Chapter 2
Transportation and land use

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2.1 The relationship between land use and transportation

Understanding the relationship between land use and transportation is extremely important for designing a prosperous and safe transportation society.[1)]

Land use and transportation are interdependent, similar to a chicken-and-egg relation. Effective utilization of land stimulates urban activities, and roads and other transportation facilities are maintained so as to allow for new transportation-related activity. Creating new roads or expanding existing ones increases the attractiveness of the land they pass through, promoting new urban facilities. When cities are growing slowly, it is easy for land utilization and traffic planning to match pace. In times of rapid economic growth, however, demand for land use accelerates and development of transportation facilities may be unable to keep up. Many cities experiencing a high degree of economic growth will therefore experience heavy congestion and other transportation problems.

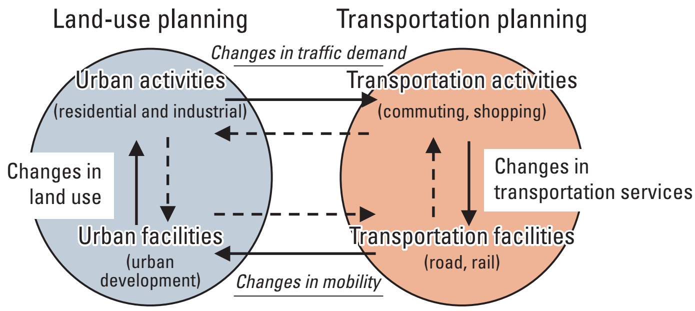

Figure 1. Relation between land use and traffic planning

How can the best balance be maintained between land use and transportation? Japan experienced a period of rapid motorization, a time during which it was impossible to keep up with demands for road expansion and other transportation facility development, and therefore implemented policies to regulate transportation demand itself. Such policies are called transportation demand management (TDM). Examples of TDM include changing peak demand times and shifting demand to other modes of transportation, thereby enabling existing roads to be utilized to the fullest extent possible.

An even more fundamental approach is promoting optimal land use. For example, when transportation facilities are poor, the floor area ratio can be kept low and then the ratio can be increased according to the progress of transportation infrastructure development. Efforts can thus be made to achieve a balance. Long-term sustainability should also be considered by altering the urban structure itself. For example, transportation demands that are concentrated in downtown areas can be dispersed to city sub-centers and core cities, thereby relieving congestion and promoting development of a more balanced city overall. Such efforts in Tokyo and other large cities have been implemented as the construction of multi-polar, distributed urban structures. The Third National Capital Region Development Plan (1976), for example, recommends a more wide-area, multipolar distribution to correct Japan's over-concentration on Tokyo, and the follow-up Fourth Development Plan (1986) suggests prioritizing development of business core cities and secondary core cities with the goal of creating a more multi-zonal, multi-nuclear urban structure.

There are differences in the emphasis placed on transportation problems such as congestion, noise, and air pollution, depending on the region and era. Having entered the 21st century, the traffic problems currently facing Japan, such as adapting to becoming a super-aged society and addressing global environmental issues, reflect increasingly long-term, wide-area considerations. However, even for such new problems, considering land use and transportation planning over time can lead to finding solutions to a variety of transportation problems so as to meet the needs of the future.

What kind of urban structure should be aimed for, and by what method should such an urban structure be developed? What kind of transportation facilities will be emphasized at that time? How should the remaining localized congestion be addressed? In this section, how developed countries are addressing such issues is examined in order to learn about four keywords necessary in urban development for the next generation.

2.2 Compact cities

2.2.1 Why are compact cities needed?

The question of how to plan and aggregate urban areas that have expanded with the progress of motorization so that they can be converted to sustainable cities is a significant problem that faces mature societies. In Japan, which has entered an era of population decline, intelligent reduction in the scale of now unneeded urban areas ("smart shrinking") has become an urgent task. In the Second Report of the Panel on Infrastructure Development (2007), the following problems may arise when the structure of diffuse cities is left unaddressed:

- Difficulty in maintaining public transportation: It is difficult to ensure demand for public transportation in low-density cities.
- Problems with transportation in a super-aged society: There will be an increased number of transportation-disadvantaged individuals who cannot operate automobiles.
- Increased environmental load: Excessive reliance on automobiles increases environmental load.
- Further decline of central urban areas: Promotion of suburban development causes a relative decline in the attractiveness of urban areas within cities.

- Pressures on municipal finances: Increased maintenance costs of expanded urban areas.

Even in developing countries experiencing economic growth, inducing urban structures that are appropriate to periods of population increase is important for avoiding problems seen in developed countries.

2.2.2 What is a compact city?

A compact city is one in which functions required for daily life are aggregated in the city center, and one with a maintainable city structure that retains an appropriate population density while remaining resident-friendly and environmentally friendly. In periods of population growth there is a tendency for urban areas to encroach on green spaces, while in periods of population decline there is a tendency for green space to expand into urban areas. It is hoped that this will lead to an appropriate scale reduction of the city itself. In particular, it is important that aggregation along public transportation lines strikes a proper balance between the use of automobiles and public transportation.

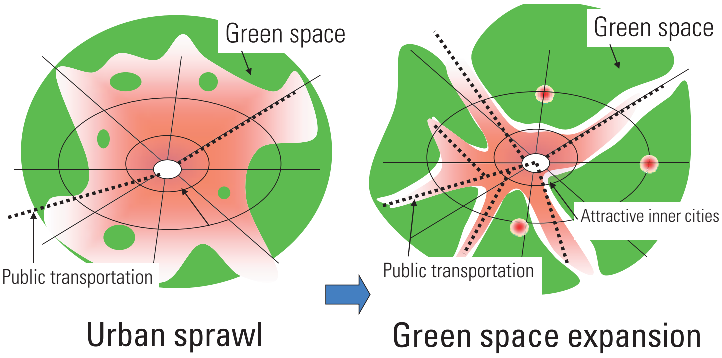

Figure 2. Smart shrink

2.2.3 Proposal for network-type compact cities

Compact cities first attracted attention when they were proposed in the 1987 Brundtland Report as an urban model for sustainable development. Such cities aim at an environment that promotes public transportation and walking, and avoids over-reliance on privately owned automobiles. However, it is extremely difficult for cities to aggregate once they have expanded, and although local governments may establish urban planning master plans as goals, achieving such goals requires a long time. Escape from low-density, automobile-oriented urban structures cannot be achieved without further urban planning that features public transportation as its core. Here, we propose the "network-type compact city,"[2] based on transit-oriented development (TOD), which is

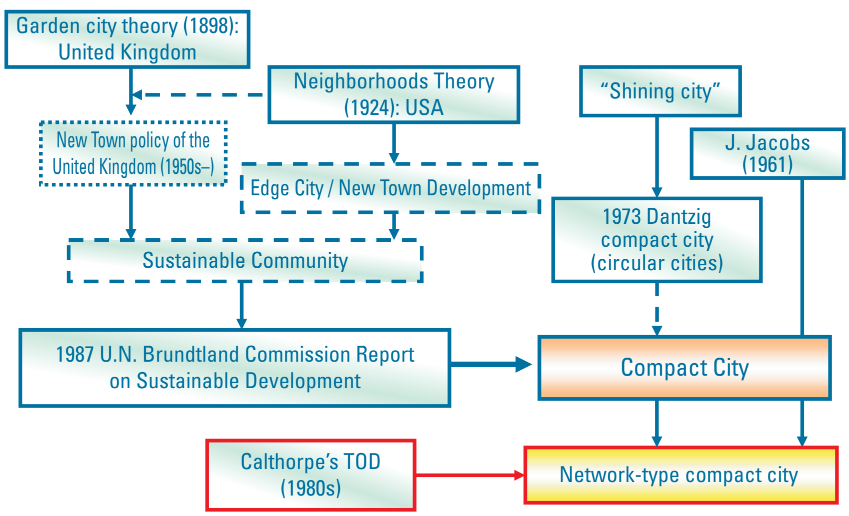

Figure 3. A genealogy of network-type compact cities

described below.

A network-type compact city is one in which the various attractive features of the city are aggregated (compacted) in multiple areas that are connected (networked) by various modes of transportation, with a focus on highly convenient public transportation. Figure 4 shows the structure of such a city. In this context, the word "compact" does not necessarily mean concentration at a single point but rather efficient aggregation over multiple hubs. One feature of network-type compact cities is that they have disaster resilience. Ensuring redundancy through the interconnection of multiple hubs of aggregation means that even if one part of the city is affected by a disaster, resilience of the city overall is increased because other areas can flexibly participate in recovery efforts.

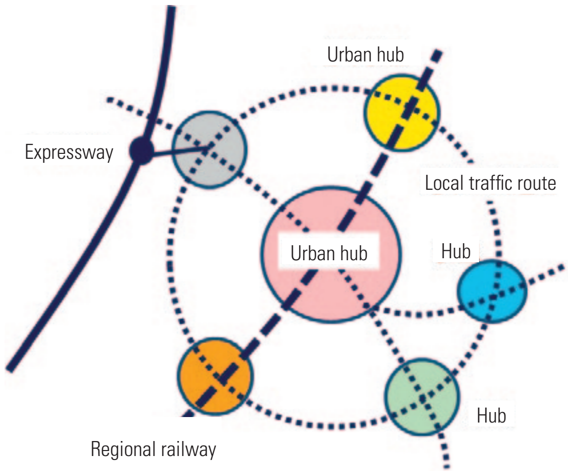

Figure 4. A network-type compact city

2.3 Transit-oriented development (TOD)

2.3.1 The pros and cons of automobile-dependent city development

In times of rapidly increasing urban population, cities suffer from shortages of residential areas, which leads to the development of many large-scale suburbs. Railway lines are often developed in large suburban cities, and further increase with the expansion of public transportation networks. Very different from the development of regional cities, the development of suburbs is often done regardless of the convenience of public transportation, greatly increasing reliance on automobiles. Furthermore, commercial development often occurs on the assumption of high automobile utilization, resulting in continued development in areas along suburban bypass routes, spurring the decline of central urban areas.

The automobile is indeed a comfortable and convenient mode of transportation, but over-reliance on automobiles detracts from other modes of transportation, and leads to the building of a society that is unfriendly toward transportation-disadvantaged residents who do not own an automobile. Learning from this, developed countries are turning their attention toward urban planning that focuses on public transportation.

2.3.2 What is TOD?

TOD means urban development that is centered on public transportation and avoids over-reliance on automobiles. Its fundamental concepts were proposed in the 1980s by Calthorpe, but precursors to this

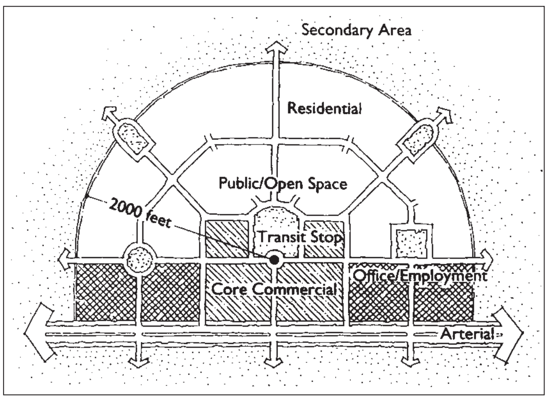

Figure 5. Conceptual diagram of TOD (P. Calthorpe)[3)]

concept can be seen in Japan in the development of areas around train stations, promoted by private railway companies since before World War II. Such development aimed at city planning in which commercial, industrial, and residential functions were situated in an area within 600 m from train stations, allowing a walking-based lifestyle.[4)]

TOD is performed with an emphasis on three important elements, called the three D's: [5)]

Figure 6. San Francisco (Fruitvale Transit Village)

Density: Maintenance of public transportation requires ensuring a certain degree of population density. That degree will vary somewhat depending on regional characteristics, but in general planning should ensure that population density does not go below 40 persons per hectare.

Diversity: It is important that commercial, medical, welfare, and other public functions be aggregated around train stations, so that basic life activities can be performed within walking distance.

Design: Good spatial design is vital to inducing land use. Attractive spaces have an effect on how people choose where to live.

2.3.3 Urban area aggregation through implementation of TOD

Cities are connected with other cities by rapid rail systems and other forms of high-speed public transportation, and the downtown areas of those cities are connected to their suburbs by light rail transit (LRT) and bus rapid transit (BRT) systems, thus providing public transportation that is both punctual and fast. TOD is mainly implemented along such public transportation routes.[6)] Providing high levels of public transportation service in such areas over a long period of time and in a punctual manner promotes urban aggregation. In contrast, in suburban areas experiencing population decline, variable public transportation systems such as demand response transit (DRT) are implemented.

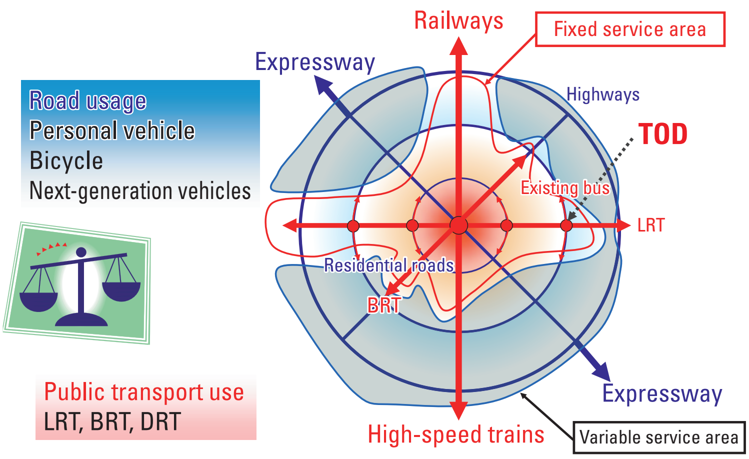

Figure 7. Urban space design implementing TOD

Transportation-disadvantaged residents such as the elderly are encouraged to live in TOD areas, while large families who most greatly benefit from the utility of automobiles are encouraged to raise their children in the green-rich areas of the suburbs. Selection of residential areas according to lifestyle thus allows for urban planning that best accommodates all generations.

2.4 Next-generation public transportation systems

2.4.1 Reconstruction of the hierarchical nature of urban transport

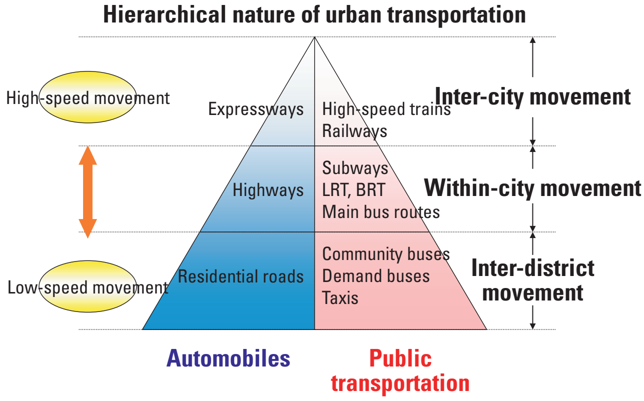

Figure 8. Hierarchical nature of urban transportation

In many regional areas, trends toward excessive reliance on automobiles have led to cities in which the only means of transport in and out of the city is by automobile. This has led to significant destruction of the traditional hierarchical nature of urban transport, such as through-traffic encroaching into residential areas and bus companies being forced to close routes. Development of a society that is environmentally friendly and compatible with a super-aged society requires the urgent reconstruction of a transportation system that does not rely on automobiles alone.

Desirable next-generation transportation systems must strike a balance between automobiles and public transportation, through a hierarchical differentiation of transportation functions. Considering automobile traffic, this hierarchy forms a pyramid with highways that maximize traffic functionality at the top and highly accessible nearby residential roads at the bottom. Similarly, with regards to public transportation the pyramid has rapid rail transit that allows high-speed movement between cities at the top and community-level bus services that allow movement between districts at the bottom. As one works toward the bottom of the pyramid, transportation speed decreases while flexibility of service increases.

2.4.2 Functionality of next-generation public transportation systems

Revitalizing public transportation systems in cities in decline will require improving comfort and convenience. To that end, the following functions are required:

Punctuality: The system should not be affected by traffic congestion, such as through the use of traffic lanes dedicated to public transportation.

Comfort: Transportation should be elderly-friendly, for example, by having little vibration and being barrier-free.

Environmentally friendly: The system should consume little energy, and minimize noise and pollutant emissions.

Attractiveness: Vehicles and pick-up locations should contribute to city planning by being suited to the landscape.

The most important thing is that the system draws riders away from their automobiles and provides sufficient added value to alter land use along routes.

2.4.3 LRT and BRT

Examples of public transportation systems that contain the above-mentioned functionality are next-generation LRT and BRT systems.

In contrast to heavy rail systems that provide transportation between cities, LRT systems provide transportation within a city. In Japan, these often take the form of next-generation tram systems. They are characterized by having improved functionality over older tram systems, being better integrated with other modes of transportation, and contributing to urban development by functioning as a comprehensive transportation system. The first LRT system was developed in Edmonton, Canada, in 1978. Since then, LRT systems have been introduced in 111 cities (as of 2008) throughout the world.[7)]

BRT systems provide large-scale, rapid transport of passengers by bus. Unlike traditional bus routes, these systems use dedicated traffic lanes to allow frequent and punctual service, which can in some situations improve transportation capacity through the use of articulated vehicles and allow for smoother boarding at dedicated stops. Such systems are already in place in locations such as Ottawa (Canada), Curitiba (Brazil), and Bogota (Columbia).

A common feature between both systems is that they are introduced not as isolated methods of transportation, but as one facet of a sustainable mobility system suited to next-generation cities. Such attractive public transportation systems are expected to be effective at promoting better and more aggregated land use.

Figure 9. LRT in Houston

Figure 10. BRT in Curitiba

2.5 Large-scale development and transportation assessment

2.5.1 Traffic problems caused by large-scale development

In recent years, intensive land use and progress of the automobile society has brought about large-scale development not only in cities but also in their suburbs. Traffic generated by new development is extremely heavy and has an effect over a wide area. The regions surrounding newly developed areas frequently already have a considerable amount of traffic demand, resulting in road congestion in some areas, so new developments have a high risk of further intensifying congestion, accidents, pollution, and other transportation-related problems. So what methods are there for easing chronic traffic congestion, while still maintaining a balance between land use and transportation? This section describes one basic method, traffic assessment for large-scale development.

2.5.2 What is a traffic assessment?

Traffic impact assessments, or simply traffic assessments, are a method and system for assessing in advance the effects of development plans on transportation in order to implement traffic policy from the perspective of harmonizing land use and transportation.

In a broad sense, traffic assessment is a macro-level approach for controlling land use patterns, density, and urban traffic master plans. In a more narrow sense, it can be applied as a micro-, district-level approach, which in Japan has been implemented for development exceeding a certain scale by the Ministry of Land, Infrastructure and Transport's "Large-scale Development District-related Traffic Planning Manual," by the Ministry of Economy, Trade and Industry's "Large-Scale Retail Stores Location Law," and by public safety commissions or traffic administrators' "prior traffic measures". Generally speaking, "transportation assessment" refers to the narrower definition.[8)]

2.5.3 Proper provision of parking lots for areas of large-scale development

When performing large-scale development, it is necessary to provide adequate parking that is commensurate with the traffic demand. For example, the Large-Scale Retail Stores Location Law requires that a person who establishes large retail stores secure an adequate number of parking spaces.

The number of necessary parking spaces is determined by using an equation that takes the number of customers, peak ratio, car ownership ratio, parking lot usage time, and other factors as parameters. It is important to verify at the development assessment stage that an appropriate number of parking spaces will be available.

$$X = \frac{A \times S \times B \times C \times E}{D}$$

A: Number of daily customers by store floor space (persons/1000 m^2)
S: Store floor space (1000 m^2) B: Peak ratio (%)
C: Car ownership ratio (%) D: Average number of car passengers (persons)
E: Average parking time coefficient

2.5.4 Traffic simulations for large-scale development

It is extremely important in traffic assessment to grasp traffic conditions quantitatively and in detail. Innovations in information technology since the 1990s have resulted in dramatic improvements to computer processing capabilities, allowing detailed, second-scale reproduction of traffic conditions and visual representations as animations, including signal controls, traffic lane construction, and other aspects. As result, many traffic simulators have been developed and practically implemented both in Japan (tiss-NET,

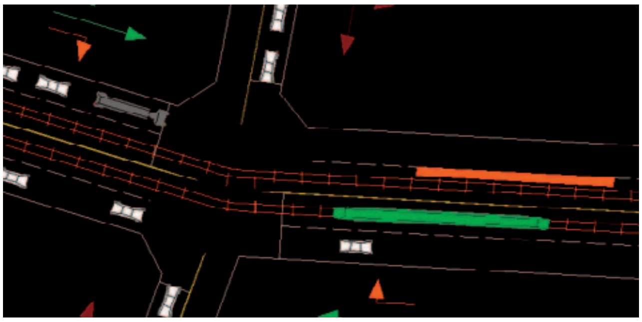

Figure 11. Traffic simulation screen

AVENUE, TRAFFICSS, VISITOK, etc.) and overseas (NETSIM, Pramics, WATSim, etc.).

Developing traffic simulations requires substantial time and effort, so application conditions need to be publicly documented. Consideration of traffic simulations from early stages allows those wishing to open stores to apply them to site selection. Table 1 shows the implementation conditions for a traffic simulation performed in Tochigi prefecture.

Table 1. Conditions of the traffic simulations in Tochigi Prefecture

Peak arriving vehicles	Relation between lot shape and traffic	
	No risk of congestion	Risk of congestion
200–600 vehicles (100 vehicles per direction)	Not needed	Needed
600 or more vehicles	Needed	

From these results, merchants, road managers, and traffic control personnel can consider the effects of congestion reduction policies before the establishment of large-scale stores. Note that there are many significant effects of large-scale development, and in situations where mitigation measures are difficult through transportation facility development, reconsideration of site selection for large-scale development may become necessary.[9)]

References
1) Sugiyama, Masahiro, Sotaro Kunihisa, Mitsuyuki Asano, and Hirohito Kuse, eds. 2003. *Asu no toshi kotsu seisaku* [The Future of Urban Transport Policy]. Seibundo Publishing. (in Japanese)
2) Morimoto, A. 2012. "A preliminary proposal for urban and transportation planning in response to the Great East Japan Earthquake." *IATSS Research* Vol. 36, No. 1: 20–23.
3) Calthorpe, Peter. 1993. *The Next American Metropolis: Ecology, Community, and the American Dream.* Princeton Architectural Press.
4) Transit Cooperative Research Program. 2004. *TCRP Report 102, Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects.* Transportation Research Board.
5) *Developing Around Transit: Strategies and Solutions That Work.* ULI (the Urban Land Institute). 2004.
6) Hayashi, Yoshitsugu, Kenji Doi, Hirokazu Kato, and International Association of Traffic and Safety Sciences, eds. 2009. *Toshi no kuoritei sutokku: Tochi riyo, ryokuchi, kotsu no togo senryaku* [Quality Stock of Cities: Integrated strategy of land use, green space and transportation]. Kajima Institute Publishing. (in Japanese)
7) "Special Supplement: Challenges and Visions for Implementing Light Rail Transit in Japan." *IATSS Review* Vol. 34, No. 2. 2009. (in Japanese)
8) *Kotsu asesumento ni kansuru chosa hokoku sho* [Investigation Research Report on Transportation Assessment]. International Association of Traffic and Safety Sciences. March 2001. (in Japanese)
9) Seki, Tatsuya, and Akinori Morimoto. 2010. "Daikibokaihatsu ni okeru kotsu asesumento no seiri to kongo no tenbo" [A Review of Traffic Impact Assessment in Japan]. *Journal of JSCE(D)* Vol. 66, No. 2: 255–268. (in Japanese)

Recommended Reading
1) Randall, Thomas, ed. 2003. *Sustainable Urban Design: An Environmental Approach.* Spon Press.
2) Jenks, Mike, Elizabeth Burton, and Katie Williams, eds. 1996. *The Compact City: A Sustainable Urban Form?* Taylor & Francis.
3) *Site Impact Traffic Assessment: Problems and Solutions, Proceedings of the Conference, Chicago.* The American Society of Civil Engineering. 1992.
4) *Transportation Impact Analyses for Site Development.* Institute of Transportation Engineers. 2006.

Practical application projects for reference
A land utilization framework and transportation system for declining population: 132–135
Urban development from parking lots considering inner-city parking density: 140–143