A Modified Highway Interchange Design for Improved Land Use and Transportation Efficiency: Case Study of the Guangzhou-Shenzhen Superhighway Guangdong, China

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Abstract

As the first privately-built toll road in China, the 122.8 km Guangzhou-Shenzhen (GS) Superhighway pioneered many new concepts. From the highway design perspective, the most significant is a modified highway interchange design to allow for the incorporation of nearly 600,000 sq. ft. of commercial/retail space under each of the highway's interchanges. By adding the collection of tolls, bus transfer stations and the land use and local traffic impacts of creating "new towns" about every 7 km, designing these interchanges for flow, access and safety was a major challenge. However, successful execution of the concept should result in improved land use and transportation efficiency in the long run—and thus, a more financially-viable project.

This paper describes the factors leading up to the decision to build these new interchanges, the basic design of the typical GS interchange and some of the issues raised.

Background

In 1987, Hopewell China Development (Superhighway) Ltd. (a subsidiary of Hopewell Holdings Ltd., a Hong Kong-based, publicly-traded development company) entered into an agreement with the Guangdong Provincial Highway Construction Company to build, operate and transfer (BOT) ownership of a dual 3-lane toll road from Guangzhou City to Shenzhen Special Economic Zone at the China-Hong Kong border, in Guangdong Province, China. The GS Superhighway is the first privately-financed toll road in the whole of China. There are two barrier toll plazas (one at each end of the road) and fourteen "interchange" toll plazas. The roadway is built with a design speed of up to 120 km/hr and connects the major metropolises of Hong Kong, Shenzhen and Guangzhou, with populations of about 6 million each. (See Figure 1)

To finance the tollroad, Hopewell Holdings obtained US$800 million in syndicated bank loans and put up US$200 million from its own assets (The Chinese partner also contributed an amount in Chinese currency renminbi roughly equivalent to US$200 million.). Because so much of the entire financial risk of the project (more than 83% of the total project cost) would be borne by Hopewell, the company designed all aspects of the highway to minimize construction-related and tollroad operating costs and maximize tollroad-related revenues while striving for operational safety and efficiency.

In addition to vehicular toll revenues (the rates for which would be set by the Chinese government), one of the most important sources of revenues is the retail/commercial development opportunities at the highway interchanges. As part of the Project Agreement with the Chinese authorities, Hopewell secured development rights within the land acquired for the interchanges. In effect, Hopewell was allowed to build major retail/commercial centers at each of the GS Superhighway's interchanges and use revenues generated from the retail/commercial development to pay back its creditors—and to make some profit. [d,e]

However, unlike the situation with mass transit facilities, where many types of design plans have been developed throughout the world for commercial/retail operations at transit centers, there simply were no highway interchange design concepts to be found that would efficiently accommodate commercial/retail land use within a highway interchange. Because of the importance of the retail/commercial revenues to the ultimate success of the highway project, it was imperative that a new interchange design be developed.

Interchange Design Considerations

Unlike typical freeway diamond and cloverleaf interchange land use and design configurations such as those used in the United States, nine[f] of the thirteen interchanges were to be built as elevated structures within a modified diamond format to allow for shopping malls at their cores. From an engineering design perspective, local through traffic had to cross the Superhighway either from above or below. Due to the soft terrain and river branches in the Pearl River Delta over which the highway passes, most of the highway had to be elevated on piers. To maximize the efficiency of intermodal transfers, capture

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[d]In addition, Hopewell secured the rights to develop residential and retail property under the elevated road at strategic locations. The 122.8 km GS Superhighway contains 45 km of elevated road and bridgeworks, which is longer than all the bridgeworks put together in Hong Kong. These property developments will be described in a subsequent paper.
[e]See article in South China Morning Post, August 1994, Reference 3.
[f]The nine interchanges as described exclude the Tai Ping Interchange. The Taiping Interchange had to accommodate three major highway approaches, and therefore, its design is based on a completely different concept. That unique interchange will be described in a subsequent paper.

economic value created by the concentration of multiple transportation modes at these interchanges, and take advantage of the engineering design that already required elevation of the roadway, Hopewell added an extra two meters of height for the roadway surface at the interchanges and created space underneath for retail and commercial space. (See Figures 2A and 2B).

The location of the shopping mall at the center of the interchanges drove the decision making on many other aspects of these unique facilities. Convenient auto and transit access for customers to and from these centers would be critical to the financial success of the commercial enterprises. Therefore, customers would need to be able to access the centers both from the highway and from the surrounding neighborhoods. Bus transfer stations and parking would be required. Certainly, toll collection would also have to be conducted at the interchange locations both for returning traffic and for traffic entering from and exiting to the local area. In the end, it became clear that the GS Superhighway interchanges would become major activity centers—small towns in and of themselves.[g]

Basic Interchange Design

The basic design of the GS Superhighway interchanges incorporates the following functions:

- Vehicular access onto and egress off of the highway
- Toll collection
- Commercial/retail development (e.g., food, exhibition, retail, entertainment, etc.)
- Parking for shopping and park-and-ride
- Bus transfers
- Local pass-through traffic
- Gas filling stations

The inclusion of retail/commercial within the interchange itself results in the clustering of retail/commercial-related activities—such as parking and bus transfers—toward the center of the interchange. Toll collection could be accommodated further out (but obviously still within the confines of the interchange). Local traffic would require both access to and around the interchange.

Vehicular access and egress

Access to and egress from the GS Superhighway are accomplished by means of a system of in/out ramps. The ramp system sorts traffic into two basic categories: Those internal to the Superhighway system (including car parking and bus transfers) and those moving into or out of the system (for example, off the Superhighway and into the neighboring suburb). Traffic in the latter category must pass through toll plazas; traffic in the former need not. The access and egress ramping system is illustrated in Figure 3.

Toll collection

A vehicle entering the Superhighway must stop at an entry toll plaza to obtain proof of entry (either by ticket or by Stored Value Card previously procured). Upon exiting, the toll must be paid at an exit toll plaza based on the distance travelled. The entry and exit toll plaza locations are illustrated in Figure 4.

Retail/Commercial

In the typical GS Superhighway interchange, a shopping mall is provided under the highway itself. The rationale for this was based on cost engineering and economic land development principles. Each shopping mall measures approximately 450 m in length and 42 m in width, and is thus capable of providing about 600,000 sq. ft. of retail/commercial within its structural bounds. (See Figures 5, 6, 7 and 8.)

Bus Transfers

The predominant mode of travel in China is still non-auto: Pedestrian, bicycle and bus. For longer trips, jitneys and larger, fixed-route transit services offer shoppers and commuters on the GS Superhighway the access and mobility they require. In addition to many local bus operators, Hopewell plans to operate a joint venture bus service to enhance the ease of access by customers of its retail/commercial shops. To accommodate the major flows of local and line-haul transit passengers along the Guangzhou-Shenzhen corridor, bus transfer facilities must be provided. These facilities are illustrated in Figure 9.

Parking

Although auto ownership is currently very low in China (fewer than 5% of households own private automobiles in Guangdong Province), there are many business-owned automobiles in Guangzhou and Shenzhen Cities. Ample parking must be provided in order to ensure the long-term economic viability of the retail/commercial centers. In addition, adequate parking must be provided to accommodate the future park-and-shop and park-and-ride demand which is anticipated in the Guangzhou-Hong Kong corridor. The parking lot locations, which can easily accommodate decked structures in the future, are illustrated in Figure 10.

Local Pass-through traffic

Most of the GS interchanges are situated at locations where the superhighway intersects local primary roads. Thus, it was important that local pass-through traffic be accommodated in the design of the interchanges. Local pass-through traffic routing is illustrated in Figure 11.

Gasoline Filling Stations

Critical to the users of the superhighway is the availability of retail gasoline filling stations along the roadway. Figure 12 illustrates the location of stations at each of the interchanges.

Issues

The simple economics of the GS Superhighway project dictated that a unique, new design solution be found for the multi-use highway interchanges. In this first, private, 122.8 km segment of China's Superhighway tollroad system, a prototype design has been developed and built. As would be expected with such a revolutionary new concept of incorporating so many functions (functions which are typically separated into different locations along a highway), there are many traffic engineering and land use issues to address.

[g]There was a striking parallel between this project and the railroad projects that were built in the U.S. during the 1800's. Indeed, the GS Superhighway is very likely to spawn the equivalent to the early railroad towns of the U.S. at its interchanges.

These include:

- Line of sight and lane merge criteria for highway design
- Signage system requirements for safe traffic flow
- Surrounding land use impacts
- Accommodation of local pedestrian and bicycle traffic patterns
- Safe and efficient transfer facilities for transit patrons

Notwithstanding these challenges, there are overwhelming reasons to support this interchange concept and refine the design to ensure greater transport operational efficiency and safety as well as provide for the balanced use of land and growth of the neighboring suburbs. As China, a country with nearly one-quarter of the world's population, modernizes for the 21st century, transport infrastructure will play a critical role. The planned construction of 30,000 km of new highways throughout the country will significantly influence the patterns of growth and societal lifestyles, in much the same way the construction of the Federal Interstate Highway System did in the U.S. over the past several decades. The importance of "getting it right" at China's new highway interchanges—by safely and efficiently incorporating multimodal access to new town centers—is an imperative that cannot be overstated.

Further Work

Much work needs to be done in addition to the design and construction of the initial GS interchanges. Many of the interchanges are nearing completion and analysis and assessment of these prototypes should be performed so that design of future interchanges can be improved. Traffic engineering, traffic management, mode transfers, toll collection, non-motorized transport planning and design are but a few of the areas that should be addressed. Regional impacts of the interchanges also should be analyzed so as to provide a basis for supportive local land use and transportation policies.

ITE will be developing guidelines for modified Interchange design that will incorporate the multiple functions Hopewell has found that it must include in its GS Superhighway interchanges. A new task committee has been established, chaired by Joel P. Leisch (F). We encourage transportation professionals from all disciplines to participate in this exciting endeavor.

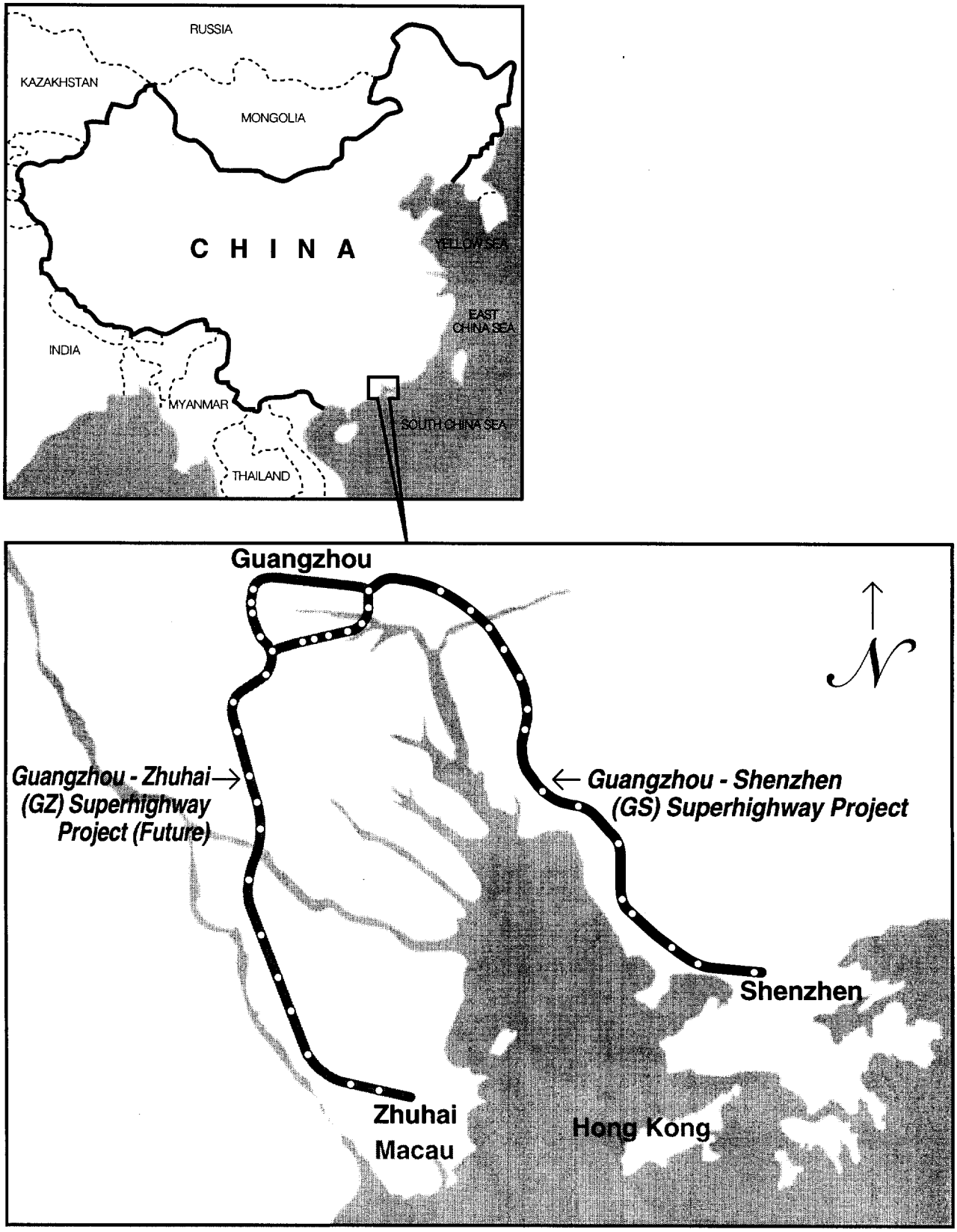
References

1. Hopewell China Development (Superhighway) Limited, US$800,000,000 Project Financing for The HK-Canton Highway, December 1990.

2. American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets, 1994.

3. "On the Fast Track to Success: Wu Close to Reaching Goal," South China Morning Post, International Weekly for the Weekend of July 23-24, 1994.

Figure 1
Project Location



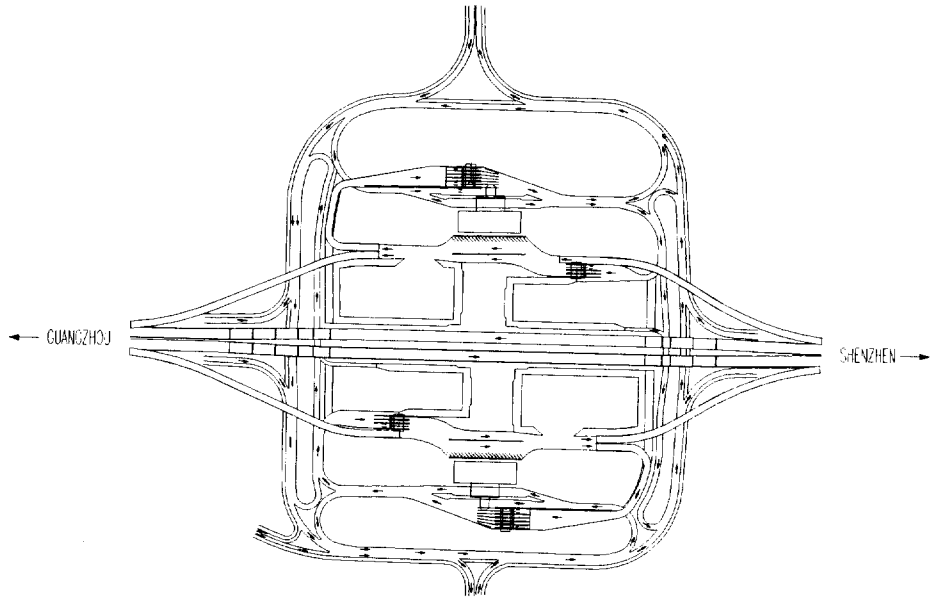
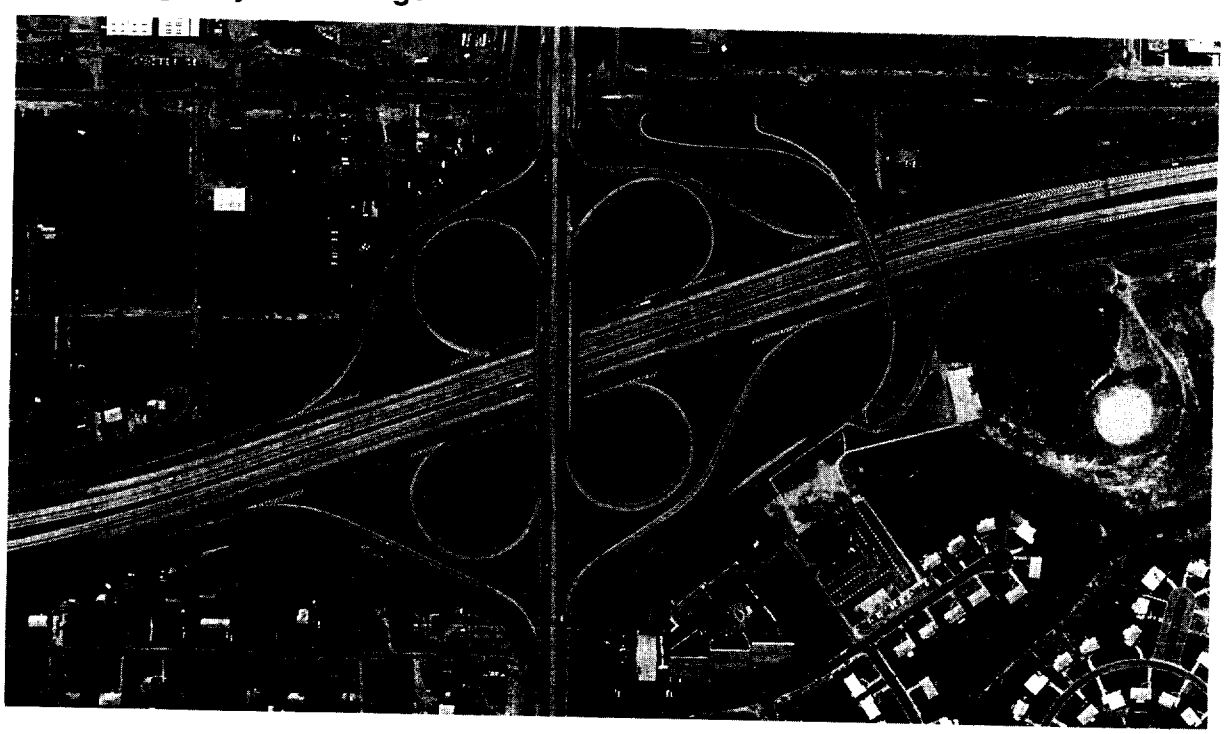


Figure 2A
Basic GS Superhighway Interchange

Figure 2B
Typical Highway Interchange



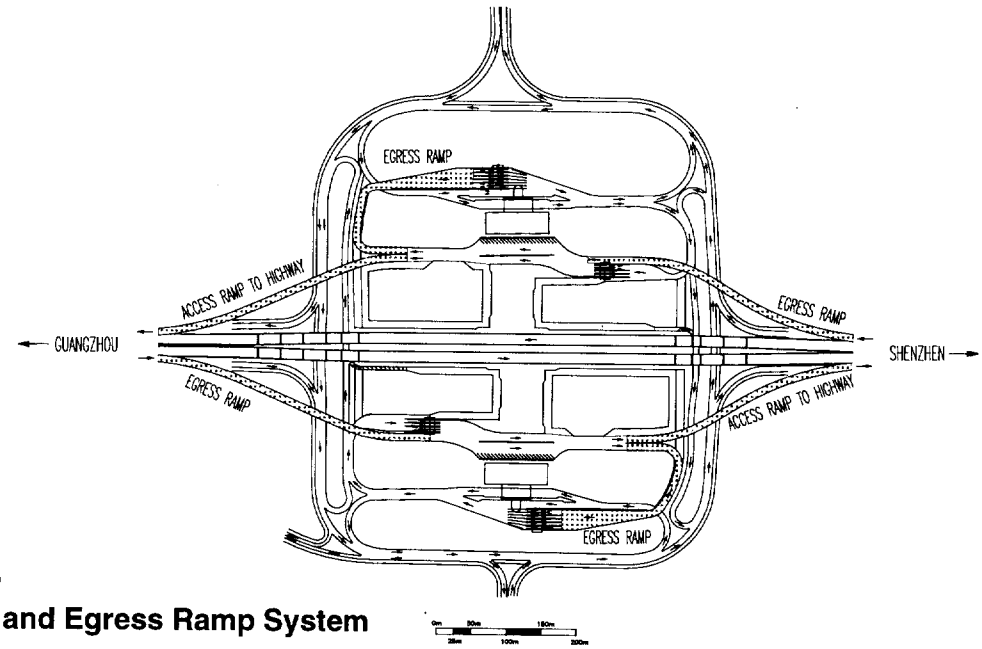


Figure 3
Access and Egress Ramp System

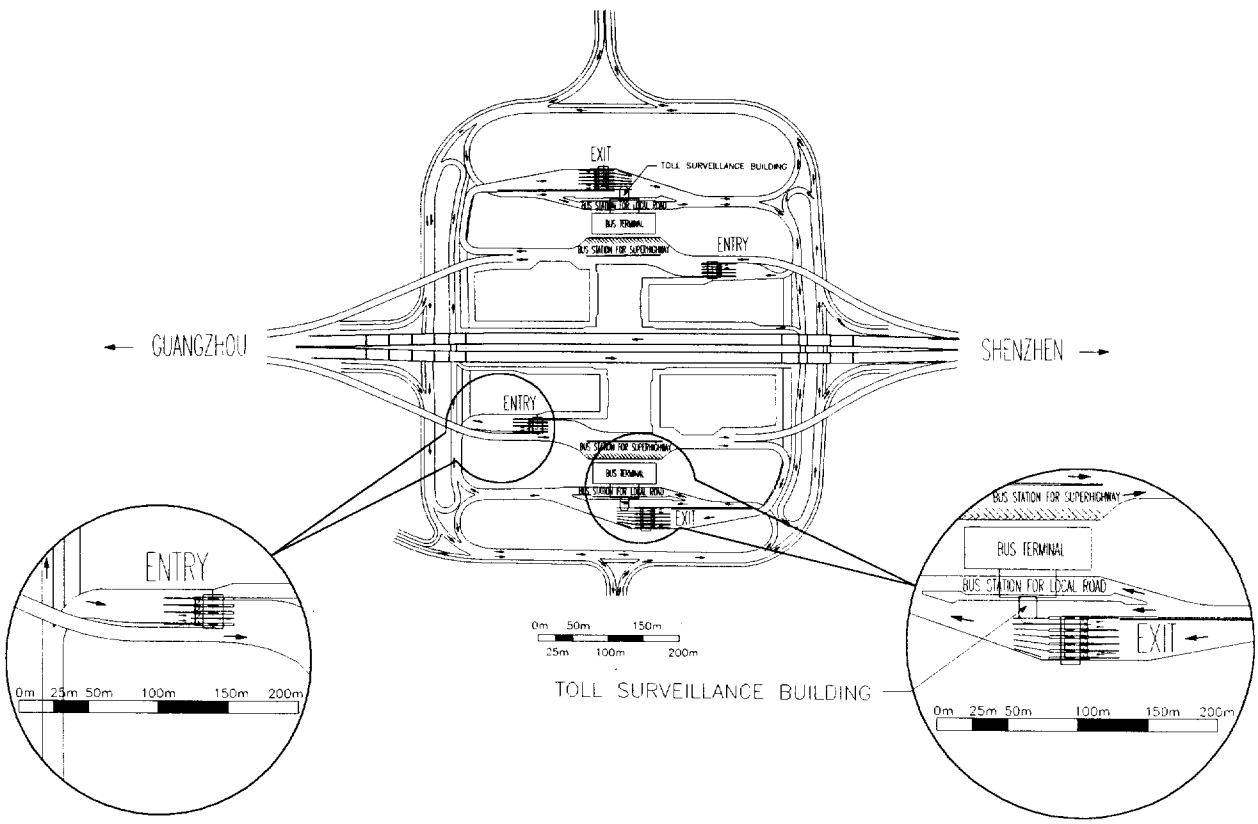


Figure 4
Entry and Exit Toll Plazas

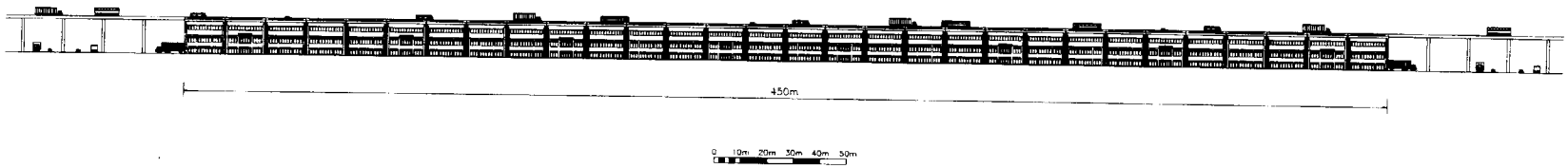


Figure 5
GS Superhighway Interchange--Shopping Mall Front Elevation

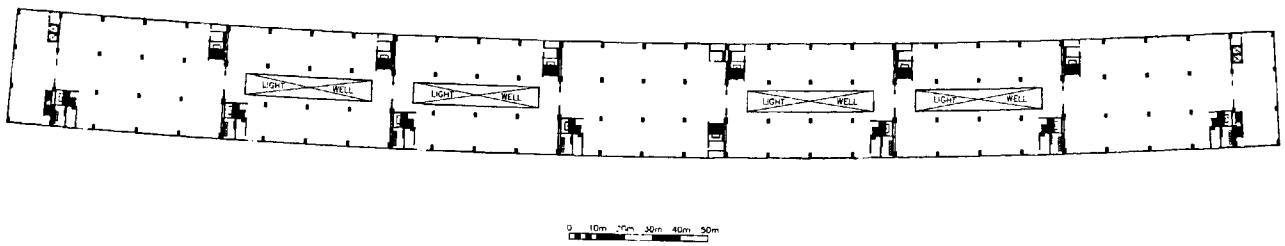


Figure 6
GS Superhighway Interchange--Floor Plan

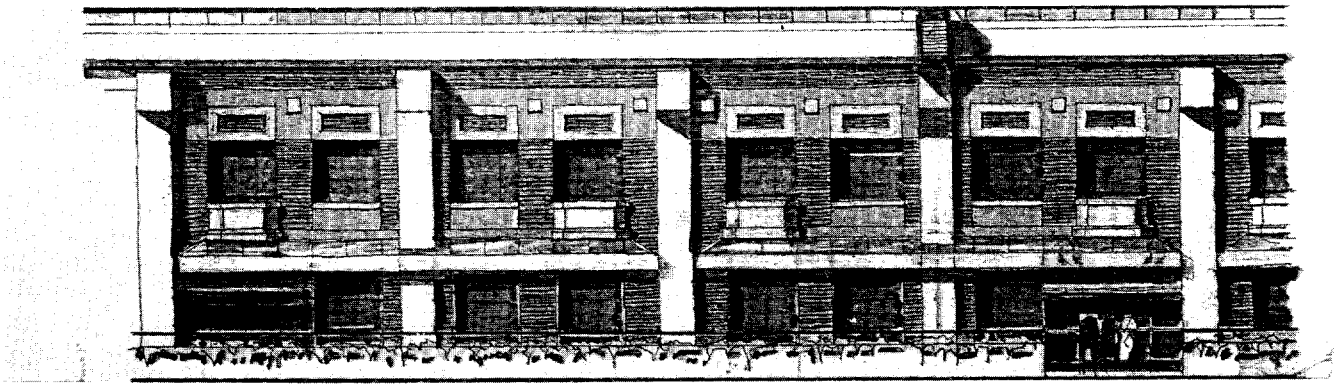


Figure 7
Shopping Mall--Artist's Front Elevation

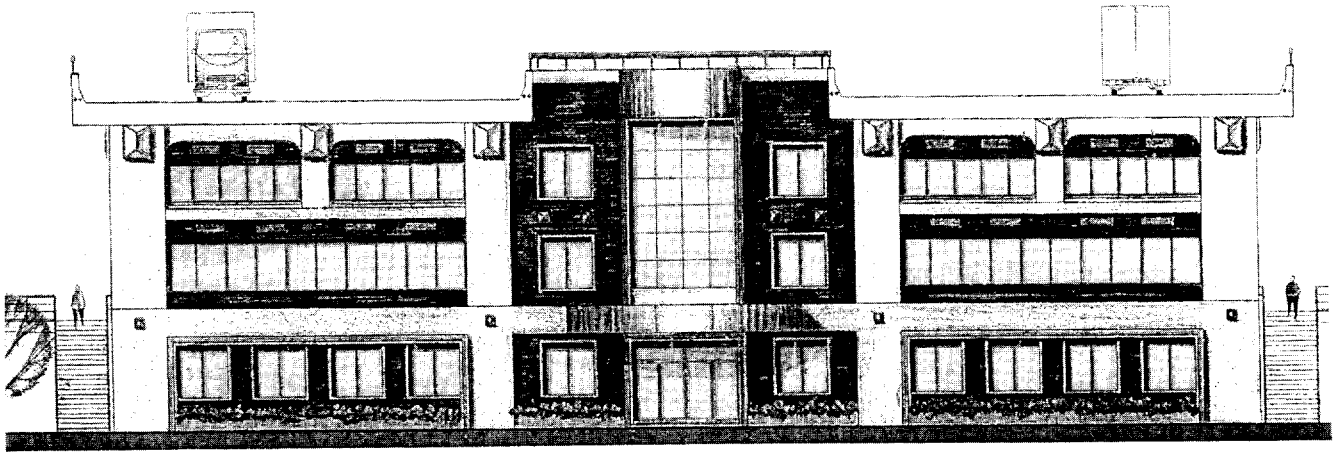


Figure 8
Shopping Mall--Artist's End Elevation

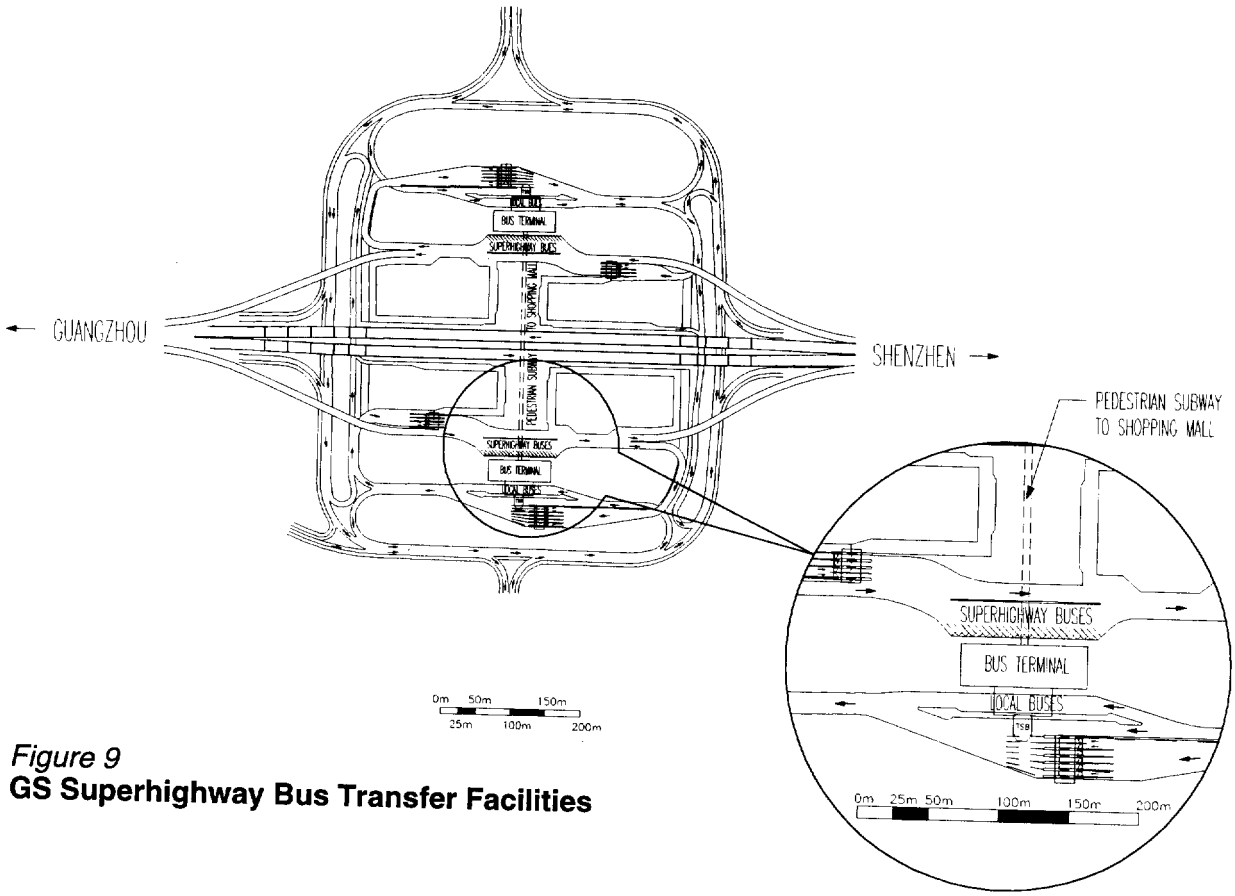


Figure 9
GS Superhighway Bus Transfer Facilities

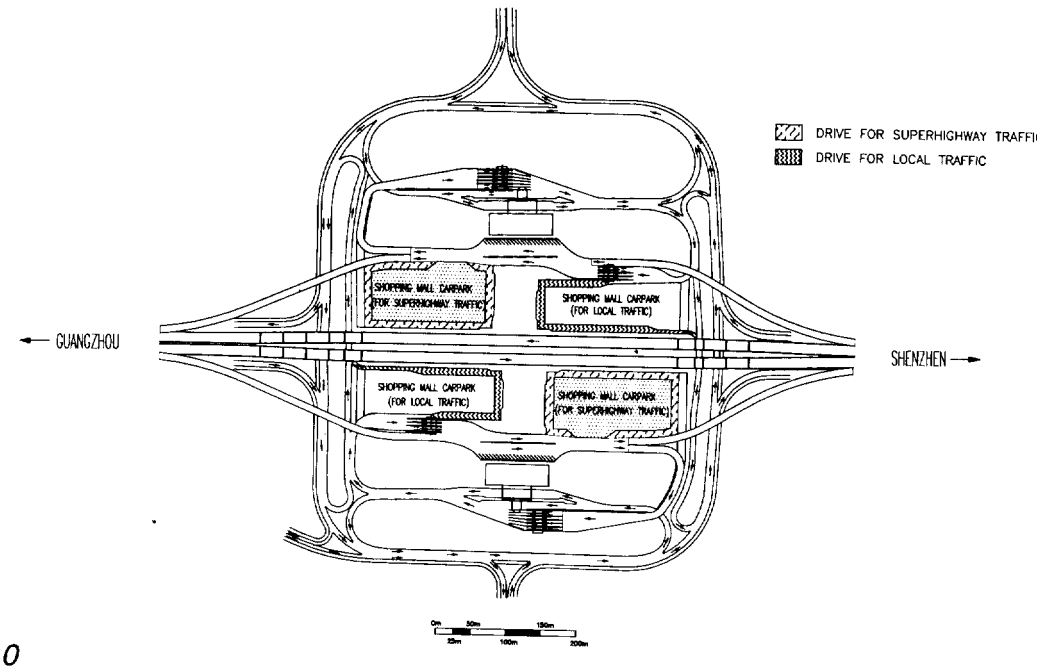


Figure 10
GS Superhighway Interchange Parking Lots

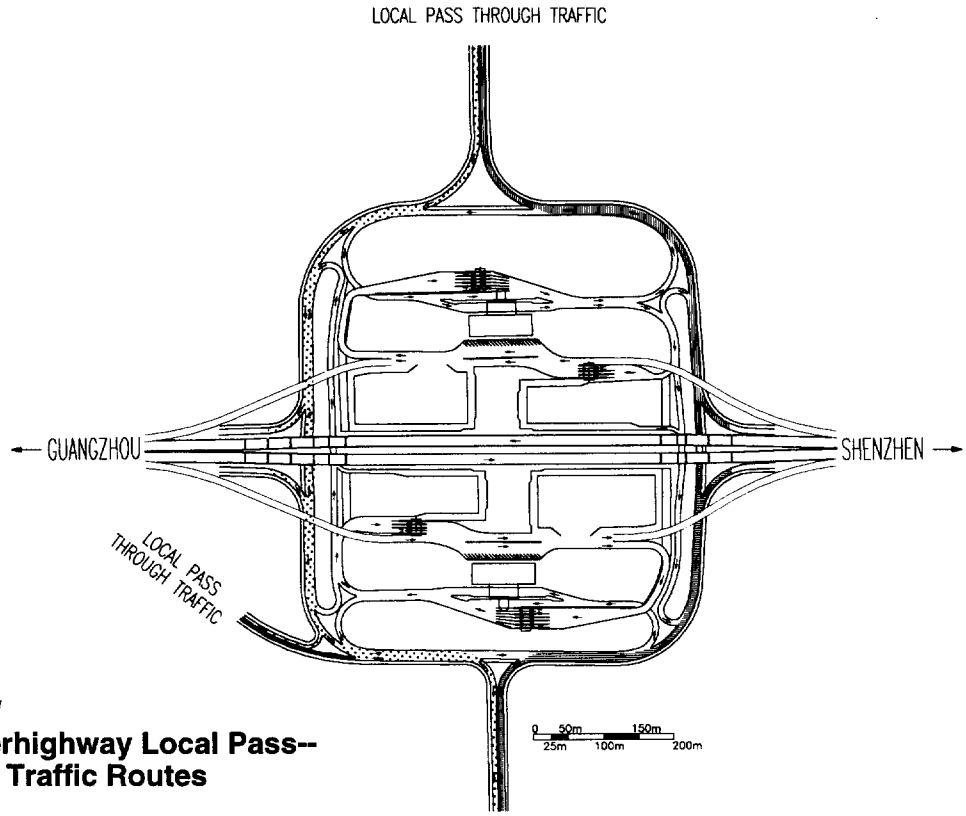


Figure 11
GS Superhighway Local Pass--Through Traffic Routes

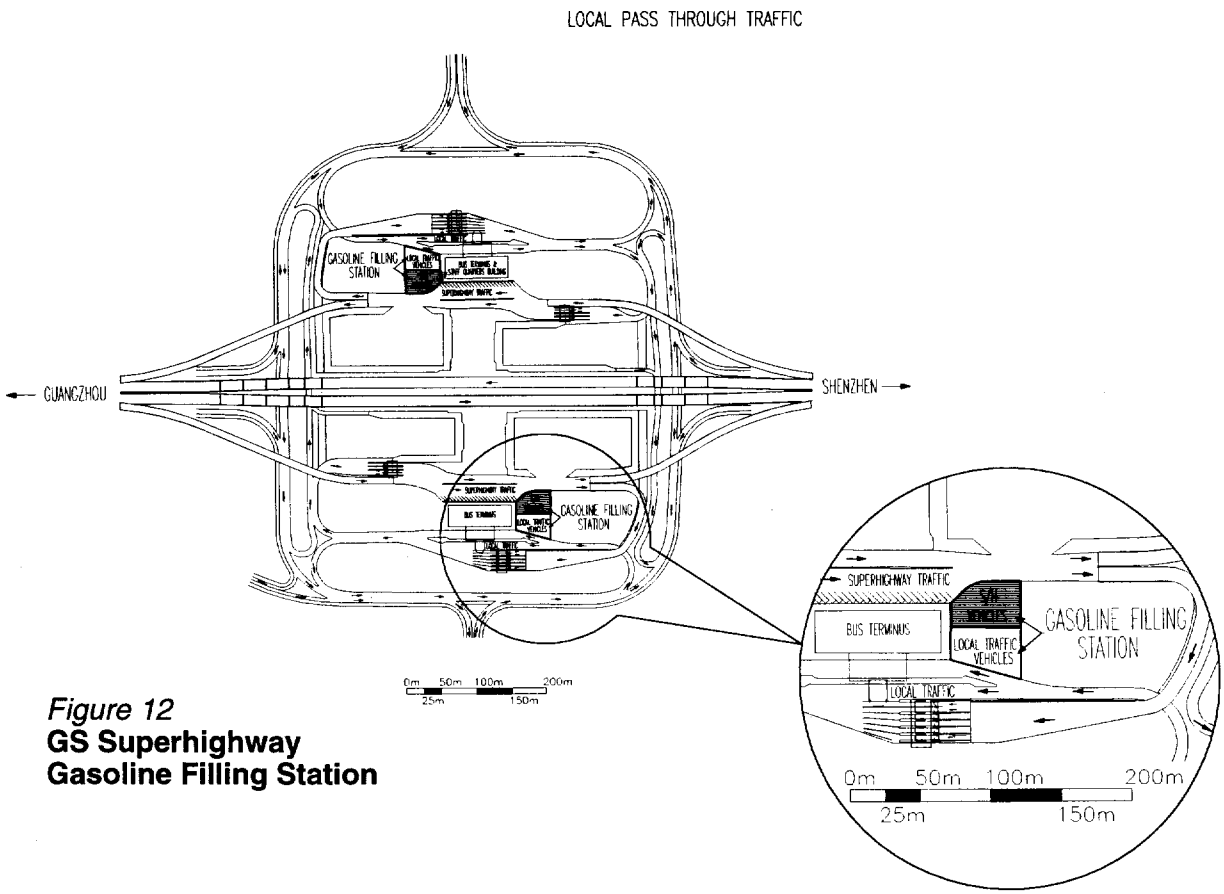


Figure 12
GS Superhighway Gasoline Filling Station