# Chapter 2
# Systematic and Behavior-Oriented Approaches for Sustainable Urban and Transport Policies

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**Abstract** To realize a sustainable urban and transportation society, good governance is required. This should be supported by systematic and scientific approaches that can generate informative indicators of factors such as policy evaluation, decision making, implementation, and monitoring. Urban and transportation systems are complex, and managing them needs interdisciplinary knowledge. Accordingly, this chapter argues for the importance of developing integrated urban and transportation models, and implementing interdisciplinary behavioral studies. The key point is to represent changes in the system and citizens' life behavior with regard to quality of life, environmental capacity and social equity. Both backcasting (top-down) and forecasting (bottom-up) approaches should be utilized, with sustainability transition emphasized as part of an interactive planning and policy-making scheme. Finally, context-sensitive urban designs should be promoted.

**Keywords** Behavioral change • Context-sensitive urban design • Cross-sectoral policies • Integrated models • QOL • Sustainability transition • Systematic approach

## 2.1 Background

In the year 1800, only 2 % of the world's population was urbanized, but in 1950, 30 % of the world's population lived in cities (UNHSP/BASICS1/02). Currently, for the first time in history, more people now live in urban than in rural areas (The United Nations 2011). It is estimated that half of the population of Asia will live in cities by 2020, Africa will probably reach a 50 % urbanization rate in 2035,

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and this growth in urbanization will be unequally distributed, mostly in the developing world: Asia, Africa and Latin America (The United Nations 2012).

The above rapid urbanization has resulted in an exponential growth in mobility, which has contributed to great social and economic advances on the one hand but has caused various problems (e.g., traffic congestion, declines in road safety, excessive energy consumption, air pollution and the resulting worsened health conditions) on the other. Especially in developing countries, such issues are serious and complicated because of the extreme lack of urban infrastructure, poor construction and maintenance of facilities, and disorderly urban land development. There is also high dependence on ill-equipped paratransit systems (e.g., jeepneys, tricycles, tuk-tuks, soibikes, pedicabs, rickshaws and dilimans), poverty and lack of governance (e.g., lack of funding, insufficient laws and regulations, lack of qualified people, and low levels of technological development). Comparing developing with developed countries, one can easily observe similarities in the growth process because developing countries attempt to catch up with developed countries by imitating their development patterns. However, increasing concerns about environmental issues around the globe give rise to dissimilarity. In the past, when developed countries were in situations similar to those in developing countries now, they did not have to pay so much attention to environmental issues because economic growth was the highest priority among policy objectives. Currently, policy makers in developing countries face increasing constraints, such as monetary and technological limitations, lack of qualified human resources or collaboration among actors (such as government, firms and citizens), and the resultant worsened social capacity for environmental management (Zhang et al. 2005; Zhang and Fujiwara 2006a, 2007). Although developing countries are currently not major contributors to environmental burdens, challenges in developing countries will have worldwide implications.

Developing cities in a more sustainable way is therefore of increasing importance. As Bossel (1999) argues, the sustainable development of human society has environmental, material, ecological, social, economic, legal, cultural, political and psychological dimensions that require attention. Some forms of sustainable development can be expected to be much more acceptable to people. In the context of urban transportation system, UITP (2003) advocates that sustainable transportation is an aspect of global sustainability that involves meeting present needs without reducing the ability of future generation to meet theirs. A sustainable transportation system should meet the basic access needs of individuals and societies, be affordable, operate efficiently, and limit its emissions and waste to remain within the planet's ability to absorb them.

## 2.2 Importance of Systematic Thinking

To meet various human needs for urban spaces/functions and at the same time to mitigate the impact of human activities on the environment, urban systems must be appropriately designed. There is no doubt that investment in urban infrastructure (e.g., roads, transit systems, sewerage and water systems, urban amenities, community and cultural facilities) plays a key role. Because improvement in urban infrastructure is usually large scale and extremely expensive, such investments must be as efficient and cost-effective as possible. Meanwhile, to reduce environmental emissions, our whole society must make various practical efforts by fully utilizing available capital assets (including natural, physical, financial, human and social capital) with good collaboration of various stakeholders including government, firms and civil society. Government and firms are required to guide people toward living in a low-carbon society; however, they may fail because of their "soft heartedness" toward citizens/consumers. In case both market and government failures occur, citizens must protect themselves. For example, they may need to reconsider their energy-intensive lifestyles, to be more cost sensitive and altruistic, and to make more proenvironmental choices of goods/services, and they may be required to share responsibility. To realize a socially acceptable sustainable urban and transportation society, it is becoming extremely important to improve understanding of citizen and consumer behaviors. Note that sustainability cannot be realized in an instant. Emphasis must be placed on the "sustainability transition" (Expert Group on the Urban Environment 1996). In other words, the way to move from the current unsustainable state to a future sustainable state should be emphasized.

To tackle the unsustainable urban and transportation issues, it has been argued that various policies should be packaged (e.g., Institute of Highways and Transportation 1996). These policies may include the following:

- Integrated land-use and transportation planning,
- Anti-car measures (e.g., control of car ownership and use, road pricing, enforcement of illegal parking),
- Transit-friendly measures (e.g., prioritizing transit systems, providing information, IC cards and fare systems),
- Pedestrian- and bicycle-friendly measures (e.g., traffic calming, providing pedestrian/bicycle spaces and open spaces),
- Improving road networks (e.g., creating arterial road networks, reallocating road space, implementing environmental measures at the roadside, and providing parking spaces),
- Universal design for transportation-poor people,
- New technologies (e.g., ITS (intelligent transport systems) and low-emission vehicles), and
- Policies to support voluntary changes in behavior.

To date, various planning theories have been developed and applied in practice, including system and rationalism theories, Marxist theory, advocacy planning theory, new right urban planning, pragmatism and post-pragmatism theory, postmodern planning theory, and interactive planning theory (American Planning Association 2006). In recent years, the interactive planning theory has increased in popularity because of its theoretical features, in that it attempts to realize consensus building based on dialogue in the ideal public situation where no external pressure is imposed and workshop and round-table approaches are usually adopted. In reality, however, it is difficult to prepare an ideal planning situation. Policy makers are required to solve issues arising from complexity, various constraints and diverse values. To support such difficult decisions, systematic thinking is especially important. Policies need to be properly evaluated to build consensus among the public before implementing them. Policies should be evaluated by addressing the following concerns (Hanley and Spash 2003):

- Appropriateness (e.g., what information on impacts and trade-offs is required for the decisions?),
- Equity (e.g., what is the distribution of benefits and costs among members of the community?),
- Effectiveness (e.g., is the alternative likely to produce the desired results?),
- Adequacy (e.g., does the alternative correspond to the scale of the problem and to the level of expectation of problem solution?),
- Efficiency (e.g., does the alternative provide sufficient benefits to justify the costs?),
- Implementation feasibility (e.g., availability of funds, administrative or legal barriers, organizational capability, public acceptance), and
- Sensitivity analysis (e.g., sensitivity of analysis results to the change of assumptions made, and the likelihood of these changes occurring).

Approaches to support the complicated and difficult policy decisions above usually include the following:

1. The rational actor approach in which alternatives are selected to obtain a set of predetermined goals and objectives that maximizes utility;
2. The satisfying approach in which the first alternative that meets the minimal level of acceptability is selected;
3. The incremental approach in which decision making is geared toward avoiding problems rather than attaining objectives;
4. The organizational process approach in which decisions are highly influenced by organizational structures, channels of communication, and standard operating procedures, and
5. The political bargaining approach in which the decision process is pluralistic and characterized by conflict and bargaining.

The above-mentioned methods and theories are usually applied independently or jointly depending on context, issues and countries. Applying these methods/theories also requires the consideration of steps throughout the policy-making process, which are usually: identifying issues; setting goals, objectives and priorities; collecting and analyzing data; generating alternatives; predicting future evaluations; making decisions about planning; implementing the planning, management and maintenance processes; monitoring; and recommencing the process. Nevertheless, in practice, the monitoring step in particular is usually ignored because it requires continuous monitoring. Monitoring progress of policies is itself a public expense and therefore has an opportunity cost (Maxwell and Conway 2000), which in many cases becomes a barrier to its implementation.

## 2.3 Methods of Building Integrated Models

The development of integrated models has been popular in the context of land-use and transportation systems, which are usually interdependent of each other (Timmermans 2003; Wegener 2005; Miller 2006). Land-use patterns influence choice of residential and work location as well as the locations of activity facilities. Consequently, they affect a series of decisions regarding trips, such as whether to take a trip (trip generation), how frequently trips are taken (trip frequency), where to go (destination choice), how to travel (travel mode choice), when to go (departure time choice), and which route to take (route choice). Conversely, a transportation system also generates a variety of outputs such as travel time, cost, emissions and noise, which determine factors such as the accessibility of places connected to the transport system, quality of life/work, and activity facility environment. Accessibility and quality of environment significantly influence land price, which is the most important determinant of supply in a land-use system. It should be noted that relationships between land use and transportation are usually cyclic and change over time (Giuliano 1989).

There are a number of integrated land-use transport systems that are in use today, such as ITLUP, EMPAL, DRAM, METROPILUS, MEPLAN, TRANUS, RURBAN, and UrbanSim. There are significant variations among these models with respect to overall model structure, comprehensiveness, theoretical foundations, modeling techniques, dynamics, data requirements and model calibration. Detailed reviews are given by Wegener and Fürst (1999), Timmermans (2003), Wegener (2005) and Miller (2006). To date, the integrated models above have mainly been applied in North American and European cities (Wegener 2005). There are only limited applications in developing countries (e.g., Ratchapolsitte et al. 1986; Udomsri 1993; Emberger et al. 2005; Vichiensan and Miyamoto 2005). The lack of application in developing countries may be because of the data requirements for integrated models, lack of consideration of behavioral mechanisms specific to developing countries in the models, and lack of human resources.

One of the most prominent characteristics of developing countries is the enormous growth of their urban areas (Echenique 1986). Because the pace of development is very rapid in urban areas, it becomes very difficult to deal with problems of urbanization in developing countries. This leaves many suburban areas with inadequate supplies of urban infrastructure such as water, sewerage and transportation. In addition, many policies adopted to cope with urbanization problems in the developing world have become insufficient and have imposed high financial costs on society (Echenique 1986). Thus, an integrated model for developing countries should capture the development dynamics properly and should locate the various well-defined and realistic public policies appropriately. Moreover, the model should be sufficiently flexible to use available data, which is the main source of bottlenecks in developing a comprehensive integrated urban model in developing country contexts.

Bearing in mind the above-mentioned difficulties in the context of developing countries, some issues related to the development of integrated urban models are discussed below from the perspectives of population and economic activities, land use, location choice, transportation, and policies. Developing countries are characterized by rapid population increase as well as high levels of migration to urban areas. On the other hand, formal economic activities often fail to attract an adequate supply of labor in urban areas. The immediate solution to this inadequacy is supplied by informal sectors of the economy, which are rarely seen in developed economies. In the informal sectors, workers often are not registered properly and are paid on an informal basis to avoid the required payments for government social security and welfare services. Population and workforce development in urban areas is conditioned on very diverse dynamics such as population increases in other urban areas and surrounding rural areas. Thus, increases in the population in both urban and rural areas, and development of general economic activities should be modeled separately. As indicated above, population increases are very rapid in developing countries, and economic activities are very diverse. Accordingly, changes in land use also occur very fast. Changes in both resident population and economic activities occur in both formal and informal ways in developing countries, such as in slum housing and industrial areas. Such rapid changes in land-use patterns should be properly represented. Furthermore, location is chosen during the development of land use. In this regard, population increases and economic activities should be disaggregated into households and individual businesses, which are expected to choose among the available land uses. Heterogeneity in location choice decisions cannot be ignored. With regard to transportation, at least, trip generation, distribution, and modal splits should be built as dynamic models, such as in the manner suggested by Sugie et al. (2001), who built a dynamic travel demand model with state dependence, serial correlation and heterogeneity at the aggregate level based on a person's trip data with three time points. At the same time, because paratransit (an informal transport mode) in developing countries plays dual roles, such as providing convenient and flexible transport services, and providing employment opportunities to low-income people, it must be properly represented in the integrated model to clarify its position in future transportation systems from the perspectives of not only transportation services but also social equity.

All public policies should aim to improve people's quality of life (QOL). Implementation of policies cannot have an impact on nature that exceeds its carrying capacity. In the case of urban and transportation development, as UITP (2003) argues, sustainable transportation systems are required to balance economic development, environmental emission and social equity. In this case, sustainability becomes the policy goal. Specifically, in the economic field, accessibility and mobility should be maximized; in the environmental field, emissions from transportation systems should be minimized, and in the social field, equity in accessibility and mobility should be maximized. Obviously, these sustainability goals must be realized with consideration for various uncertainties and constraints. Examples of such constraints could be civil minimum standards of accessibility and mobility, environmental standards and limits (i.e., capacity), technological and institutional constraints, and public acceptance. From this viewpoint, the integrated models reviewed above can be called "bottom-up" approaches in the sense that the models are based on past and present information without incorporating any policy goals. Bottom-up approaches are usually used to identify potential policies based on scenario analysis, whereby detailed policy goals are not defined in advance, and forecasting is therefore required. On the other hand, because of the difficulties of following the demand trend in resolving various transportation issues, target-based planning and policy decisions have recently grown in popularity, especially in the design of a low-carbon society. For such planning and policy decisions, top-down modeling approaches enhanced by the incorporation of backcasting techniques are required. Target-based planning is proposed, reflecting the facts that reality is complex and that information is imperfect, and the need for planning to be sufficiently flexible to account for, and adapt to, changing circumstances (Maxwell and Conway 2000). Planning needs to move from a blueprint to a process approach, and targets can be used to monitor the progress of policy. In essence, developing a top-down modeling approach is a multiobjective optimization problem (such as those approached with the bi-level programming (BLP) method) because it must consider not only future targets but also current system performance as well as various constraints.

As the Expert Group on the Urban Environment (1996) argued, the "sustainability transition" should be emphasized over the final goals of sustainability. For this purpose, as well as to enhance the public acceptance of policies, bottom-up approaches and top-down approaches may be combined in a hybrid approach to achieve policy goals and to monitor the progress of policy implementation. One critical difference between top-down and bottom-up approaches is that constraints in policy implementation are explicitly reflected in the modeling process of top-down approaches. In contrast, constraints are usually considered in examining the feasibility of policy scenarios identified after the model construction. A conceptual illustration of this hybrid modeling process is shown in Fig. 2.1 and briefly discussed below.

*Policy goals*: In the top-down approaches, policy goals with detailed targets (e.g., reducing $CO_2$ emissions in 2050 by 50 %) are predefined. To achieve policy targets, the best policy set is identified. On the other hand, in the bottom-up approaches, policy scenarios are first proposed and the effects of each scenario are evaluated; based on the scenario analysis results, better policy sets are determined. The experience of developed countries suggests that in the era when infrastructure construction was the focus in policy agenda, they mainly adopted top-down approaches. With the progress of urban development, circumstances surrounding policy decisions changed dramatically, and goal setting itself has become increasingly difficult. Now, partially because citizen participation has become more popular, bottom-up approaches are widely applied. Meanwhile, issues such as global warming have attracted greater attention from various stakeholders, including governments, firms and civil society. To respond to such new policy requirements, top-down approaches with clear targets are gaining in popularity. To realize policy goals specified in the top-down approaches, citizen participation is obviously required, especially in the stage of policy implementation.

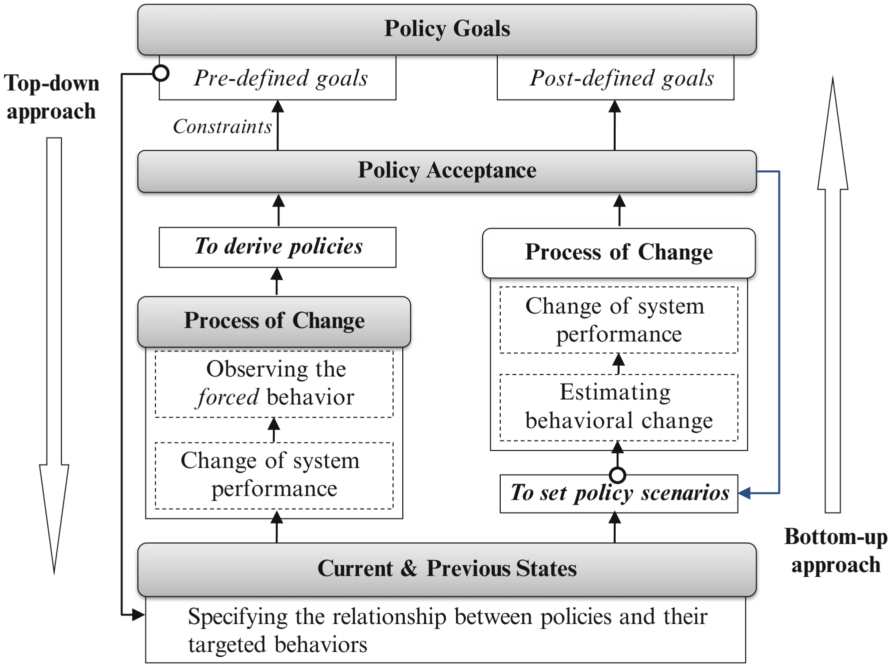


**Fig. 2.1** Conceptual illustration of hybrid-type integrated models

*Current and previous states*: To build any type of models, it is necessary to understand current and previous states to clarify the relationships between policies and targeted behaviors/systems. Various types of surveys have been used to provide well-grounded insights for urban and transportation policy decisions. Of course, reliable survey data are essential to support better policy decisions. To date, travel diary surveys, activity diary surveys, panel surveys and stated preference surveys (e.g., Richardson et al. 1995; Stopher and Jones 2003) have been developed to improve understanding of activity and travel behavior for various policy purposes. On the other hand, it is known that activity and travel behavior changes according to time and context. Temporal changes also show variation in time scales (e.g., hour-to-hour, day-to-day, week-to-week, season-to-season, and/or year-to-year variations). To capture such changes, panel surveys could and should be used (e.g., Golob et al. 1997; Stopher 2009); however, in reality, their application is very limited for various reasons, one of which is that they are time-consuming and too costly. As a result, in practice, transportation surveys are usually conducted by focusing on a representative (or an average) day (at most several days), and the survey results are then used to predict long-term and/or short-term travel demand. Moreover, it is difficult to apply existing survey methods to capture the influence of different contexts, which can be classified into individual-specific, alternative-specific, and circumstantial contexts (Zhang et al. 2004b). The first type refers to the attributes of individuals and their households. The second indicates the context of availability, number and attributes of alternatives as well as the associated correlation structures. The last type refers to circumstantial factors (e.g., weather, economic conditions, and city characteristics), which are common to all decision makers. In theory, it is obvious that information collected on one or several days cannot be used to capture fully the temporal and contextual variations in behavior of the whole population. Interestingly, several so-called "continuous" surveys have been conducted around the world at the national, regional and metropolitan levels. In these surveys, "data for each respondent are sought for the 24 h of the day in the seven days of the week and in all seasons of the year; further, the effort should be kept going for several years" (de Ortúzar et al. 2011). Therefore, it is extremely important to capture the past and current states properly based on continuous rather than cross-sectional surveys (i.e., surveys are conducted at a specific point in time).

*Process of change*: This term refers to changes in system performance as well as users' behavioral changes. In practice, monitoring of policies has been ignored because of factors such as political pressures and budget constraints. In fact, policies identified during the decision-making process are made based on assumptions. Because information about the future is insufficient and uncertain, the expected effects of policies may not be realized. For this reason, it is extremely important to monitor the actual effects of policies. If the effects are too far from, or in conflict with, the goals, redesign of policies is required. In the top-down approaches, changes in system performance are required to meet policy goals. To achieve these changes, users should be effectively encouraged to change their behavior. In the bottom-up approaches, changes in users' behavior in each scenario are estimated, and based on these estimates and changes in system inventories (supply), change in system performance is calculated. It may be seen that in either case, change in user behavior is the core of the analysis. To date, supply-centric policies have dominated the practice. In reality, traffic congestion is still serious, and the resulting air pollution remains problematic. All these facts suggest that supply-centric approaches alone cannot resolve various transportation-related issues. Considering the limitations of supply-centric approaches, demand-centric approaches should be emphasized. Practical policy decisions have only scratched the surface of users' decisions about their behavior.

## 2.4 Importance of Behavior Studies

Increasing traffic capacity by constructing new roads has been observed to be ineffective in reducing traffic congestion and resolving associated issues. Recently, recognizing the limitations of supply-oriented policies in resolving transportation issues, a new approach, known as the A–S–I (A: Avoid/Reduce, S: Shift/ Maintain, I: Improve) approach, was proposed to reduce GHG emissions, energy consumption and congestion, with the final objective of creating more livable cities (www.sutp.org). The ASI approach aims to mitigate the impacts of transportation activities.

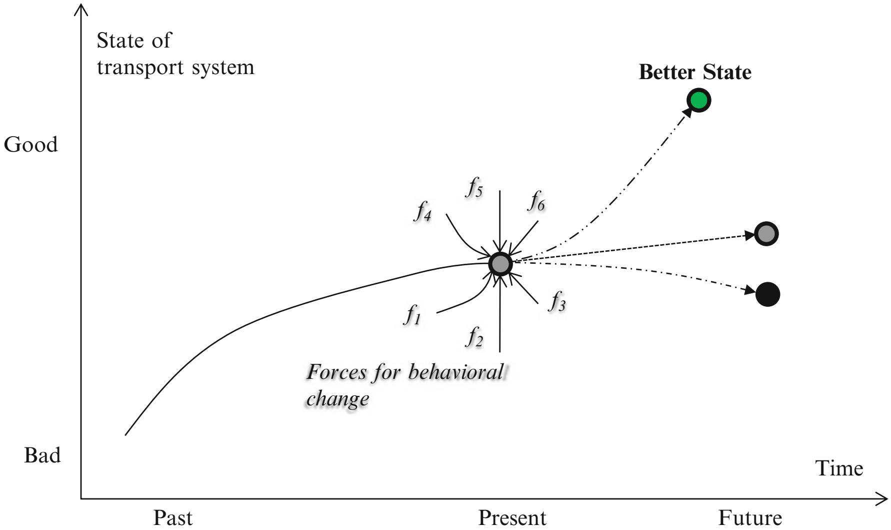


**Fig. 2.2** Forces for behavioral change and transport policy decisions

Because of climate change, as GTZ (2009) argues, transportation systems will confront more extreme weather conditions if no adaptive measures are taken. More frequent disruptions and higher economic costs must be expected, so adaptation measures are required. It is further argued that a resilient transport system is the backbone of a sustainable urban system and is necessary to avoid large and costly disruptions to urban life.

Generally, transport policies are intended to transform currently undesirable transport systems into better ones. The problem is whether and how users of transport systems follow the proposed policies or planning. Therefore, to support transport policy and planning decisions, it is essential to understand and measure the behavior of users properly. This study only focuses on travelers (i.e., passengers), and attempts to propose better methods to measure travelers' responses to policies or planning. As shown in Fig. 2.2, various forces can result in behavioral changes; some improve behavior, such as $f_1$ and $f_2$, while others, such as $f_4$–$f_6$, play the opposite role. Different forces could act on behaviors in either a linear or a nonlinear way. It is expected that travelers might respond differently even to the same force, and such responses may change over time and from context to context. Thus, it becomes important for policy decision makers to capture travelers' responses to policies in a proper manner. In other words, transportation planners need to understand people's responses when introducing new policies. However, people's responses to a policy usually differ among population groups and in most cases are not transferable across space and over time. This means that analysis results obtained from one city cannot be applied directly to other cities, suggesting that it is important to implement relevant surveys to investigate behavior and/or attitudes, and/or to develop models to represent/predict behavior/attitudes.

## 2.5 Travel Behavior Theory

### *2.5.1 General Features of Travel Behavior*

Travel behavior theory is a discipline about how people make a trip across space and over time, and how people use different transport modes and so on. Decisions usually include trip frequency (how many trips do people take in a given time period (e.g., a day)?), activity choice (what kinds of activities do people participate in after the trip?), destination choice (where do they go?), travel mode choice (which travel mode do they take?), departure time choice (when is the trip taken?), and route choice (which route do people choose for a trip?). Travel behavior theory helps transportation researchers and policy makers to understand travel choices and the conditions that encourage people to change their travel behavior. To change travel behavior, for example, measures include:

1. Increasing the cost and difficulty of private car use (e.g., increase gasoline taxes, introduce a congestion charge),
2. Making public transport more attractive by providing cheaper and more frequent transport,
3. Managing mobility (e.g., change user attitudes by emphasizing the socioenvironmental cost of private vehicle use using effective communication), and
4. Providing information (most travel information is currently supplied to road users, but similar information should also be provided to users of public transport systems).

*Trip generation*: This refers to the decision of whether to stay at home or to participate in out-of-home activities. Understanding trip generation is essential to identifying the total amount of trips per day, which determines the magnitude of impact of travel on human lifestyles, ecosystems, and sustainable development. Reducing the total number of trips generated may be the most effective way to reduce the environmental impacts of travel. Because of capability constraints, some people may have few chances to take trips for out-of-home activities. Efforts to address such social inequity would require focus on decisions concerning trip generation.

*Activity choice (Trip purpose)*: Generally, a trip can be taken for one or more purposes, such as commuting, shopping, and recreation. Trip purpose corresponds to choice concerning types of activities. Trip purpose is closely related to the flexibility of trip scheduling and consequently determines the possibility of reducing/modifying a particular trip for environmental purposes. Activity decisions have several important policy implications. First, if some activities can occur at home rather than outside, then some trips can be avoided. Second, activity decisions include time use (e.g., number of activities, duration and timing, sequence and activity patterns), which are closely linked with people's QOL. Third, if several activities can be performed in the same place, this can also reduce traffic loads. In other words, if urban space allows people to perform various activities within a small space (a compact city), not only can traffic demand (especially longer intracity trips) be reduced but also

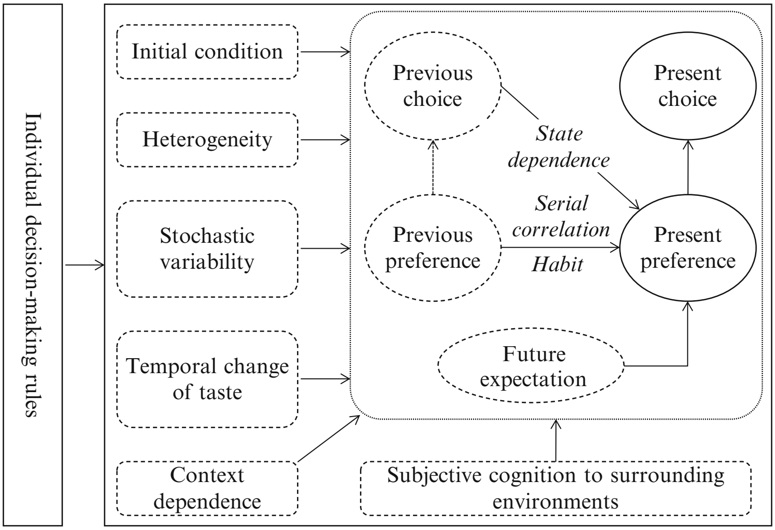


**Fig. 2.3** A general dynamic choice model structure

economic activities can be performed more efficiently, and social communication can be promoted.

*Destination choice*: This refers to where a trip goes; that is, the choice of place. Examples include workplace, city center and shopping centers in the suburbs. A traveler can perform one or more activities in a single place. Understanding choice of a destination or place is essential for promoting the development of compact cities and other environmentally friendly urban forms.

*Departure time choice*: This indicates when a person leaves from a point of origin (e.g., home or workplace). Understanding departure time choice behavior is especially useful for daily travel demand management. Comparison of the above travel choice aspects suggests that it is much easier and more practical (acceptable) to shift peak travel demand to off-peak periods.

*Travel mode choice and route choice*: These indicate type(s) of travel mode(s) (e.g., car, bus, railway, motorcycle, bicycle, and walk) and route(s) (e.g., toll road or nontoll road) chosen. To reduce environmental load from travel, it is necessary to promote the use of public transportation and bicycling/walking. It is useful to encourage those who must use their cars to use less-congested roads.

Obviously, some of the above behaviors are decided independently, while others may be connected. It is also expected that travelers' responses to transport policies may differ across the above behaviors. Ideally, they should be modeled together. However, it is difficult to include all these decisions in a single thesis. Therefore, this study only deals with some travel decisions, as clarified below. As for the behavioral mechanisms in travel decisions, a general dynamic choice model structure is given in Fig. 2.3, summarized by Zhang et al. (2004a). Specifically, current choice behavior is determined by individual preference, which is influenced by previous preferences (i.e., habit) and results of previous choices (i.e., state dependence) and sometimes by future expected behavior (or future expectation). Such behavioral mechanisms are further affected by initial conditions, heterogeneity in personal tastes over time, context dependence, and stochastic variability. It is expected that individuals' subjective recognition of the environments in which their decisions are made may also influence the above behavioral mechanisms, which are governed by individual decision-making rules. When these rules change, all the above mechanisms may also change to some extent.

### 2.5.2 Typical Travel Behavior Models

Over the past four decades, choice models have been widely applied to analyze and predict decision makers' choices of one of a finite set of mutually exclusive and collectively exhaustive alternatives. Choice models have proved to be very powerful tools for forecasting changes in people's choices according to demographics and/or attributes of the alternatives. The multinomial logit (MNL) model has become the most widely used choice model in transportation, probably owing to its simple mathematical structure and ease of estimation. Because it assumes that the error terms of the utility function are independently and identically distributed across alternatives, the MNL model is characterized by the Independence of Irrelevant Alternatives (IIA) property, which states that the odds of choosing a particular alternative are independent of the existence and attributes of any other choice alternative in one's choice set. Convincing examples have been put forward, however, to show that this property of the MNL model is counterintuitive in many real choice situations. To resolve the above issue, the development of non-IIA choice models has become a major methodological challenge in the study of individual choice behavior in many disciplines since the late 1970s. In transportation research, interest in developing non-IIA models seems to have faded slightly as a result of the emerging field of activity-based models of travel demand, but recently a renewed interest has been apparent (see Zhang et al. 2004b for an example). The majority of non-IIA models introduced in the transportation research literature avoid the IIA property by allowing for covariance between the error terms of the utility functions for all or bundles of choice alternatives in a choice set.

Following the classification by Timmermans and Golledge (1990), Zhang et al. (2004b) presented an extensive review of choice models in transportation and relevant fields at the time of writing, focusing on three categories of choice models. The first group of non-IIA models avoids the IIA property by relaxing the assumption of identically and independently distributed error terms, allowing for different variances of error terms, for positive correlations between error terms, or for both. The second group of non-IIA models circumvents the IIA property by extending the utility specification to account explicitly for similarity between choice alternatives. In other words, the models suggest that individual choice behavior is context dependent. The third group of non-IIA models assumes a hierarchical or sequential decision-making process.

Examples of the first group include McFadden's (1978) generalized extreme value (GEV) model, Hausman and Wise's (1978) conditional probit model, the multinomial probit model (Daganzo 1979), the heteroscedastic extreme value model (Bhat 1995), and the mixed logit/probit model (Brownstone et al. 2000).

For the second group, Swait and Adamowicz (2001a) proposed a latent class model of decision strategy switching to represent the influence of task complexity on consumer choice. Swait and Adamowicz (2001b) developed a theoretical model that simultaneously considers task complexity, the amount of effort applied by the consumer, ability to choose, and choice. Oppewal and Timmermans (1991) applied a mother logit model (McFadden et al. 1977) to estimate context effects in the choice of housing, shopping centers and transportation modes. Anderson et al. (1992) developed a similar model to represent attribute cross-effects and availability cross-effects in a study of mode choice. Gaudry and Dagenais (1979) proposed a dogit model to avoid the IIA property by introducing nonnegative alternative-specific parameters to represent substitution (similarity) effects. Borgers and Timmermans (1988) developed a context-sensitive model of spatial choice behavior to capture substitution/similarity effects as well as spatial structure effects.

The best-known model with a hierarchical decision structure is the NL model (Ben-Akiva and Lerman 1987), which is a special case of McFadden's GEV model. Other types of such models have also been derived from the GEV model, including the PCL, CNL, OGEV, PD and GNL models (Wen and Koppelman 2001). Recently, a nested PCL (NPCL) model was developed by Fujiwara and Zhang (2005). The GNL model in particular can include the above-mentioned models and the MNL model as special cases and closely approximates the NL model. A completely different approach is Tversky's (1972) elimination by aspects model. This model is one of the noncompensatory models. Most of the models described in this section assume that choice behavior is compensatory. These models allow a low score on an attribute to be at least partially compensated by high scores on one or more remaining attributes. In contrast, noncompensatory models assume that individuals screen choice alternatives on an attribute-by-attribute basis when arriving at a choice.

### *2.5.3 Important Decision-Making Mechanisms*

Careful review of travel behavior models suggests that the following behavioral mechanisms are important in travel decisions: heterogeneous dynamics, similarities in bundle choice behavior, reference dependence, and group decision-making mechanisms.

#### 2.5.3.1 Heterogeneous Dynamics

Heterogeneous dynamics indicate that choice behavior changes over time (i.e., temporal change) and that such changes differ across individuals (Zhang et al. 2004a).

1. *Temporal Behavioral Changes*
   Temporal changes can be classified based on the time interval, such as real-time change, change between peak and off-peak hours, day-to-day, week-to-week, season-to-season, and year-to-year changes. Some changes may recur periodically, while others may recur at a certain rate over time (or change at a regular rate). Because choice behavior is highly adaptive and context dependent (McFadden 2001), changes to decision contexts over time may result in changes in behavior. Changes of factors affecting travel behavior over time may also lead to a change in behavior, such as travelers' attributes (e.g., age, employment, family structure, habits, attitudes, and motivations), factors of choice alternatives (e.g., travel time and cost, and trip purpose), and circumstantial factors (e.g., weather, economic situation, car ownership among the population, and policies of road pricing for road users).

   To capture these behavioral changes, it is first useful to introduce the above factors into travel behavior models or to build dynamic behavior models. The development of disaggregate dynamic travel behavior models has been pursued since the 1980s. Heckman (1981) proposed a typical dynamic discrete choice model in which true state dependence, cumulative effects and behavior inertia are jointly accommodated. Recently, in line with Heckman's model, Swait et al. (2004) derived a new dynamic model derived from the well-known GEV model family (McFadden 1978), into which initial conditions, future behavior expectations, state dependence, the scale parameter of time-variant taste, covariance structure and preference can be simultaneously incorporated.
2. *Heterogeneity*
   Heterogeneity can be caused not only by the observed characteristics of individuals (e.g., gender, age, income, and number of households) but also by unobserved characteristics (e.g., omitted variables of the preference, attitudes and motives) (Reader 1993; Sugie et al. 1995, 1996; Swait and Bernardino 2000; Zhang et al. 2001). The former is called observed heterogeneity and the latter unobserved heterogeneity.

   Observed heterogeneity can be captured using market-segmentation techniques (e.g., Tynan and Drayton 1987; Morikawa and Shiromizu 1991). In the marketing research field, various scanner panel data are available. Such panel data can be used to explore the observed heterogeneity of each individual consumer directly (Terui and Dahana 2006). In the transport sector, various IC cards have been widely introduced (Bagchi and White 2005). The rapid progress of such information and communication technologies makes the direct observation of human behavior over time and across space easier. Although the privacy issue cannot be ignored, a new way of directly observing behavioral changes is surely opened.

   Unobserved heterogeneity can be observed in many components of choice models, including taste for alternatives, taste for attributes, error structure, state dependence, initial conditions in panel analysis, choice set, and model structure.

   *Taste for alternatives*: This is described as a form of "alternative-specific constant term." When it does not follow a probability distribution—that is, it is assumed to be invariant over the population—the choice model is called a "fixed-effect model." In contrast, when it follows a distribution, it is called a "random-effect model," which further consists of parametric and nonparametric models (Chamberlain 1980; Reader 1993; Sugie et al. 1995, 1996; Zhang et al. 2001; Heckman and Singer 1984).

*Taste for attributes*: Attributes can be alternative-specific and/or alternative-generic. It is usually assumed that taste parameters follow a multivariate normal distribution. Mixed logit and mixed probit models are the two main types of models (Bhat 2001; Bhat and Guo 2004; Revelt and Train 1998; Brownstone et al. 2000; Rossi et al. 1996; Hensher and Greene 2003).

*Error structure*: Bhat (1997) defined the parameters of a logsum variable in a nested logit model as a function of individual attributes to represent the error covariance structure with heterogeneity and applied it to the analysis of intercity transportation. Recently, multilevel modeling approaches have become a more general method for capturing heterogeneous error structures by dividing the error terms into different unobserved stochastic components (e.g., Chikaraishi et al. 2009, 2010).

*State dependence*: Bhat and Castelar (2002) analyzed a congestion pricing policy using a mixed logit model by including three kinds of heterogeneity (preference, state dependence and the preference for LOS variables) in a combined RP/SP model.

*Initial condition*: This is a special behavioral phenomenon in the panel analysis. Two typical methods were proposed to represent its heterogeneity—the fixed initial condition method and the correlating initial condition method—where the former disregards the influence of unobservable heterogeneity, while the latter takes it into account (Heckman 1981).

*Choices set*: Chiang et al. (1999) proposed a model to describe jointly the heterogeneity of a choice set and that of preference parameters. As for preferences, it is assumed that the parameter follows a normal probability distribution.

*Model structure*: In discrete choice behavior, Wu et al. (2011), for example, developed a heterogeneous choice model of destination and travel parties by combining a nested logit model and a latent class model. Using the same latent class model, Kuwano et al. (2007) developed a household vehicle holding duration model for continuous choice behavior. Walker and Ben-Akiva (2002) proposed a generalized random utility model that can comprehensively represent the error structure, latent classes, latent variables, and heterogeneity of SP and RP data.

#### 2.5.3.2 Similarities in Bundle Choice Behavior

It is not unusual that consumers choose a set of alternatives (i.e., a bundle alternative) in a single purchase situation. Targeting such consumer behavior, firms often sell their goods in packages: sporting and cultural organizations offer season tickets, banks offer checking, safe deposit, and travelers' check services for a single fee (Adams and Yellen 1976). In economics, such sales of packages are called "commodity bundling." In fact, travelers also often make a joint choice of two or more travel decisions, such as travel mode and departure time, or destination, travel mode and route. In other words, travelers choose a combination of two or more travel elements. This is an example of bundle choice in transportation.

In marketing research, bundle choice is classified as a part of multiple-category choice. Conceptually, a multiple-category choice can be defined as a decision process in which the choice of one product or brand is affected by the presence of another product in a different category, and there are a variety of ways in which choices across different product categories may be linked (Russell et al. 1999). Bodapati (1996) uses a nested logit framework to represent bundle choices. Manchanda et al. (1999) use a multivariate probit (MVP) model to reveal how marketing activity in one product category influences purchase incidence decisions in another category. In addition, market basket analysis is an attractive approach to studying the composition of a basket (or bundle) of products purchased by a household on a single shopping occasion (Russell et al. 1997).

Related to the above bundle choice, Zhang et al. (2004b) develop a relative utility model in the context of transportation. The concept of relative utility assumes that utility is meaningful only relative to some reference point(s). It is argued that an individual evaluates an alternative by comparing it with other alternatives, or perhaps with the alternatives previously chosen by the individual, or with those chosen by other individuals. The form of the relative utility function shows that the relative utility of an alternative is defined as a special case by reflecting the influences of other alternatives in the choice set. Thus it is expected that relative utility can be used to represent cross-category choice dependence. Compared with existing cross-category modeling approaches, the relative utility model can be estimated much more easily using the standard maximum likelihood estimation method, without the difficult hierarchical Bayesian estimation technique.

#### 2.5.3.3 Reference Dependence

From a psychological viewpoint, choice behavior is highly adaptive and context dependent (Tversky and Simonson 1993; McFadden 2001). Kahneman and Tversky (1979) argue that choice behavior depends on status quo or reference point and that a change of reference point may lead to preference reversal. Considering that the development of travel behavior models was intended to support policy decisions, it is important to define context dependence properly to avoid seriously biased inferences. For this reason, Zhang et al. (2004b) reclassify context into alternative-specific, circumstantial, and individual-specific contexts, and formulate a relative utility model that uses these reference points as anchor points. Conceptually, it is assumed that an individual evaluates an alternative in a choice set in comparison with other alternatives (alternative-oriented relative utility), with the alternatives that the individual has chosen in the past (or possibly the future) (time-oriented relative utility), or with the alternatives chosen by other individuals (individual (or decision-maker)-oriented relative utility). Circumstantial context further suggests that such decision-making mechanisms vary with contextual factors (e.g., weather and economic situation), which are common to all individuals (decision makers).

As a theory of decision making under uncertainty, Kahneman and Tversky (1979) proposed prospect theory, whereby prospects are coded in terms of gains and losses with respect to a reference point rather than in terms of final wealth. They found for gambling behavior that people's decisions tend to be more sensitive to losses than to gains. Generally, utility and prospect are two completely different concepts. Moreover, although it is not readily evident that prospect theory is necessarily sound for daily travel decisions (Timmermans 2010), the curvature of the model may be useful in some travel contexts.

In traditional utility theory, utility is often defined in terms of final wealth. In prospect theory, change of reference can result in the reverse of preferences. Therefore, it is important to define reference point(s) in a more rational and convincing way. Unlike the concept of traditional utility, relative utility argues that utility is only meaningful relative to some reference point(s), and conceptually it allows the existence of multiple reference points in a systematic way. Prospect theory argues that people's decisions tend to be more sensitive to losses than to gains, where gains and losses are defined with respect to a reference point, but it has not been concerned about specifying reference point(s). To overcome the above shortcomings of the relative utility model and prospect theory, Zhang et al. (2013) integrates them to incorporate simultaneously various context dependences as well as asymmetric and nonlinear responses.

#### 2.5.3.4 Group Decision-Making Mechanisms

In transportation research, individuals have traditionally been regarded as decision-making units or as representatives and independent agents. However, it is well known that individual choice behavior is often influenced by the existence, opinions, and/or behavior of other people, and in some cases, choices are made jointly by a group of people (Thorndike 1938; Corfman and Gupta 1993). Many group-based models have been developed in other disciplines, such as social psychology, marketing research and economics, to describe various aspects (e.g., decision processes and outcomes) of group decisions (Corfman and Gupta 1993). However, although joint activity participation, household resource allocation (e.g., car ownership and use), and task and time allocation are all likely to involve group decisions, research on group decision-making mechanisms is still very limited in transportation (Zhang et al. 2009). Studies of modeling such group decisions in transportation based on group decision-making theories have been conducted since the 1990s (e.g., Timmermans et al. 1992). Currently, increasing numbers of researchers have shown interest in group decision-making mechanisms in various contexts of activity–travel behavior and have confirmed the effectiveness of incorporating group decision-making mechanisms in comparison with traditional models (e.g., Zhang et al. 2002; Vovsha et al. 2003;

Hensher 2004; Bhat and Pendyala 2005; Gliebe and Koppelman 2005; Zhang and Fujiwara 2006b; 2009). In particular, Zhang et al. (2009) have developed a household discrete choice behavior model incorporating heterogeneous group decision-making mechanisms in the context of car ownership behavior. Further efforts should be made to reveal more general group decision rules and to suggest effective survey methods to capture group decision-making processes.

## 2.6 Methodological Challenges

### *2.6.1 A Systematic Framework for Urban Environmental Management*

To realize a sustainable urban and transportation society, policy makers and other stakeholders are required to make various efforts based on better governance. Such governance should be supported by systematic and scientific approaches, which can generate informative indicators for policy evaluation, decision making, implementation, monitoring, and so on. Segnestam (2002) summarizes the most important lessons learned from the existing studies and suggests that the following aspects are important when developing a set of indicators: (1) development and harmonization of a framework to organize information; (2) definition of selection criteria, indicator sets, and analytical methods/tools; (3) establishment of a participatory/consultative network; (4) data search and development of databases for indicator sets and analytical tools; (5) development of capacities and tools to visualize information and analyze cause–effect relationships; (6) development of test studies for the validation of project results; (7) dissemination of information and tools; and (8) design of actions and implementation. In line with such considerations, a promising indicator framework is the drivers–pressure–state–impacts–response (DPSIR) framework proposed by the OECD (OECD 1999; VRDC 2001). In this framework, social and economic developments exert pressure (P) on the environment, and as a consequence, the state (S) of the environment changes, as in the provision of adequate conditions for health, resource availability, and biodiversity. Finally, this leads to impacts (I) on human health, ecosystems, and materials that may elicit a societal response (R), which directly feeds back to the driving forces (D), or on the state (S), or impacts (I) through adaptation or curative action. The DPSIR framework is useful in describing the relationships between the origins and consequences of environmental problems.

Recognizing the importance of capacity building in environmental management, Zhang and Fujiwara (2007) further introduced the concept of capacity into the DPSIR framework (called the DPSIR+C). Figure 2.4 shows the manner in which the DPSIR+C framework can be applied in the context of urban air quality management. In the figure, the arrows with solid lines indicate how the capacity influences the D–P–S–I–R elements, while the arrows with dotted lines indicate how the

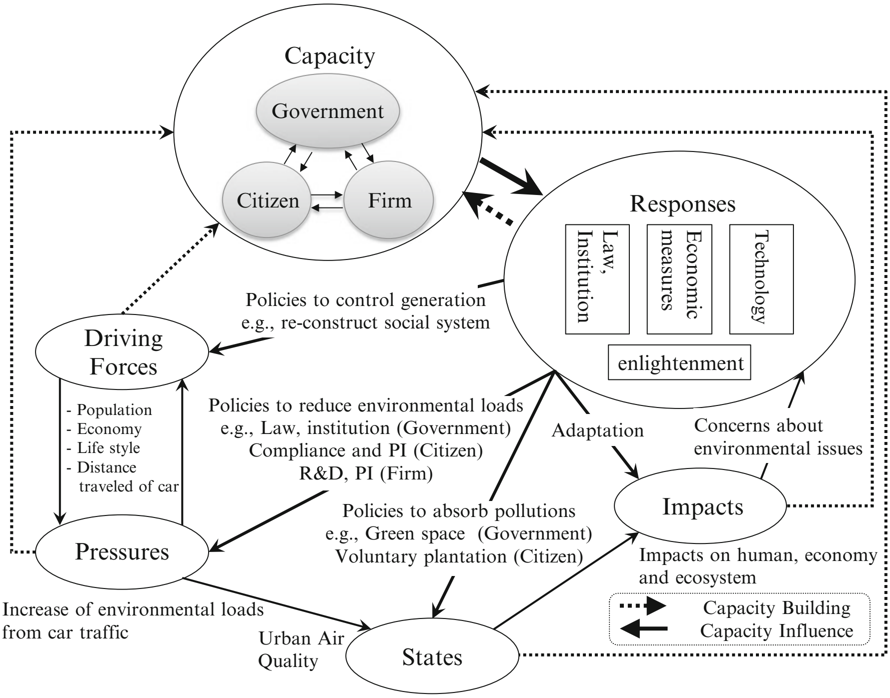


**Fig. 2.4** DPSIR+C framework: An example of urban air quality management

capacity should be built, taking into consideration the cause–effect relationships among the D–P–S–I–R elements. It is argued that capacity is the basis of good responses to the D–P–S–I elements. Without such capacity, it is difficult to expect good responses. One can see a two-way relationship between capacity and responses. The arrow from responses to capacity means that lessons/experiences at previous points in time help each actor improve its capacity. The D–P–S–I elements could also contribute to capacity building but in a different manner. For example, in the case of urban air quality management, population and economic growth, lifestyle, and distance traveled may be major driving forces that exert pressure on the environment through the increase of environmental loads from car traffic. Such pressures could inversely influence the driving forces in a positive or negative way. Negative influence refers to the situation whereby an uncontrolled or poorly controlled increase in environmental loads could induce people to travel for longer periods, while positive influence indicates that, for example, a proportion of the population might voluntarily reduce distances traveled in response to an increase in environmental loads. States can be represented by the urban air quality term, which results from the influence of pressure. Impact has been defined in various ways. However, we argue that the extreme impacts of environmental issues are on people (e.g., health and QOL) and natural systems (or ecosystems, e.g., biodiversity). Impacts on human society and natural systems may give rise to concerns over environmental issues. Such concerns lead to a response, such as policy decisions about the enforcement of laws and institutions, economic measures (e.g., road pricing), support and promotion of technological innovation, and enlightenment. Responses could occur to tackle any of the D–P–S–I elements. In the case of driving forces, reconstructing our social system on the basis of an environmentally friendly lifestyle could effectively control traffic generation. Policies to reduce environmental loads include the enforcement of laws and institutions by government, compliance and public involvement by citizens and firms, and technological development by firms. On the other hand, for example, increasing areas for green spaces and voluntary plantation could contribute to the absorption of air pollution. All responses rely heavily on social capacity.

### *2.6.2 An Integrated Framework for Urban System Design*

Urban systems are complex. Dealing with complex systems needs interdisciplinary knowledge. In the above DPSIR+C framework, socioeconomic development models should first be built to provide information on driving forces (D) of urban and transportation activities, which are represented by land-use models and transportation models. Because land-use and transportation systems are usually interrelated, the two models should be integrated. Land use dictates the locations of activities and their intensity; this affects transportation demand and supply, which in turn affects accessibility. As a result, land-use distribution is affected by accessibility and evolves according to changes in accessibility. Various pollutants are emitted as outputs of land-use and transportation systems, which impose pressure (P) on urban systems. Environmental emission models can serve to capture such emissions. Land-use models and transportation models not only can represent various interactions between land-use and transportation systems but also can accommodate various urban policy variables (responses: R). Emissions from urban and transportation activities will be spread over the whole urban space. To capture such dispersion of emissions, air pollution dispersion models are useful. Using such models, states (S) of air quality can be properly described. Land-use changes and emissions from urban and transportation activities can cause damage (i.e., impacts (I)) to ecosystems. Such impacts can be illustrated using ecosystem models. Ideally, all the above models should be integrated (i.e., form integrated urban models) to provide various inputs for environmental impact assessment models in a consistent and systematic way. Environmental impact assessment models should be developed to generate indicators of air quality, QOL and ecosystems, where social capacity for urban system management should also be reflected. The above modeling components are illustrated in Fig. 2.5.

In making policy decisions on low-carbon cities, enforcement of laws and institutional rules, economic measures (e.g., pricing), technological innovations (e.g., new energy and new technology), and enlightenment (e.g., encouraging voluntary behavioral change) should be in the list of alternative policies together with measures for improving the social capacity of urban system management. Technological

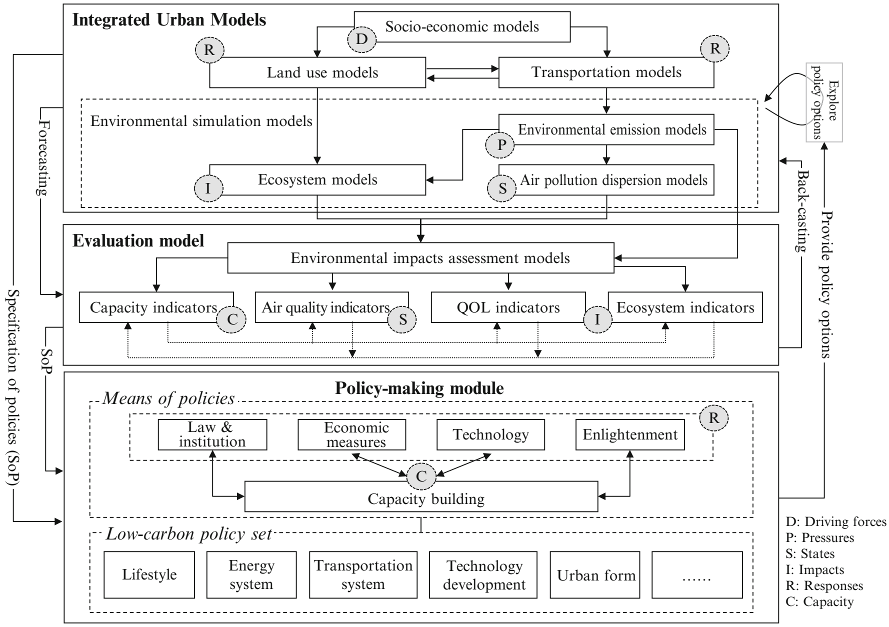


**Fig. 2.5** A conceptual integrated framework for urban system design

innovations should take into account the diversity of potential technologies to enhance the survival capability of human society. Rebound effects of new technologies cannot be ignored. Both pull-type and push-type policies should be properly implemented jointly to enhance the effectiveness of policies. At the same time, it should be recognized that there is no one-size-fits-all policy across nations/cities and over time. Local contexts should be reflected. For detailed low-carbon urban policies, urban form, technology development, transportation systems, energy, and lifestyle should be in the choice set.

The key point is to represent changes in both urban systems and the citizens' behaviors, considering people's QOL, environmental capacity and social equity. Both backcasting (top-down) and forecasting (bottom-up) methods will be utilized to derive cost-effective paths that could achieve the desired low-carbon state of an urban system, taking into account the importance of interactive planning and policy making.

### *2.6.3 Behavioral Studies: From Independent to Integrative Behavior Studies*

On average, 60 % of the world's GDP is accounted for by consumer spending on goods and services (UNEP 2009), and 20 % of the world's people—in the US, Europe, Japan and Australia—account for 86 % of the total world expenditure on consumption (UNEP 2002). Households are responsible for approximately 15 % to 20 % of total energy demands in OECD countries (OECD 2001). It is predicted that global energy consumption is set to surge by 44 % between 2006 and 2030, with non-OECD countries seeing a 73 % increase (US-EIA 2009). It is also estimated that five planets would be needed for everyone in the world to adopt the consumption patterns and lifestyles of the average citizen in North America (WWF Living Planet Report 2006). The above facts suggest that encouraging behavioral changes from unsustainable to sustainable lifestyles is important. This is also true in the context of urban and transportation development. In the Eco-Model City Project of Japan (http://ecomodelproject.go.jp/en/doc/D7), 82 cities participated in a contest, in which 80 % of participants claimed that lifestyle change was required to realize low-carbon cities.

To reduce emissions from citizens' urban activities, behavioral changes in various life domains are required, including residences, in-home activities, travel, and out-of-home activities, all of which are supported by various forms of urban infrastructure (e.g., transportation systems, offices, stores, schools, parks, and factories). Various forms of urban infrastructure are managed by governmental sectors. In many countries, the bad effects of the vertically structured administration on citizens' lives have become increasingly remarkable in the field of urban planning and management. To avoid further unease or insecurity about the future lives of citizens, a cross-sectoral approach is required. Civil life, such as work, residence, travel, child care and nursing care, education, shopping, leisure and tourism activities, is usually decided over either long- or short-term periods in various contexts with the consideration of the needs of households and their members and performed at various places under the influence of social networks and time and monetary constraints. To date, several theories have been developed to deal with parts of civil life, such as travel behavior theory, home economics, environmental behavior theory, health behavior theory, human life environment theory, and tourism behavior theory. However, no theory has been proposed to cover the whole life of a citizen in an integrative way. Therefore, it is necessary to establish an innovative theory that can cover major domains of citizens' lives to support cross-sectoral urban planning and management policies (Zhang et al. 2012). For this purpose, further interdisciplinary studies are needed.

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