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Acoustical environment of urban area related to the city development *

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Abstract—The relationship between urban development and noise pollution was analyzed. The analysis, based on a wide range of measurements and statistical data, revealed the changes of the ambient noise resulting from city development. In conclusion, some fundamental measures for improving the acoustical environment were suggested, such as the division of cities into functional areas and the development of a well designed road network. In addition, the town planning, architecture and the implementation of appropriate regulations could also help to reduce noise levels was suggested as well.

Keywords: acoustical environment; city planning; urban area; road network; sound barrier.

1 The relationship between urban development and community noise

In recent years cities have developed rapidly as more and more people have migrated from the countryside into the urban areas and engaged in various economic activities. Taking Nanjing City as an example, community noise has certain obvious characteristics.

The noise generated by industrial activity has become increasingly intrusion. There are about 4000 enterprises in Nanjing, more than 200 of which have been established since 1991. In 1995 approximately 1500 construction sites were in operation, most of them in residential areas.

Various means of transportation have been increasing rapidly. Table 1 shows the increase in numbers of vehicles in recent years. Table 2 shows the change of the public transportation in Nanjing City between 1986 and 1995.

Table 1 The increase in the numbers of vehicles in Nanjing between 1986 and 1995

Year	Total number of all kinds of vehicles	Types			
		Tracks and buses	Motorcycles	Tractors	Others
1986	51639	32129	7483	11202	825
1989	100235	44390	23886	27742	4217
1995	172302	72474	58699	31422	9707

Source: The year books of Nanjing City

Table 2 Changes in public transportation between 1986 and 1995

Year	Bus			Taxi	
	Number of bus routes	Total length of bus routes, km	Total number of buses	Saloons	Cars
1986	80	1174	1085	115	96
1990	80	1290	1131	173	98
1995	86	1290	2300	7000	2300

Source: The year books of Nanjing City

Over the last ten years railways have expanded by running trains of greater length at an

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increased frequency, resulting in a serious problem for the adjacent areas. Noise levels have increased by nearly one third. In 1996, there are 52 routes in Nanjing, airlines operated out of Nanjing at a frequency of 89 flights per week.

The number of domestic appliances in urban areas has been increasing rapidly. Table 3 shows the increase in the number of various kinds of appliance per hundred families in the urban areas of Jiangsu Province.

Table 3 Changes of the number of various kinds of appliances owned by every one hundred families in urban areas

Year	Television sets, black & white	Color television sets	Recorders, cassette	Washing machines	Refrigerators
1985	91.0	9.0	41.0	48.0	6.0
1989	115.7	46.3	69.6	85.4	44.1
1994	128.3	83.5	73.4	94.3	68.5

Source: The years books of Jiangsu Province

2 Changes in the acoustical environment caused by various activities in city

2.1 Noise from factories

With the reconstruction of mixed function zones in some parts of Nanjing, certain factories have been relocated away from urban areas. For example, the noise level in silk factory loom shops can reach levels as high as 100 dB(A) and, in one case, the operations of a silk factory and a nearby glass factory produced noise levels upto NR-55 in an adjacent school. When the factories were moved away the living conditions of residents in the area were much improved. During the last ten years more than 300 enterprises have been relocated and their machinery has been modernized. As a result of the large scale elimination of mixed function zones, noise pollution from factories in Nanjing City has been somewhat reduced.

2.2 Noise from construction sites

Recently there have been many construction sites in operation in the residential areas of Nanjing. Although, in the long term, these buildings could make a significant contribution both to the economic and environmental development of the city, but the construction noise has caused serious problems for people living in the urban areas, especially during the night in summer. Most construction machinery produces very high noise levels. For example the noise level 15 m from a concrete mixer may rise as high as 86—100 dB(A), while the noise from pile drivers may reach 110—136 dB(A). In addition, the noise from heavy trucks may exceed 80 dB(A). These high noise levels cause the residents in nearby areas to make many complaints. In order to provide a reasonable environment for the National Entrance Examination for Higher Institutions, the Government of Nanjing City enforced a ban on all construction work between 6th and 8th July, 1996.

2.3 Traffic noise in urban areas

Table 4 shows the number of vehicles and the resulting noise levels per hour of traffic over the Nanjing Yangtze River Bridge from 1976 to 1996. Table 5 shows the changes in the frequency and noise levels per hour on another major traffic route in Nanjing City between 1976 and 1996. Table 4 shows that, over the past 20 year, traffic passing over Nanjing Yangtze River Bridge trebled every ten years. L_{50} increased by 9 dB(A) every year and L_{eq} increased by a total of 7.8 dB(A).

Table 5 shows that the amount of traffic passing through another main traffic route has trebled in the last 20 years. L_{50} increased by only 7.5 dB(A). The small drop in the L_{50} in 1996 was due to the strict prohibition of the use of vehicle horns. L_{eq} increased by 3.5 dB(A). The reasons for these differences are as follows:

Table 4 Comparison of the total number of vehicles/h and the noise level from 1976 to 1996 on Yangtze River Bridge

Times of statistics & measurements	Number of vehicles/h						Total number	Traffic noise level from the center of flow of nearside carriageway, dB(A)			
	Heavy		Light		Motorcycle						
	Number	%	Number	%	Number	%		L_{10}	L_{50}	L_{90}	L_{eq}
8th. Oct. 1976	264	80.5	62	19	2	0.5	328	78.5	63	51	75
18th. Oct. 1986	797	80.1	148	15	49	4.9	995	78.0	72	64	75.3
10th. Oct. 1996	1539	52.2	1092	37.1	315	10.7	2946	87.0	81.0	77.0	82.8

Table 5 Comparison of the total number of vehicles/h and the noise level from 1976 to 1996 on a traffic road of urban area in Nanjing

Times of statistics and measurements	Number of vehicles/h						Total number	Traffic noise level from the center of flow of nearside carriageway dB(A)			
	Heavy		Light		Motorcycles						
	Number	%	Number	%	Number	%		L_{10}	L_{50}	L_{90}	L_{eq}
8th. OCt. 1976	508	69.6	222	30.4	0	0	730	78	66	60	71.4
28th. Jan. 1986	340	30.0	736	64.7	60	5.3	1136	60	65	60	66.4
9th. Oct. 1996	402	19.3	1275	61.2	405	19.5	2082	78	74	69	75.0

The number of heavy vehicles passing over the Nanjing Yangtze River Bridge increased by 5.8 times, but the number of heavy vehicles passing through the other main road seems to have dropped a little.

The road network has been improved tremendously. In the last ten years, the length of roads in Nanjing has been increased by 1.4 times and the total area of roads has doubled. Approximately 100 traffic routes have been improved. Improvements include widening of roads, the building of platform bridges, tunnels and so on. By these means traffic congestion in urban areas has been markedly reduced. The average speed of vehicles has increased from 20—25 km/h to 35—45 km/h.

Table 6 compares the traffic flow per hour and the noise levels in three cities in Jiangsu Province. City C has the least traffic, but the highest noise level. This is because the number of vehicles has increased by 25 per cent every year for the last five years, while the roads have only increased by 2 per cent. The resulting congestion in the narrow streets where vehicles, bicycles and pedestrians struggle for right of way causes frequent and loud use of vehicle horns. Another factor in the increased noise level is the

Table 6 Comparison of the traffic flow number/h and the noise level in urban areas of three cities in Jiangsu Province in 1990

The names of cities	The average number of various vehicles, number/h	Traffic noise level, dB(A)			
		L_{10}	L_{50}	L_{90}	L_{eq}
Nanjing	674	76.3	68.1	61.0	73.5
S	452	73	66.5	60.3	73.7
C	260	81	71	62	77.0

Source: The Environmental Protection Bureaux of the three cities

illegal use of noisy, obsolete vehicles.

2.4 Noise from the community

Street hawking, outdoor commercial activities, children playing, light vehicles, motorcycles and the increased use of domestic appliances, have all contributed to an obvious increase in noise levels. Noise from the community accounts for about 50 per cent of total noise levels and the proportion appears to be increasing. Fig.1 shows that changes in noise levels at two representative sites in a residential area near the railway and the traffic road between 1985 and 1995(Liu, 1990). At site A near a road at the edge of the residential area, the former background noise level is rather high in the day time, but in the quiet of the night the noise comes from the greatly increased traffic and the railway. According to data gathered at site B inside the residential area between 1985 and 1995, the background noise level in the daytime has increased by 10 dB(A). In order to avoid aircraft noise, the new airports of some cities have been sited more than 40 km away.

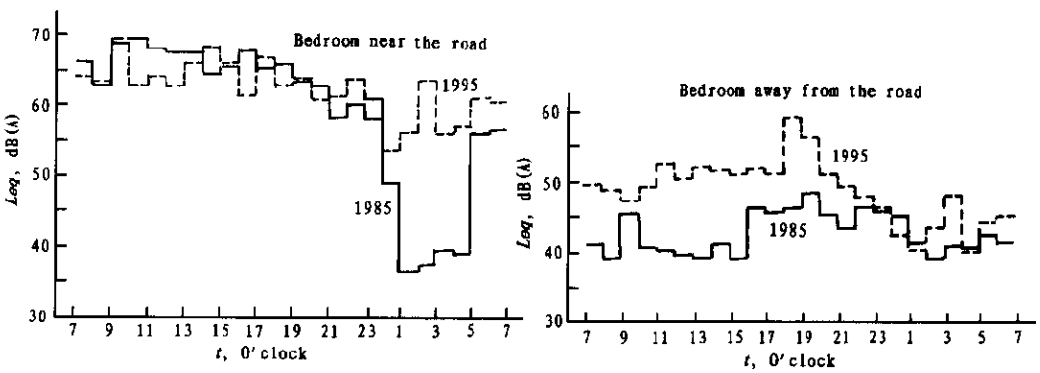

Fig.1 The pattern of dB(A) at a residential area over a 24h period(The microphones were inside the bedrooms). In the bedroom near the road, the contribution of the traffic flow to the overall noise level is dominant; in the bedroom away from the road, the contribution of the internal noise of the residential area is dominant

Table 7 shows the noise levels in two different functional zones in 1994. We can see that the noise levels exceed the Chinese Standard by 30%—56% during the day and 25%—69% at night.

Table 7 Noise levels in different built up areas of Nanjing City in 1994

The areas to be covered	The times	Noise level (Average of the year), dB(A)	Standard of China	The exceed ratio % of buil up areas
Area for residents, culture & education	Daytime	55.4	50	56.2
	Nighttime	47.1	40	68.8
The first kind of mixed areas*	Daytime	58.5	55	30.0
	Nighttime	48.2	45	25.0

* The first kind of mixed areas are areas where residents are mixed with general commerce

Fig.2 shows how the use of a "sound barrier" reduce noise from a railway. The measurement results shown in Fig.2 were made in a housing whose external wall was only 70m from the center point of the railway track. Approximately 100 trains use the railway line every day and the L_{eq} is 65 dB(A).

According to the national standard, this level should be reduced by 10 dB(A). In order to

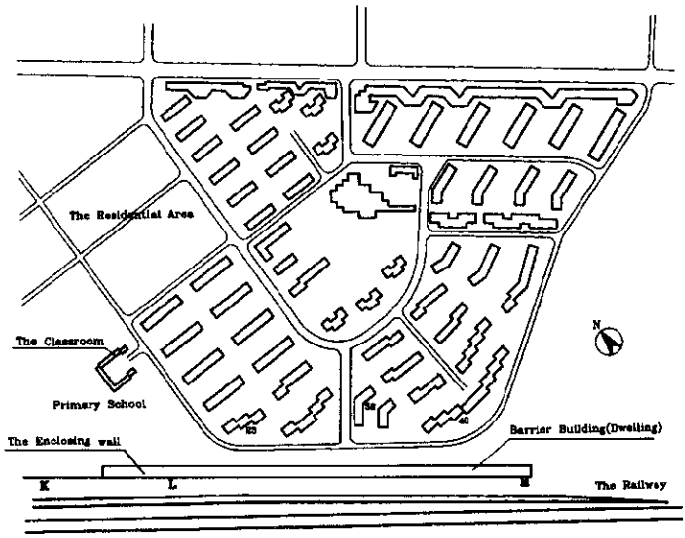

Fig.2 A residential area near the railroad

achieve this reduction, the following measures of noise reduction have been put into effected: first, the construction of a building as "sound barrier" 300m long and 12m high at a distance of 30 m from the railway in the section LM. Second, the construction of an enclosing wall 4.5 m high in the section KL. Table 8 shows the resulting noise reduction.

Table 8 Results of noise reduction by setting up the "sound barrier" between the railway line and the residential area

Noise level, dB(A)	#32 flat 6th floor bedroom	#40 flat 6th floor bedroom	#23 flat 2nd floor bedroom	#32 flat 5th floor bedroom	Primary school 3rd floor classroom	Barrier building 4th floor bedroom
The windows open	48.3	50.8	47.4	49.6	47.4	48.2
The windows close	43.1	42.5	41.1	37.2	44.2	43.6

Source: Institute of Acoustics, Nanjing University *etc*.

3 Analysis and conclusion

Higher quality of life requires not only an improved economy but also an improved environment. The question is how may these two aims be realized. On the one hand, because of the development of the economy, sources and levels of noise have been increasing. On the other hand, city planning, redevelopment of cities and the planning and reconstruction of the road network provide an opportunity to improve the acoustical environment in urban areas. Experience shows that the separation of functional zones in cities, including the removal of mixed zones in the older cities, together with an improved road system are the two fundamental measures.

The enforcing of regulations and strict management are two other important ways of reducing noise pollution. For example although traffic noise produces only 30 per cent of the total noise component in cities, because the noise levels high and very mobile, it pollutes the largest area. There are approximately 32 traffic routes in Nanjing where hooting is prohibited and, in these area, the noise level has remained at 70.9 dB(A) in spite of an increasing number of different kinds of vehicle.

On the other hand, noise levels from sources inside residential zones reach 59.6 dB(A), though the background noise levels reach 53 dB(A) during the night time. There is no clear difference between the effects of noise source inside and outside residential areas. It is clear that the government must formulate new regulations for controlling noise sources inside residential areas and improve the environmental education of the residents.

Planners and designers should take noise reduction into account in the general and detailed design of buildings. This can only have a limited effect, however, as the most effective and economical ways of improving the acoustical environment are the division of cities into functional zones and the improvement of the road system.

Reference

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