central zone. Maximum L_{Aeq} observed was 66.6 dB(A) at A location. Minimum was recorded as 62.4 dB(A) at location B at the night time, which was greater than the prescribed CPCB limits during the night time. All recorded L_{Aeq} values were above the prescribed CPCB limits. Tables 2 and 3 give the classified as well as total traffic volume count (both direction) at all 3 locations of the Central zone for the day and night time respectively.

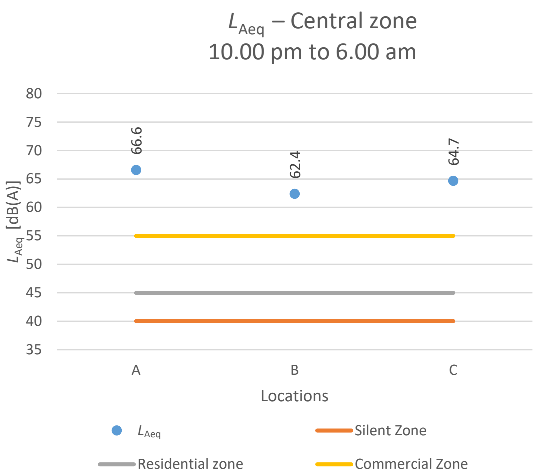

Fig. 4. Central zone – night time L_{Aeq} values at all monitoring locations.

The traffic volume composition for the day and night time at different locations of the Central zone was evaluated from the classified vehicular count data. Table 2 and 3 depict the composition of all categories of vehicles during the day and night time of the Central zone.

In the Central zone, the 2-wheeler frequency was higher during the day time. Table 2 demonstrates that 2-wheelers contribute 65–70%, 3-wheelers contribution 17–21%, 4-wheelers contribution is around 10–15%, and bus and truck contribute around 2% of noise during the day time. Table 3 shows that during the night time, 2-wheelers contribute 70–75%, 3-wheelers contribution is 8–10%, 4-wheelers contribution is around 15–20%, and bus and truck contribute around 1% of noise. The 2-wheeler and 4-wheeler frequencies were higher during the night time compared to the day time, which is the main reason for high levels of the night time noise.

Tables 4 and 5 show vehicles speed of all 3 locations of the Central zone for the day and night time respectively. These tables depict the maximum and minimum speed of the categorised vehicles. 2-wheelers' average speed ranged between 32 and 36 km/h during the day time and between 35 and 40 km/h during the night time. Similarly, 3-wheelers' average speed ranged between 30 and 35 km/h during the day time and 30 and 40 km/h during the night time. The average speed of 4-wheelers was in the range of 30–40 km/h during the day time and of 35–45 km/h during the night time. The average speed of buses and trucks ranged between 35 and 45 km/h during the day and night time.

Table 4. Central zone – day time avg. speed (6.00 am to 10.00 pm).

Locations	Average speed of vehicle [km/h]				
	2-wheeler	3-wheeler	4-wheeler	Bus	Truck
A	32.17	29.72	35.16	35.71	34.12
B	34.50	32.05	37.62	38.04	36.18
C	35.87	36.12	38.72	37.87	37.80

Table 5. Central zone – night time avg. speed (10.00 pm to 6.00 am).

Locations	Average speed of vehicle [km/h]				
	2-wheeler	3-wheeler	4-wheeler	Bus	Truck
A	38.40	34.19	38.32	39.32	39.58
B	38.51	35.25	39.14	40.19	39.40
C	38.77	38.02	40.70	39.87	40.21

Table 6. Meteorology data.

Month	Humidity [%]	Air pressure [mb]	Wind velocity [km/h]	Temperature [°C]
January, 2018	67	1014.5	8.0	31.2
February, 2018	64	1014.8	8.0	33.4

Noise propagation is affected by meteorological data, parameters like wind velocity, temperature, air pressure; humidity, that were collected from Indian Meteorological Department. These meteorological data also become one of the input parameters for SoundPLAN software. Table 6 depicts monthly average data such as temperature, humidity, air pressure, and wind velocity of Surat city. Noise monitoring was done in the month of January, 2018, and February, 2018.

3. Noise mapping process and simulation

Noise mapping has been done using computer simulation model (SoundPLAN essential 4.0). Professional calculation software (SoundPLAN software) is based on a closed calculation algorithm (Wolniewicz, Zagubień, 2015). This software can also consider elements that affect the dispersion of noise like buildings, shape of the land, capacity of an area to absorb noise (cultivated fields) or to reflect noise (concrete areas or water surface). They also take into account the obstacles in the area, which can be: barriers, the shape and the acoustical characteristics of the terrain, and meteorological conditions (Cerdá *et al.*, 2013). To develop a noise map, country-wise road calculation models such as RLS-90 from Germany, CoRTN:88 from U.K, NMPB:2008 from France, TNM2.5 from U.S., etc., are available in SoundPLAN essential 4.0 software. Among all these noise models, RLS-90 is useful to develop road traffic noise maps because this noise model has urban road inventory features (Sonaviya, Tandel, 2020). Table 7 depicts predicted noise level values.

Table 7. Predicted $L_{\text{Aeq-SoundPLAN}}$ (Central zone).

Locations	Predicted L_{Aeq}	
	Day time	Night time
A	64.8	62.9
B	64.9	58.9
C	62.8	61.5

Figures 5 and 6 depict the noise maps of the Central zone using RLS-90 model. Roads show the emission line where noise was generated by vehicles, which means that vehicles are the main source of noise.

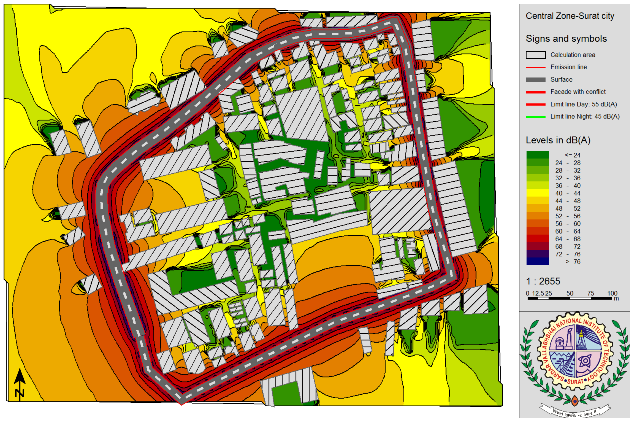

Fig. 5. Day time noise map of the Central zone using RLS-90.

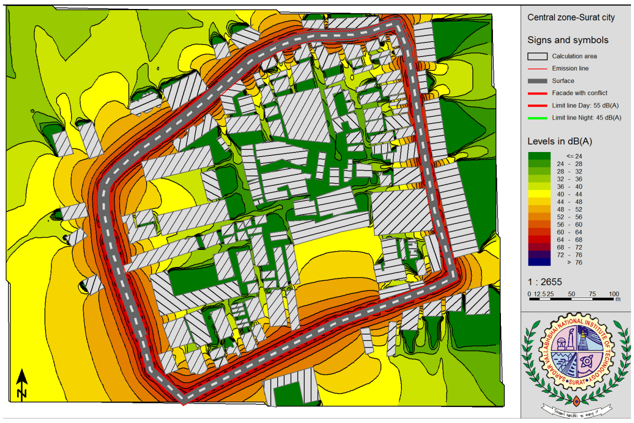

Fig. 6. Night time noise map of the Central zone using RLS-90.

SoundPLAN essential 4.0 can predict noise value at any point on the map.

In order to solve the problem of noise pollution, the experimental and simulation methods are used to study the noise reduction performance with different prohibited categories of vehicles. To reduce noise, different scenarios were adopted in SoundPLAN essential 4.0 software. In scenario 1 two-wheelers are not considered as input parameter in SoundPLAN essential 4.0. Similarly, in scenarios 2, 3, and 4, three-wheelers, four-wheelers and heavy vehicles are not considered as input parameters in SoundPLAN. Tables 8 and 9 depict the day time and night time L_{Aeq} values with different scenarios given by SoundPLAN software. From Figs 7 to 13, it is observed that if we band vehicles category-wise, the L_{Aeq} is reduced by up to 5 dB(A).

Table 8. Prohibited vehicles during the day time L_{Aeq}.

Location	L_{Aeq} [dB(A)]	Scenario 1 (2-w prohibited) L_{Aeq} [dB(A)]	Scenario 2 (3-w prohibited) L_{Aeq} [dB(A)]	Scenario 3 (4-w prohibited) L_{Aeq} [dB(A)]	Scenario 4 (heavy vehicles prohibited) L_{Aeq} [dB(A)]	Overall reduction [dB(A)]
A	64.8	61.7	60.6	60.8	61.9	up to 5 dB(A)
B	64.9	60.9	60.5	60.3	60.7	up to 5 dB(A)
C	62.8	59.3	59.3	58.7	59.2	up to 5 dB(A)

Table 9. Prohibited vehicles during the night time L_{Aeq}.

Location	L_{Aeq} [dB(A)]	Scenario 1 (2-w prohibited) L_{Aeq} [dB(A)]	Scenario 2 (3-w prohibited) L_{Aeq} [dB(A)]	Scenario 3 (4-w prohibited) L_{Aeq} [dB(A)]	Scenario 4 (heavy vehicles prohibited) L_{Aeq} [dB(A)]	Overall reduction [dB(A)]
A	62.9	60.1	61.1	61.5	61.6	up to 2 dB(A)
B	58.9	56.9	57.2	57.8	57.6	up to 2 dB(A)
C	61.5	59.0	60.8	60.3	60.7	up to 2 dB(A)

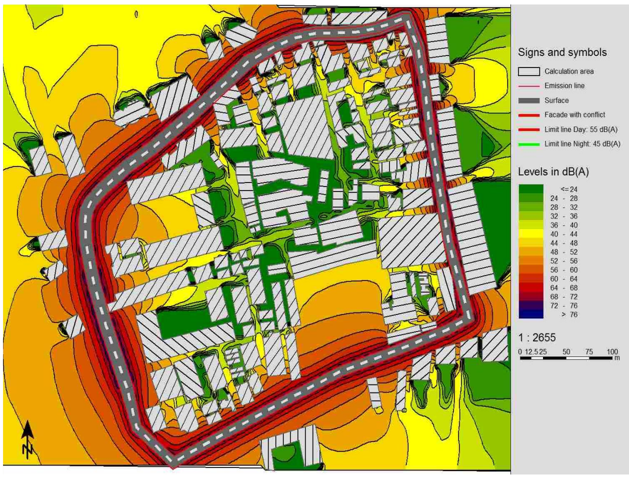

Fig. 7. Scenario 1, 2-wheelers prohibited at day time.

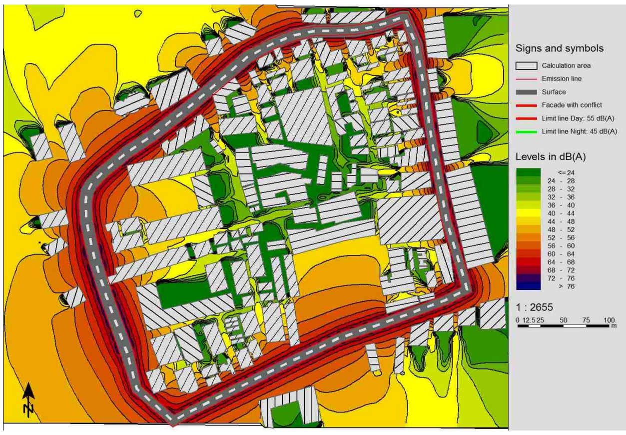

Fig. 9. Scenario 3, 4-wheelers prohibited at day time.

Fig. 8. Scenario 2, 3-wheelers prohibited at day time.

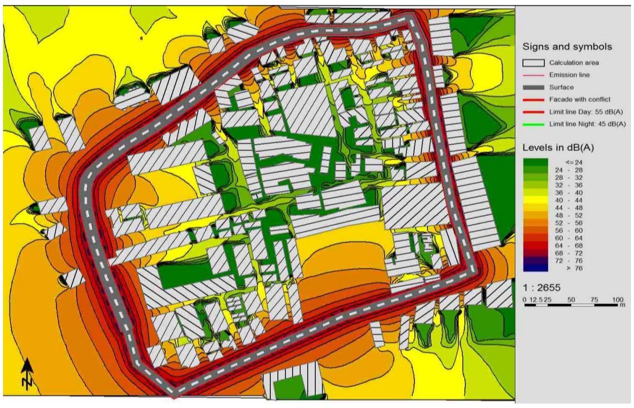

Fig. 10. Scenario 4, heavy vehicles prohibited at day time.

Fig. 11. Scenario 1, 2-wheelers prohibited at night time.

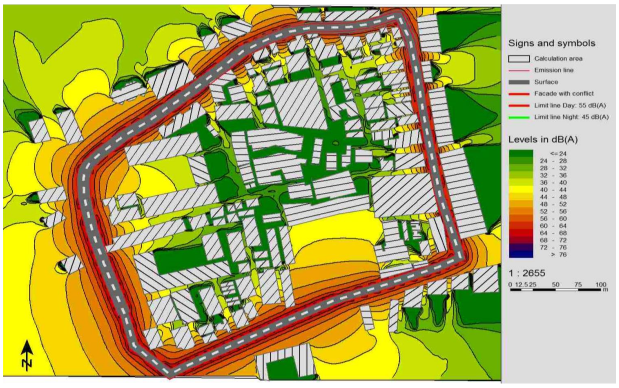

Fig. 12. Scenario 2, 3-wheelers prohibited at night time.

Fig. 13. Scenario 3, 4-wheelers prohibited at night time.

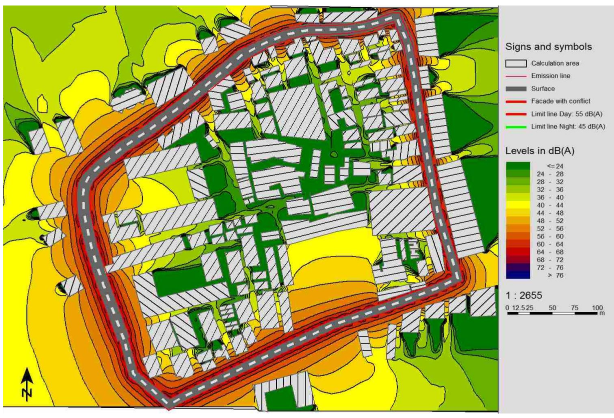

Fig. 14. Scenario 4-m heavy vehicles prohibited at night time.

4. Results and discussion

From Tables 8 and 9 it is observed that in scenario 1, if 2-wheelers are prohibited, the day time L_{Aeq} is predicted as 61.7 dB(A) and night time L_{Aeq} is predicted as 60.1 dB(A) at location A. At locations B and C, it is predicted as 60.9 dB(A) and 59.3 dB(A) at day time and 56.9 dB(A) and 59.0 dB(A) at night time. In scenario 2, if 3-wheelers are prohibited, the daytime L_{Aeq} is predicted as 60.6 dB(A) and night time L_{Aeq} is observed as 57.2 dB(A). At locations B and C, it is predicted as 60.5 dB(A) and 59.3 dB(A) at day time and 57.2 dB(A) and 60.8 dB(A) at night time.

In scenario 3, if 4-wheelers are prohibited, the day time L_{Aeq} is predicted as 60.8 dB(A) and night time L_{Aeq} is predicted as 61.5. At locations B and C, it is predicted as 60.3 dB(A) and 58.7 dB(A) at day time and 57.8 dB(A) and 60.3 dB(A) at night time. In scenario 4, if heavy wheelers are prohibited, the day time L_{Aeq} is predicted as 61.9 dB(A) and night time L_{Aeq} is predicted as 61.6 dB(A). At locations B and C, it is predicted as 60.7 dB(A) and 59.2 dB(A) at day time and 57.6 dB(A) and 60.7 dB(A) at night time.

5. Conclusion

Recently, disputes and complaints are increasing because of the noise caused by traffic. However, passive noise control is limited in mitigating noise levels. Therefore, a traffic management method to supplement the limitations of passive noise control is required. In this research, an active traffic management model was suggested, and a simulation to assess the applicability of active noise control was conducted. In simulations, noise was found to have reduced. The simulation results show that L_{Aeq} is reduced by up to 5 dB(A). This research is expected to provide the opportunity to change the noise management paradigm. Also, the proposed noise management strategies can be used as a basis for managing noise induced by heterogeneous traffic conditions. It is essential to conduct further more variations of simulations for achieving more substantial results.

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