# Role of Nonmotorized Transportation in the Major Highway System in China

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The National Major Highways of China (NMHC) is the name of the major highway system in China, which is the backbone of the country's highway transportation. A variety of transportation modes share the NMHC, including motor vehicles, bicycles, and man-powered and animal-drawn vehicles. In 1992 the total percentage of nonmotorized transportation in China was 13.2 percent. As such, nonmotorized transportation modes must be considered in developing future strategies for the NMHC. The characteristics of nonmotorized transportation are discussed using statistical traffic data for the NMHC between 1988 and 1992. In addition, recommendations are made for the future planning of the NMHC, with special consideration given to bicycle traffic.

Economic reform policies over the past 15 years have resulted in the rapid development of highway construction in China. From 1978, an average of 10 000 km/year has been added to the highway system, totaling 1 075 000 km and including 1145 km of expressway. According to the initial plan from the Communication Ministry of China, China will have 1 250 000 km of highways by the year 2000.

Highways in China have been classified into three categories: the National Major Highways of China (NMHC), the provincial major highways of China, and the local highways. NMHC highways are assigned numbers according to their point of origination: those originating from Beijing are numbered "1xx" and total 12 in number, those having north-south orientations are numbered "2xx" and total 28 in number, and those with east-west orientations are numbered "3xx" and total 30 in number. By 1993 the total length of the NMHC had reached 111 000 km, 10.3 percent of the total highway length in China. Moreover, 24 percent of the total kilometer tonnage was produced from transported goods. In addition, these highways link more than 80 percent of the cities having populations greater than 500,000.

As a developing country, China lags behind industrial nations in economic power. As such, transportation facilities are inadequate and insufficient. And most NMHC highways accommodate a mix of motor vehicles, tractors, bicycles, and man-powered and animal-drawn vehicles. The existence of nonmotorized transportation increases the difficulty in managing the traffic on these highways.

## NONMOTORIZED TRANSPORTATION ON NMHC

China is known as the bicycle kingdom of the world. At the end of 1992, bicycle ownership in China's urban areas had reached two bicycles for every three persons. Therefore, bicycle traffic inevitably will interfere with motor vehicle traffic on the NMHC highways.

China is an agricultural country with one-fifth of the world's population. The transport of agricultural goods by man- and animal-drawn vehicles is predominant for short-distance transportation in most areas of China, especially those areas that are undeveloped.

Motorized and nonmotorized vehicles need to be normalized for comparative analysis. The conversion factors in Table 1 for motorized and nonmotorized vehicles are calculated on the basis of their roadway capacities. The standard motor vehicle is defined as a two-axle, six-wheeled truck, called the standard Jiefangpai truck by Chinese transportation engineers. Table 2 indicates that all the annual percentages of nonmotorized transportation from 1988 through 1992 exceeded 13 percent (*1*). Although the annual percentage declined gradually from 15.7 percent in 1988 to 13.2 percent in 1992 with an average annual declining rate of 0.65 percent, this is still an exceptional transportation phenomenon in the world's highway transportation systems. Moreover, the nonmotorized traffic volume has continued to increase.

A comparison of Figures 1 and 2 shows that the percentage of bicycle traffic declined from 8.9 percent in 1988 to 6.8 percent in 1992 (*2*). Although the percentage of bicycle traffic has been decreasing gradually, it is still higher than that of many industrial nations and is not anticipated to change much over the long term. It is noteworthy that the percentage of man- and animal-drawn vehicle traffic has increased from 6.0 percent in 1991 to 6.4 percent in 1992, which is an unusual phenomenon in the world (*3*). The reasons leading to the current situation on the NMHC highways can be described as follows:

- China is a developing country, and for most people, the bicycle is the primary choice of transportation.

**TABLE 1 Conversion Factors for Motor and Nonmotorized Vehicles**

| Vehicle | Conversion Factor |
|---|---|
| Motor Vehicle | 1.0 |
| Mini Bus | 0.5 |
| Bus | 1.0 |
| Trailer | 1.5 |
| Tractor | 1.0 |
| Bicycle | 0.1 |
| Man-drawn Vehicle | 0.5 |
| Animal-drawn Vehicle | 2.0 |

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**TABLE 2 Percentages of Nonmotorized Traffic on NMHC Highways**

| Year | Percentages (%)[a] | | |
|---|---|---|---|
| | Bicycle Traffic | Man-drawn and Animal-drawn Vehicle Traffic | Total Nonmotorized Traffic |
| 1988 | 8.9 | 6.8 | 15.7 |
| 1989 | 8.4 | 6.5 | 14.9 |
| 1990 | 8.2 | 6.1 | 14.3 |
| 1991 | 7.7 | 6.0 | 13.8 |
| 1992 | 6.8 | 6.4 | 13.2 |

[a] Calculation based on motor vehicle equivalents

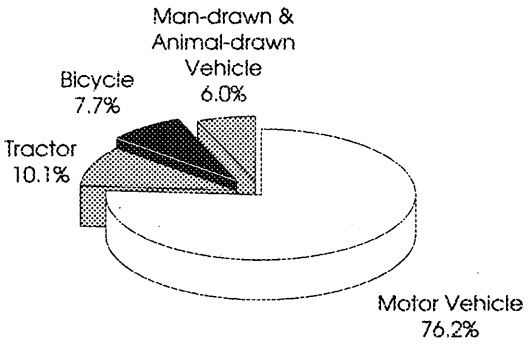


**FIGURE 1 Transportation modes on NMHC highways in percentage of traffic volume, 1991.**

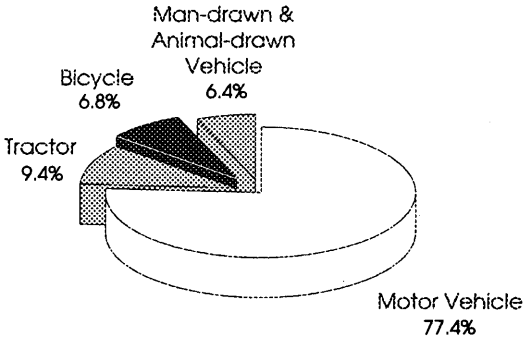


**FIGURE 2 Transportation modes on NMHC highways in percentage of traffic volume, 1992.**

- Man- and animal-drawn vehicles are used as low-cost modes of transportation and are used widely for short-distance and low-weight transportation.
- In China, towns are usually surrounded by villages less than 10 km away. Such short distances make the use of nonmotorized transportation modes physically possible.
- Nonmotorized transportation is affordable and practical and therefore is used widely in China.

## LOCATION CHARACTERISTICS OF NONMOTORIZED TRANSPORTATION

Location characteristics of nonmotorized transportation on the NMHC highways are very complicated, not only because China is a big country and the roadway conditions vary significantly but also because they are related to social and economic levels and geographic environments, such as local economic levels, population densities, and geographies and environments. In the following sections, traffic volumes and percentages of nonmotorized transportation are analyzed to identify the location characteristics of nonmotorized transportation.

Five provinces having the highest nonmotorized traffic volumes in 1992 on the NMHC highways are presented in Table 3 in motor vehicle equivalents. Five provinces having the lowest nonmotorized traffic volumes in 1992 are also given. Bicycle traffic volumes and man- and animal-drawn vehicle traffic volumes on the NMHC highways are given in Tables 4 and 5, respectively.

Table 3 indicates that nonmotorized traffic volumes are much higher in Jiangsu, Guangdong, Shanghai, Tianjin, and Beijing, where the economic levels and population densities are greater than those of most other areas in China. Guangdong and Jiangsu

**TABLE 3 Nonmotorized Traffic Volumes in Motor Vehicle Equivalents, 1992**

| Highest Five Provinces in Volume | Nonmotorized Traffic (AADT) | Lowest Five Provinces in Volume | Nonmotorized Traffic (AADT) |
|---|---|---|---|
| Jiangsu | 1,163 | Qinghai | 45 |
| Guangdong | 975 | Ningxia | 78 |
| Shanghai | 825 | Guizhou | 107 |
| Tianjin | 764 | Gansu | 162 |
| Beijing | 619 | Xinjiang | 177 |

NOTE: AADT = annual average daily traffic.

**TABLE 4 Bicycle Traffic Volumes, 1992**

| Highest Four Provinces in Volume | Bicycle Traffic (AADT) | Lowest Five Provinces in Volume | Bicycle Traffic (AADT) |
|---|---|---|---|
| Guangdong | 8,293 | Qinghai | 180 |
| Jiangsu | 5,492 | Guizhou | 292 |
| Tianjin | 5,477 | Ningxia | 470 |
| Shanghai | 8,673 | Xinjiang | 705 |
| | | Heilongjiang | 704 |

NOTE: AADT = annual average daily traffic.

**TABLE 5 Man- and Animal-Drawn Vehicle Traffic Volumes, 1992**

| Highest Five Provinces in Volume | Man-drawn Traffic (AADT) | Animal-drawn Traffic (AADT) | Lowest Five Provinces in Volume | Man-drawn Traffic (AADT) | Animal-drawn Traffic (AADT) |
|---|---|---|---|---|---|
| Jiangsu | 341 | 85 | Ningxia | 27 | 7 |
| Neimeng | 278 | 69 | Qinghai | 30 | 8 |
| Jilin | 272 | 68 | Guizhou | 82 | 21 |
| Hubei | 231 | 58 | Gansu | 90 | 22 |
| Tianjin | 217 | 54 | Xinjiang | 106 | 27 |

NOTE: AADT = annual average daily traffic.

are the two provinces having the highest economic levels in China. After the economic reformation and the opening of China to the rest of the world, the economic power in these two provinces has been greatly increased. At the same time, labor demand is increasing so greatly that the number of people moving into these provinces from other parts of China is rising yearly. Therefore the combination of all those mentioned above has led to high nonmotorized traffic volumes. Beijing, Tianjin, and Shanghai, the three municipalities directly governed by the central government, are the political, economic, and cultural centers of China. Because of the high transportation demands, population densities and transportation efficiencies of nonmotorized vehicles, forms of nonmotorized transportation, especially bicycles, are widely accepted by the citizens.

Tables 4 and 5 reveal that the distributions of bicycle transportation and man- and animal-drawn vehicle transportation among these cities are basically consistent with those of nonmotorized transportation as a whole.

**TABLE 6 Five Provinces with Highest Percentages of Nonmotorized Transportation, 1992**

| | Percentages (%) | | |
|---|---|---|---|
| Province | Bicycle Transportation | Man-drawn and Animal-drawn Transportation | Total Nonmotorized Transportation |
| Neimeng | 6.43 | 20.94 | 27.37 |
| Jilin | 7.03 | 13.01 | 20.03 |
| Hubei | 7.71 | 9.33 | 17.04 |
| Anhui | 13.58 | 3.44 | 17.02 |
| Guangxi | 14.79 | 1.86 | 16.65 |

**TABLE 7 Five Provinces with Lowest Percentages of Nonmotorized Transportation, 1992**

| | Percentages (%) | | |
|---|---|---|---|
| Province | Bicycle Transportation | Man-drawn and Animal-drawn Transportation | Total Nonmotorized Transportation |
| Ningxia | 2.83 | 1.50 | 4.32 |
| Shandong | 0.90 | 5.46 | 6.36 |
| Fujian | 5.29 | 1.47 | 6.76 |
| Tianjin | 4.55 | 2.48 | 7.03 |
| Hunan | 7.13 | 1.47 | 8.60 |

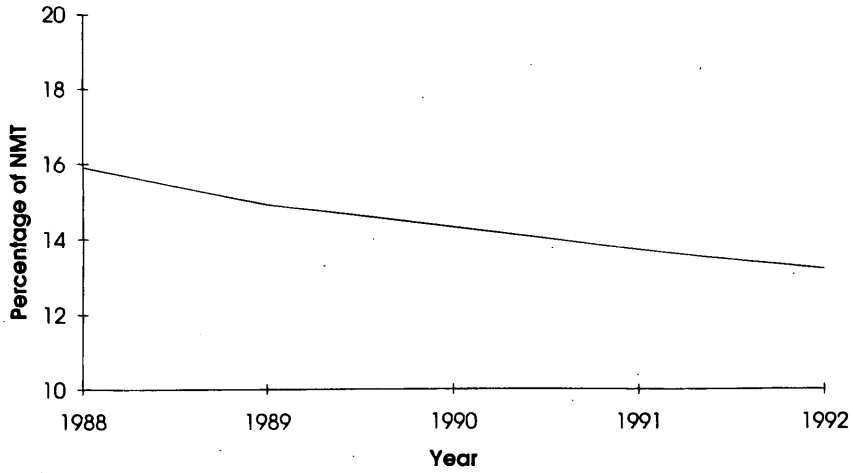


**FIGURE 3 Percentage of nonmotorized transportation (NMT).**

Table 6 presents the five provinces having the highest percentage of nonmotorized transportation. Table 7 gives the five provinces having the lowest percentage of nonmotorized transportation.

The five provinces having the highest percentages of nonmotorized transportation all have a medium economic level, even geographic environment, and lower-than-average population density. The reasons are as follows:

- Limited local economic development leads to a slow growth in motorized transportation.
- Nonmotorized transportation is more suitable for areas with high population densities and even geographic environments that require shorter traveling distances and have a sufficient labor force.

Provinces with the lowest percentages for nonmotorized transportation include comparatively developed areas, such as Fujian, Shandong, and Tianjin, as well as underdeveloped areas such as Hunan and Ningxia. In economically developed areas, motorized transportation has grown faster than nonmotorized transportation. Areas with low economic levels have a limited development of both motorized and nonmotorized transportation.

Nonmotorized transportation varies in location because of different local economic levels and the various geographic environments. Most of the areas with the higher nonmotorized traffic volumes lie along the coast of China and in the municipalities of Beijing, Shanghai, and Tianjin. The distribution of nonmotorized traffic volumes declines from east to west with the exception of the Heilongjiang and Jilin provinces.

## TIME CHARACTERISTICS OF NONMOTORIZED TRANSPORTATION

As shown in Figure 3, the percentage of nonmotorized transportation declined gradually from 1988 to 1992; this decline is anticipated to continue well into the future. The three forecasting models developed to display this trend are as follows (*4*):

1. Linear regression:

$$Y = -1248.16 - 0.62X \qquad R^2 = 0.905$$

2. Polynomial regression:

$$Y = 0.0428571X^2 - 171.191X + 170967 \qquad R^2 = 0.912$$

3. Exponential regression:

$$Y = 2.46976 * 10^{38} * 0.95783^x \qquad R^2 = 0.895$$

where $Y$ is the percentage of nonmotorized transportation for the forecasting year and $X$ is the forecasting year.

The nonmotorized traffic volumes from 1993 to 2000 on the NMHC highways are projected using the three forecasting models and are presented in Table 8. The average values for the traffic volumes of nonmotorized transportation from 1993 to 2000 are also displayed in Figure 4.

Table 9 indicates that nonmotorized traffic volumes have been increasing gradually but that their percentages have been declining slowly. This is happening because motor vehicle traffic volumes and their percentages have been increasing with the growth of the gross national product (GNP) as given in Table 10.

**TABLE 8 Projected Traffic Volumes of Nonmotorized Transportation (%)**

| Regression Model | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|
| Linear | 12.50 | 11.88 | 11.26 | 10.64 | 10.02 | 9.40 | 8.78 | 8.16 |
| Polynomial | 12.85 | 12.53 | 12.29 | 12.14 | 12.07 | 12.10 | 12.21 | 12.40 |
| Exponential | 12.60 | 12.07 | 11.56 | 11.07 | 10.60 | 10.16 | 9.73 | 9.32 |
| Average | 12.65 | 12.16 | 11.70 | 11.28 | 10.90 | 10.55 | 10.24 | 9.96 |

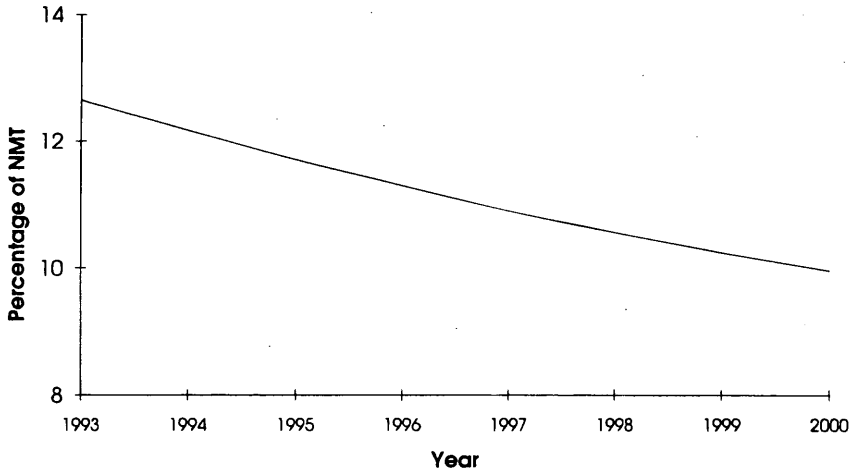


**FIGURE 4 Average percentages of traffic volumes of nonmotorized transportation (NMT).**

**TABLE 9 Nonmotorized Traffic Volumes**

| | Annual Average Daily Traffic (AADT) | | |
|---|---|---|---|
| Year | Bicycle | Man-Drawn Vehicle | Animal-Drawn Vehicle |
| 1988 | 2,118 | 41 | 162 |
| 1989 | 2,157 | 42 | 167 |
| 1990 | 2,226 | 40 | 166 |
| 1991 | 2,295 | 45 | 179 |
| 1992 | 2,290 | 54 | 215 |

## RECOMMENDATIONS

The following recommendations for future planning and management are made as a result of the preceding analysis of nonmotorized transportation on each mode of the NMHC highway system.

1. Because nonmotorized transportation will be used for a long time, interference with motor vehicle operations from nonmotorized vehicles should be examined while the capacities of NMHC highways are evaluated.
2. Although nonmotorized traffic volumes will rise continuously, their percentages will decline slowly. Since percentages for traffic volumes of motorized and nonmotorized vehicles will change, their conversion factors should be recalculated.
3. As NMHC highways are replaced with new highways, expressways, and freeways, the old roadways should be maintained for nonmotorized transportation to use. The nonmotorized traffic situation in most areas of China will not change much over the next 20 years. Therefore, in the rehabilitation of old NMHC highways, it is recommended that separated lanes for nonmotorized transportation be used.
4. For Beijing, Shanghai, Tianjin, and other economically developed areas, more attention should be paid to nonmotorized traffic planning and management.
5. China is a country with one-fifth of the world's population. There is a big gap in purchasing power between China and industrial nations. Therefore, bicycles will continue to be the primary mode of private transportation in the future and must be taken into account when NMHC highways are planned.

## CONCLUSIONS

As a developing country, China lacks the economic power of industrial nations. Most Chinese people will be unable economically to purchase motor vehicles in the coming years. Therefore, the number of nonmotorized vehicles will remain, and may even rise, as low-cost transportation modes. Because of the variety in

**TABLE 10 Relationship Between GNP and Annual Average Daily Traffic (AADT) Growth**

| | Percentages (%) | | |
|---|---|---|---|
| | Average Yearly Growth (1986-1990) | Yearly Growth from 1990 to 1991 | Yearly Growth from 1991 to 1992 |
| GNP | 7.8 | 7.0 | 12.8 |
| AADT | 8.3 | 8.4 | 12.8 |

economic levels and geographic conditions throughout China, nonmotorized traffic is distributed unevenly on the NMHC. This situation is not anticipated to change quickly in the near future. Therefore, further research and practice should be implemented to develop a strategy for accommodating both motorized and nonmotorized transportation on the NMHC highways for the present and near future.

## ACKNOWLEDGMENTS

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## REFERENCES

1. *A Collection of Traffic Volumes in the NMHC Highways.* Institute of Highway Planning and Design, Ministry of Communication of China, Beijing, 1988–1992.
2. Chen, S., and X. Liu. Overview of Bicycle Traffic of the NMHC. *Proc., International Symposium on Non-Motorized Transportation,* Beijing, China, May 1994.
3. Liu, X., L. D. Shen, and F. Ren. Overview of Bicycle Transportation in China. In *Transportation Research Record 1396*, TRB, National Research Council, Washington, D.C., 1993.
4. Liu, X., and F. Ren. Ideological System of Transport Forecasting in Highway Network Planning. *Journal of Highway and Transport,* No. 3, 1994.