Social Capacity Indicators for Environmental Management: a Case Study in Transport Sector Using Macro-Level Data

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Abstract

This paper first defines *social capacity of environmental management (SCEM)* as the capacity that the whole society, composed of three social actors: government, firms and civil society, makes use of available capital assets (including natural capital, physical capital, financial capital, human capital, and social capital) to deal with environmental problems toward sustainable states through the learning process under the influence of actors' co-existence, inter-actor interactions and future uncertainty. Then, a structural equation model is applied to estimate the *SCEM* at city level in transport sector. *Millennium Cities Database* is adopted to measure environmental sustainability. Since it is difficult to collect capacity-related data at city level, and it is also expected that capacity at nation level might influence that at city level, the capacity-related data at nation level contained in *Environmental Sustainability Index* is used to measure the influence of *SCEM* on the environmental sustainability. The effectiveness of the proposed model structure was empirically confirmed and the relationship between *SCEM* and environmental emissions was clarified. Some limitations of applying such macro-level data were also observed.

Key Words: indicator, social capacity for environmental management, structural equation model

1. Introduction

To realize globally sustainable society, both developed and developing countries need to make considerable efforts. Developing countries have to balance economic growth and environmental considerations even though they are not major contributors to environmental emissions. On the other hand, it is expected that developed countries should play more and more important roles in helping these developing countries to get over various difficulties during the process of economic growth. The experiences from developed countries could provide informative guidelines to the development in developing countries. In other words, knowledge and technology transfers should be further promoted from the perspective of efficient and effective use of existing resources.

Under such circumstances, social capacity for environmental management (SCEM) was proposed as a new concept and policy tool for capacity development in environment (Matsuoka *et al*, 2004). Capacity has been received considerable attentions from and widely used at various disciplines, such as natural resource management, public administration, health sciences, and development for at least three decades. Capacity has been approached from a variety of perspectives (e.g., economic growth, organizational survival, service provision) and at many different scales (e.g., organization, local, and regional, national) (Ivey *et al*, 2004). SCEM is defined as the capacity to manage environmental problems in a social system composed of three social actors: government, firms and citizens, and their interrelationships. It is expected that such definition of social capacity will be helpful to effective environment management. However, careful reviews about the existing research suggest that this definition is not sufficient (Zhang *et al*, 2005). This is briefly summarized as follows:

1) Capacity is a relative concept. As a result, it is meaningful only relative to some reference point(s) or benchmark(s). To define the capacity, selection of temporal and spatial reference point(s) becomes important.
2) To provide policy makers with informative advices/recommendations, capacity should be goal-oriented. In other words, the capacity should be defined, incorporating the relationship between capacity indicators and environmental emissions.
3) The interrelationships among actors are not stable over time. Accordingly, the definition of capacity should reflect such dynamic characteristics. On the other hand, the concept of citizens is too narrow. Civil society should be used because of its generality and extensiveness. Citizens are only a part of civil society.
4) Capacity should be defined from the holistic perspective. Otherwise, it could not be used to properly measure the genuine effects of policies.
5) There exist some sub-actors (e.g., the media and scientists) shared by government, firm and civil society. This has not been made clear in the previous definition of SCEM.

SCEM seems similar to the concept of social capital, which has been a key concept in sociology. As described by Pretty and Ward (2001), social capital captures the ideas that captures the idea that social bonds and social norms are an important part of the basis for sustainable livelihoods. Its value was identified by Jacobs (1961) and Bourdieu (1986), later given a clear theoretical framework by Coleman (1988, 1990), and brought to wide attention by Putnam (1993, 1995). Bubolz (2001) argues that social capital is nothing but a resource (i.e., matter, energy, or information converted into specific forms for attaining goals) embedded in relationships among people upon which they can draw to provide information or other resources or to facilitate activity of social or personal benefit. Social capital is one part of capital asset, which also includes human capital, financial capital, physical (or human-made) capital and natural capital (Bubola, 2001; Rudd, 2004). In this sense, SCEM is different from the concept of social capital. Based on the above-mentioned discussion and the extensive reviews by Zhang *et al* (2005), we can redefine the SCEM as follows, which is conceptually described in Figure 1.

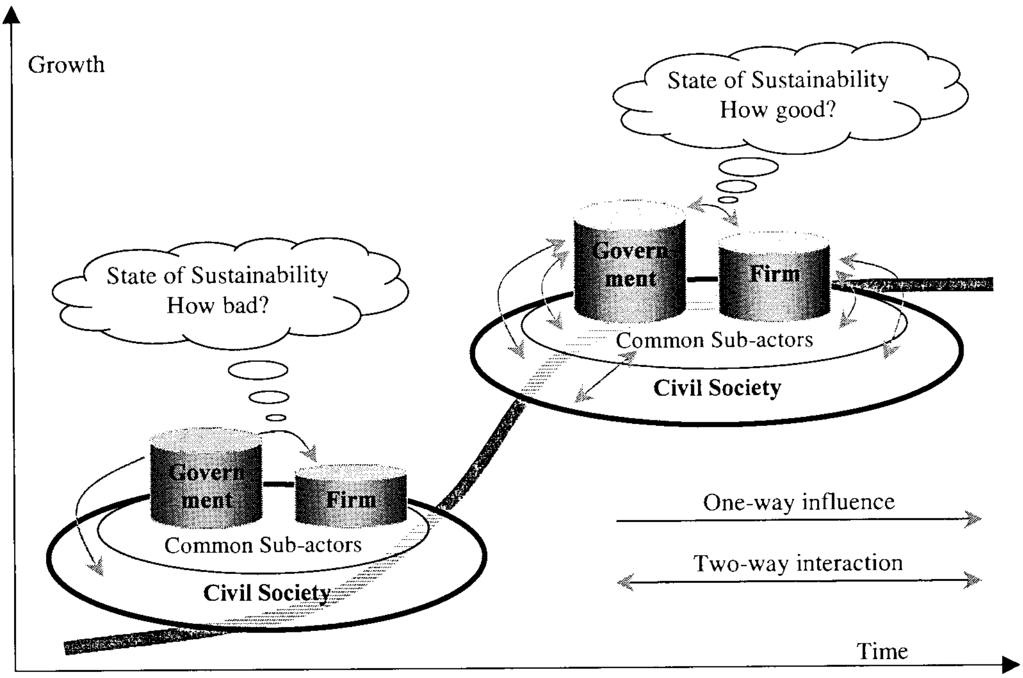

Figure 1. Conceptual description of social capacity.

> SCEM refers to the capacity that *the whole society*, composed of three social actors: *government, firms and civil society*, makes use of *available capital assets* (including *natural* capital, *physical* capital, *financial* capital, *human* capital, and *social* capital) to deal with environmental problems *toward sustainable states* through the *learning process* under the influence of *actors' co-existence, inter-actor interactions* and *future uncertainty*.

To help effective environmental management, it is required to develop the appropriate indicators for such social capacity. Indicators have been used for a long time as a tool with which more information can be obtained about issues as varied as people's health, weather, and economic welfare (Segnestam, 2002). Indicators provide information on matters of wider significance than what is actually measured or make perceptible a trend or phenomenon that is not immediately detectable (Hammond *et al*, 1995). However, compared to indicators of economic and social aspects, environmental and sustainable development indicators are a relatively new phenomenon. The Rio Conference on Environment and Development in 1992, and other similar environmental milestone activities and happenings, recognized the need for better and more knowledge and information about environmental conditions, trends, and impacts. Since then, a lot of work has been done on environmental indicators both at national and international level in recent years (Niemeijer, 2002). The geographic focus of the existing indicators varies from regional (e.g., Jones *et al*, 1998) to national (e.g., The Heinz Center, 1999) to multi-national (e.g., World Economic Forum, 2001) and the topical focus ranges from a particular sector such as transport (e.g., EEA, 2000) or agriculture (e.g., MAFF, 2000) to the environment in its widest sense (e.g., EEA, 2001) and in some cases even beyond the environment by looking at indicators for sustainable development (e.g., IWG-SDI, 2001). Reports further vary in whether they look only at the state of the environment (e.g., NRC, 2000) or also at driving forces, pressures and responses (e.g., OECD, 2001).

Even though there exist various relevant data sources available and accessible at the nation level, however, data at the city level are very limited. In the case of developing countries, collection of data even at the nation level is not an easy task. Of course, quality of the collected data is another issue. Such data availability makes it difficult to measure such social capacity.

This paper reports current research findings about the measurement of such capacity at the city level in the context of urban air quality management.

The rest of this paper is organized as follows. Section 2 briefly introduces the methodology used for the measurement of social capacity. Following that, Section 3 describes that data used in this study. Section 4 discusses the estimation results about social capacity. Finally, Section 5 concludes the study and mentions some future research issues.

2. Measuring Social Capacity Based on a Structural Equation Model

One of the most popular indicator frameworks is the DPSIR (Driving forces, Pressure, State, Impact, Response) framework (see Figure 2) developed by OECD (1999) (also see VRDC, 2001). In this framework, social and economic developments exert pressure on the environment and, as a consequence, the state of the environment changes, such as the provision of adequate conditions for health, resources availability and biodiversity. Finally, this leads to impacts on human health, ecosystems and materials that may elicit a societal response that feed back on the driving forces, or on the state or impacts directly, through adaptation or curative action.

Based on this DPSIR framework, many international organizations have developed various indicators for the purpose of environmental management (Niemeijer, 2002). In order to meet this information needed for environmental management, indicators should reflect all elements of the causal chain that links human activities to their ultimate environmental impacts and the societal responses to these impacts. In this sense, the DPSIR framework is useful in describing the relationships between the origins and consequences of environmental problems. However, this framework is very conceptual and does not tell people how to measure these relationships.

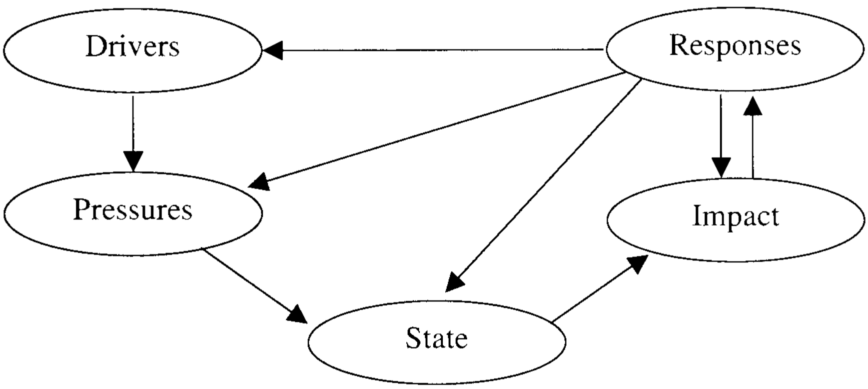

Figure 2. The DPSIR framework for reporting on environmental issues (Source: OECD, 1999; VRDC, 2001)

This paper proposes to apply a structural equation modeling approach to capture the above-mentioned complex cause-effect relationships existing in the measurement of social capacity. Structural equation model is a set of simultaneous equations and has been proven useful in solving many substantive research problems in social and behavioral sciences. Such models have been used in the study of macro-economic policy formation, intergenerational occupational mobility, racial discrimination in employment, housing and earnings, studies of antecedents and consequences of drug use, scholastic achievement, evaluation of social action programs, voting behavior, studies of genetic and cultural effects, factors in cognitive test performance, consumer behavior, and many other phenomena including transportation. Methodologically, the models play many roles, including simultaneous equation systems, linear causal analysis, path analysis, structural equation models, dependence analysis, and cross-legged panel correlation technique (Jöreskog and Sörbom, 1989). Structural equation model is used to specify the phenomenon under study in terms of putative cause-effect variables and their indicators. Following the descriptions by Jöreskog and Sörbom (1989), the full model structure can be summarized by the following three equations.

Structural Equation Model:

$$\eta = B\eta + \Gamma\xi + \zeta \quad (1)$$

Measurement Model for y:

$$y = \Lambda_y \eta + \varepsilon \quad (2)$$

Measurement Model for x:

$$x = \Lambda_x \xi + \delta \quad (3)$$

Here, $\eta' = (\eta_1, \eta_2, ..., \eta_m)$ and $\xi' = (\xi_1, \xi_2, ..., \xi_m)$ are latent dependent and independent variables, respectively. Vectors η and ξ are not observed, but instead $y' = (y_1, y_2, ..., y_p)$ and $x' = (x_1, x_2, ..., x_q)$ are observed dependent and independent variables. ζ , ε , δ are the vectors of error terms, and B , Γ , Λ_x, Λ_y are the unknown parameters.

In this paper, we propose using the latent variables to measure social capacity. Fujiwara *et al* (2004a, 2004b and 2005) already confirmed the validity of such structural equation model in evaluating sustainability of urban development using a repeated cross-sectional data with four time points, which were collected from 46 developed and developing cities by Kenworthy *et al* (2000). However, they did not incorporate the social capacity into the models.

3. Data

As mentioned above, capacity-related data is very limited at the city level. To collect such data in developing cities is also a time-consuming task. On the other hand, there exist some data available at the nation level. Considering such data availability, it becomes necessary to combine these two types of data in order to derive some operational social capacity indicators.

We first suggest using the data collected at the city level to measure the environmental sustainability in the context of urban air quality management. In this study, we adopt the “Millennium Cities Database” (Vivier, 2001), which was compiled by UITP, in collaboration with Professors Jeff Kenworthy and Felix Laube at Murdoch University. The database includes the data covering 100 cities worldwide (see Table 1). The data collected concerns demographics, economics and urban structure, the car population, taxis, the road network, parking, public transport networks (supply, use and cost), the mobility of individuals, the choice of transport mode and transport system efficiency and its environmental impact (travel times and costs, energy consumption, pollution, accidents, etc.). In total, 66 raw

Table 1. Cities in “Millennium Cities Database”.

Western European Cities (35)	Northern American Cities (15)
Austria: Graz, Vienna Belgium: Brussels Denmark: Copenhagen Finland: Helsinki France: Lille, Lyon, Marseille, Nantes, Paris Germany: Berlin, Frankfurt, Hamburg, Dusseldorf, Munich, Ruhr, Stuttgart Greece: Athens Italy: Milan, Bologna, Rome, Turin The Netherlands: Amsterdam Norway: Oslo Portugal: Lisbon Spain: Barcelona, Madrid Sweden: Stockholm Switzerland: Bern, Geneva, Zurich England: Glasgow, London, Manchester, Newcastle	Canada: Calgary, Montreal, Ottawa, Toronto, Vancouver United States: Atlanta, Chicago, Denver, Houston, Los Angeles, New York, Phoenix, San Diego, San Francisco, Washington **Latin American Cities (10)** Argentina: Buenos Aires Brazil: Brasilia, Curitiba, Rio de Janeiro, Salvador, Sao Paulo Chili: Santiago Colombia: Bogota Mexico: Mexico City Venezuela: Caracas
Eastern European Cities (6)	African Cities (8)
Czech Republic: Prague Hungary: Budapest Portland: Krakow, Warsaw Russia: Moscow Turkey: Istanbul	Egypt: Cairo Ivory coast: Abijan Morocco: Casablanca Senegal: Dakar South Africa: Cape Town, Johannesburg Tunisia: Tunis Zimbabwe: Harare
Asian Cities (18)	Oceania Cities (5)
India: Mumbai, Chennai, Delhi Indonesia: Jakarta Thailand: Bangkok Philippine: Manila Vietnam: Ho Chi Minh City Malaysia: Kuala Lumpur Singapore: Singapore Japan: Osaka, Sapporo, Tokyo China: Beijing, Hong Kong, Shanghai, Guangzhou Korea: Seoul Taipei: Taipei	Australia: Brisbane, Melbourne, Perth, Sydney New Zealand: Wellington **Middle East Cities (3)** Israel: Tel Aviv Iran: Tehran Saudi Arabia: Riyadh

Source: Vivier (2001)

Table 2. Indicators used for measuring social capacity.

Indicators by actor		Unit	Mean	Min	Max
Indicators for civil society					
Average life expectancy index	(C1)	[0, 1]	0.82	0.30	0.99
Education level index	(C2)	[0, 1]	0.90	0.37	0.99
Indicators for government					
IUCN member organizations	(G1)	Organizations per million population	0.42	0.01	7.85
Global environmental facility participation	(G2)	Standardized scale (Z score)	-0.05	-0.17	6.01
Compliance with environmental agreements	(G3)	Survey responses: 1 (strongly disagree) to 7 (strongly agree)	4.40	3	6.70
Number of memberships in environmental intergovernmental organizations	(G4)	Number of memberships	12	2	35
Indicators for firm					
Expenditure for R&D as a percentage of GNP	(F1)	%	0.64	0.01	3.76
R&D scientists and engineers	(F2)	Persons per million population	663.5	3	4909
ISO 14001 certified companies	(F3)	Companies per million dollars GDP	0.05	0.03	30.8
Levels of environmental competitiveness	(F4)	Survey responses: 1 (strongly disagree) to 7 (strongly agree)	4.35	3.20	5.90

Source: World Economic Forum (2001)

indicators (175 basic raw indicators) have been investigated. Due to the existence of missing data, the following cities were excluded from the analysis in this study: Abijan, Buenos Aires, Brasilia, Caracas, Casablanca, Delhi, Istanbul, Lisbon, Moscow, Salvador, Turin, and Warsaw. As a result, 88 cities were selected.

On the other hand, since it is difficult to collect capacity-related data at the city level, and it is also expected that capacity at the nation level might influence the one at the city level, we further suggest using the capacity-related data at the nation level contained in “Environmental Sustainability Index” (World Economic Forum, 2001) to measure the influence of social capacity on environmental sustainability at the city level. Table 2 shows the selected indicators used for measuring the capacity. Figure 3 shows the distributions of each transformed indicator (D_{ij}) by nation, which is defined in equation (4).

$$D_{ij} = \frac{d_{ij}}{max\{d_{ij} | j=1,...,J\}} \qquad (4)$$

where, D_{ij} indicates the transformed indicator of actor i at nation j, and d_{ij} refers to the indicator shown in Table 2, i.e., C1~C2, G1~G4, F1~F4.

Since the transformed indicator D_{ij} is defined relative to the frontier (i.e., maximum value among all the target nations), it is possible to directly compare the capacity of each nation by individual indicator.

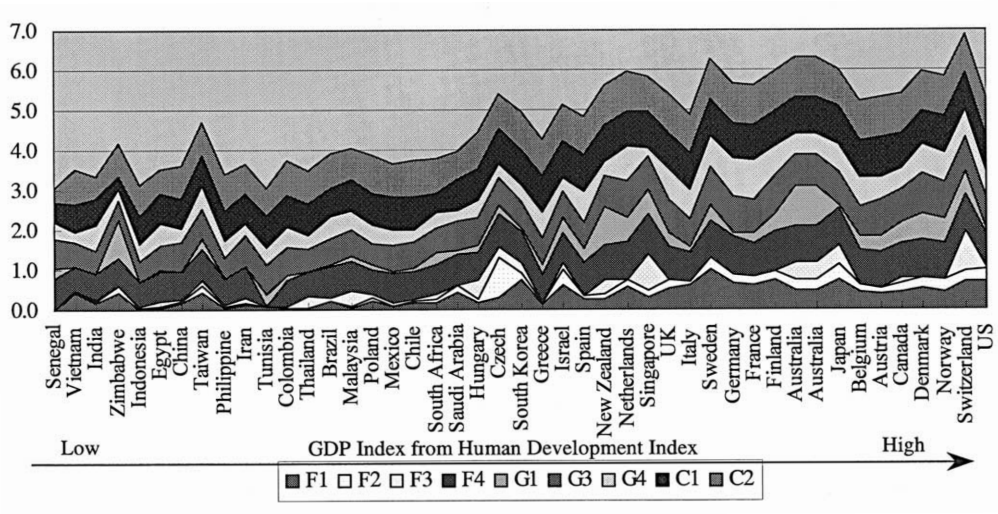

Figure 3. Capacity indicators for the target nations.

It is obvious that each indicator shows large variation, suggesting the importance of incorporating such heterogeneity across countries/regions when measuring the capacity. However, for some indicators, the difference between the developed and developing countries is not so large than expected.

From Figure 3, one can compare the capacities of different nations by each individual indicator. However, it is expected that all or some of indicators, rather than a single indicator, determine the capacity of a nation. In such case, in order to define the capacity based on multiple indicators, it becomes important how to weigh different indicators. Most of existing approaches determine these weights exogenously. For example, in the case of famous index HDI, it assumes that life expectancy index, education level index and GDP index have the same weight, i.e. 1/3. We argue that such weights should be determined based on the interrelationships between the capacity indicators and policy goals (e.g., reducing environmental emissions). The structural equation modeling approach introduced in Section 2 will be helpful because it can estimate the weights endogenously. We will examine the influence of such variation patterns, shown in Figure 3, on the capacity for each actor, at next section.

4. Model Estimation and Evaluation of Social Capacity

To establish social capacity evaluation model in the context of urban air quality management, we introduce seven latent variables: “capacities of civil society, firm and government”, and “land use”, “transport supply”, “transport demand” and “environmental emissions”. Since it is known that there exists convex relationship between economic activity and environmental emissions (i.e., Environmental Kuznets Curve), we adopt the root of each observed environmental emission variable (i.e., NOx, SO_2, CO and VHC in this study) before the estimation. Model parameters are estimated based on maximum likelihood method. We show the estimation results in Figure 4. It is obvious that values of GFI and AGFI (model accuracy indices) are relatively high, and most of the estimated parameters are statistically significant and also have the expected signs. These estimation results suggest the validity of established model.

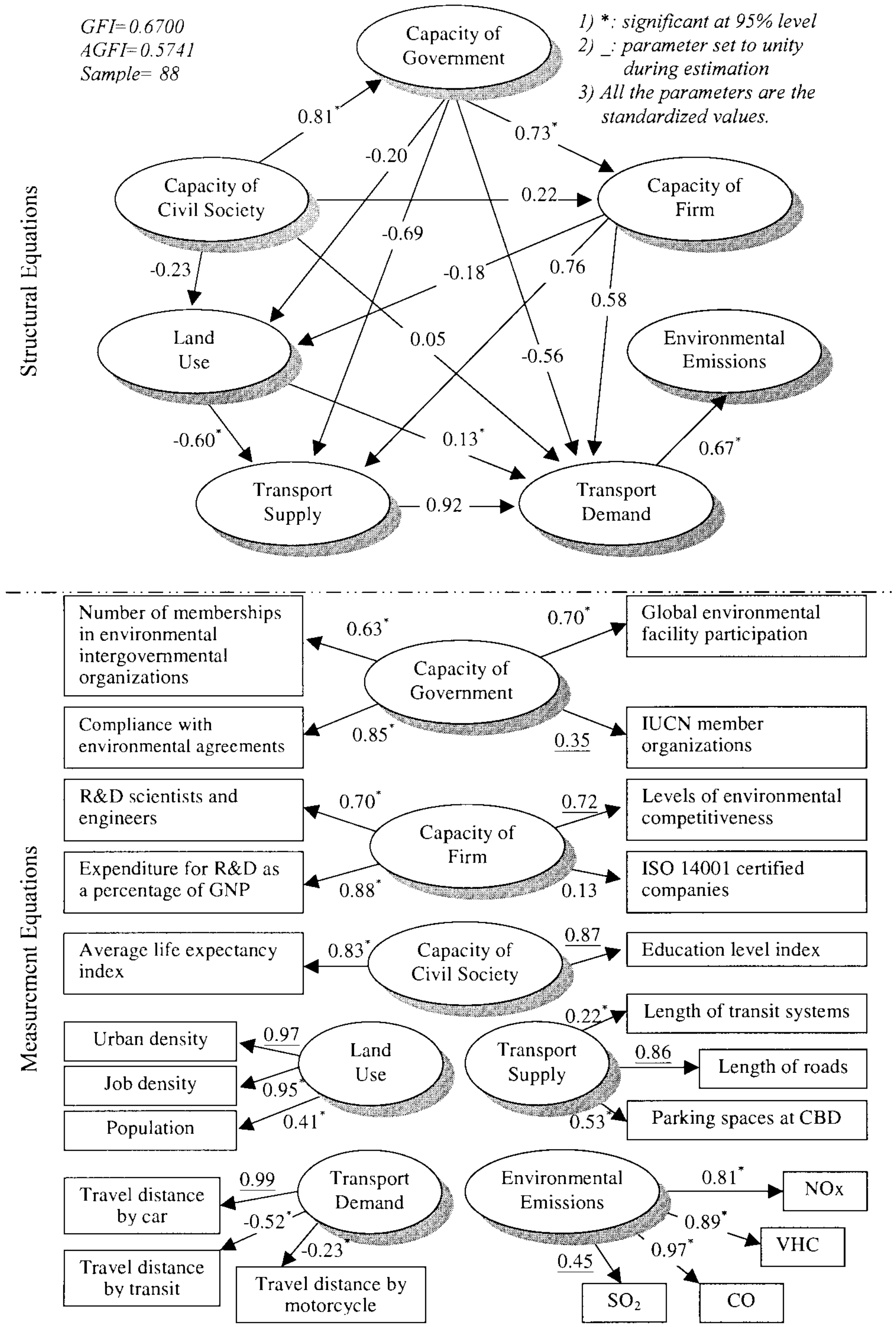

Figure 4. Estimation results of social capacity evaluation model.

4.1. Interactions among actors

We found that "capacity of civil society" affects "capacity of government" and "capacity of government" influences "capacity of firm". However, "capacity of civil society" does not contribute to the development of "capacity of firm" from the statistical viewpoint. Up to now, many international organizations have developed various indicators, however, little has quantitatively discussed about such interactions.

On the other hand, it is expected that such interactions might differ according to development stages for each nation. We have not confirmed this point due to the data limitation, but this should be one of important future research tasks.

4.2. Evaluation of social capacity

To measure each actor's capacity, we first calculate the value of each latent capacity variable. Since the data used for the calculation are not the same, the calculated values of latent variables have different scales. To make the comparisons of actors' capacities possible, we define the capacity indicator for each actor as follows:

$$C_{ij} = \frac{\eta_{ij}}{max\{\eta_{ij} | j=1,...,J\}} \quad (5)$$

where, C_{ij} indicates capacity indicator of actor i at city j, and η_{ij} refers to the value of latent capacity variable directly calculated from the structural equation model.

In other words, we use the frontier (i.e., maximum value) of each latent capacity variable as a reference point. The smaller the difference between the frontier ($max\{\eta_{ij} | j = 1,...,J\}$) and the variable η_{ij} is, the higher the capacity of actor i at city j is. We show capacity indicator C_{ij} with respect to each actor in Figure 5. One can observe that on average, the developed cities show higher values of capacity indicators than the developing cities. Such intuitive results suggest that using the data at the nation level could be used to measure each actor's capacity. In most cities, capacity of civil society and government is higher than the one of firm. Another feature is that capacities of civil society and government are closer to the frontier than the capacity of firm. One of interesting findings is that a large percentage of developed countries have the similar capacities of firms to some of developing countries. This finding is very

Table 3. Social capacity by regions.

Region	Capacity of Civil Society	Capacity of Firm	Capacity of Government
Africa	0.6232	0.3548	0.5904
Developing Asian Region	0.7501	0.4172	0.6017
Middle East	0.8014	0.4880	0.6443
Latin America	0.8074	0.4293	0.6473
Eastern Europe	0.8678	0.5945	0.7291
Wealthy Asian Region	0.8800	0.6825	0.7524
North America	0.9335	0.5588	0.8270
Western Europe	0.9389	0.5586	0.8890
Oceania Region	0.9508	0.7126	0.9642

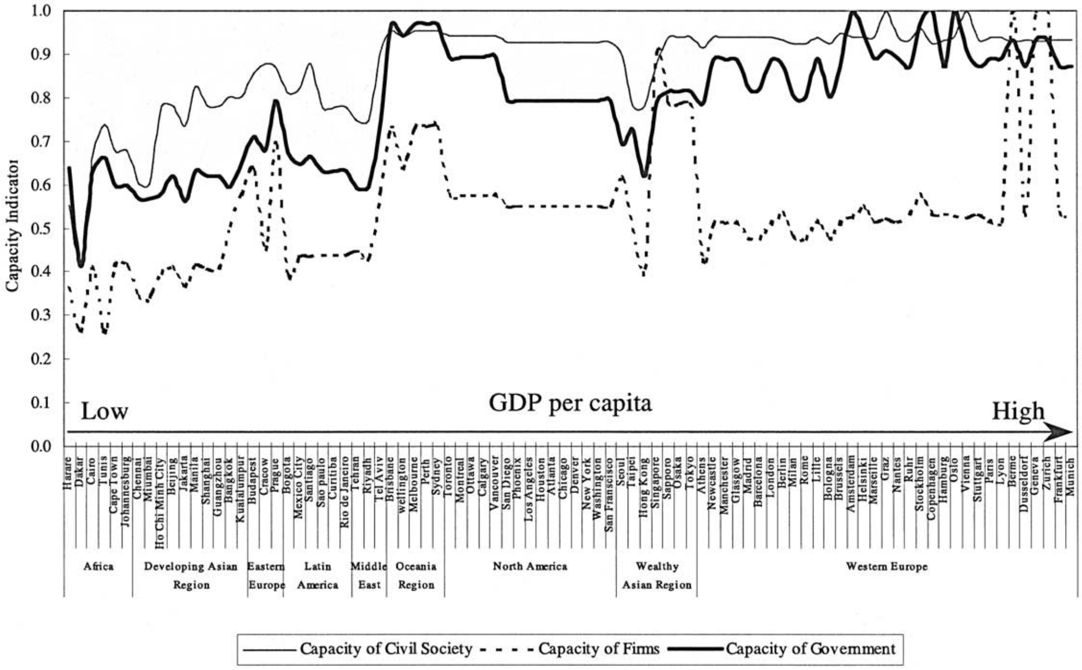

Figure 5. Distribution of capacity indicator for each actor.

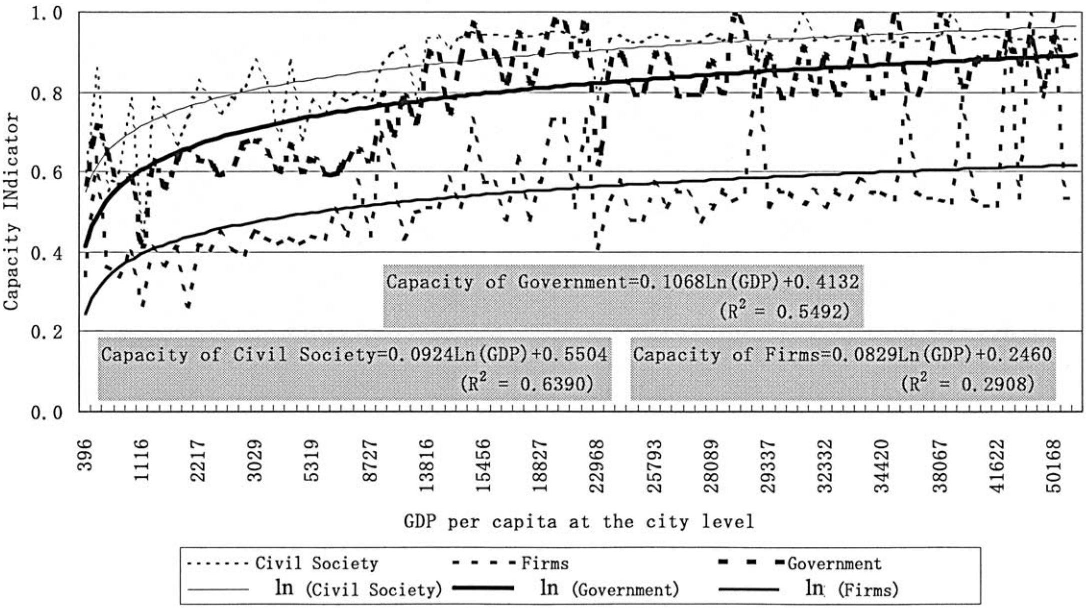

Figure 6. Relationship between capacity indicator and development stage.

surprising, but supports the observations from Figure 3.

We also calculate the average values of capacity indicators for all the targeted regions (in total, 9) (see Table 3). Among these regions, the Oceania region shows the highest capacity for each actor, and the African region has the lowest value. The developing Asian regions come to the second lowest place.

To confirm how capacity indicators differ according to development stages, we estimated a regression model (see Figure 6) for each actor, where dependent variable is capacity indicator and independent variable is GDP per capita at the city level. GDP is usually used as a proxy variable to represent development stage. As a result, we found there exist some relationship between capacity and GDP for civil society and government, but for the firm, the relationship is very weak. This might suggest that we need to select some other data to represent the development stage, either a single indicator or a composite index. This needs to be further explored in the future.

4.3. Influence of social capacity on environmental emissions

To analyze the influence of social capacity on environmental emission at the city level, we show the standardized total effects calculated from the structural equation model in Table 4. The most influential factor on environmental emissions is "capacity of firm" and "capacity of government" has the lowest influence. This implies that at current stage, government has been played a very limited role in controlling environmental emissions. For other factors, "travel demand", "travel supply", "capacity of civil society" and "land use" show the large influences in order. This also suggests the importance of transportation demand management policies.

We also found that government capacity has a negative effect on environmental emissions. However, the capacities for civil society and firm have positive total effects. In other words, enhancing the capacity of government could contribute to the reduction of environmental load, but the capacities for civil society and firm are not the case. This seems not intuitive. At the same time, this reflects the difficulty in

Table 4. Standardized total effects obtained from structural equation model.

Standardized Total Effects	Capacity Of Civil Society	Capacity of Government	Capacity of Firm	Land Use	Transport Supply	Transport Demand	Environmental Emissions
Capacity of Government	0.8090						
Capacity of Firm	0.8130	0.7280					
Land Use	-0.5310	-0.3290	-0.1750				
Transport Supply	0.6390	0.0660	0.8640	-0.6030			
Transport Demand	0.5790	-0.1270	1.3450	-0.4180	0.9150		
Environmental Emissions	0.3900	-0.0850	0.9050	-0.2820	0.6160	0.6730	
NOx	0.3170	-0.0690	0.7360	-0.2290	0.5010	0.5470	0.8130
VHC	0.3470	-0.0760	0.8070	-0.2510	0.5490	0.6000	0.8910
SO_2	0.1740	-0.0380	0.4040	-0.1260	0.2750	0.3000	0.4460
CO	0.3790	-0.0830	0.8800	-0.2740	0.5980	0.6540	0.9710

measuring social capacity using macro-level (aggregate) data. It might be due to another reason, i.e., the macro-level data seldom include the data related to the quality of environmental management. To overcome this shortcoming, one needs to collect some data via questionnaire survey, which aims at investigating the quality of environmental management. Zhang *et al* (2004) made the first attempt from such point of view.

5. Conclusions and Future Research Issues

We developed and empirically confirmed the effectiveness of an operational model for evaluating social capacity in the context of urban air quality management, considering the data availability in developing countries. We clarified the relationship between social capacity development and environmental emissions. There is no doubt that macro-level data could be used to measure social capacity to some extent, however, we also confirmed the limitations of such data. One of the most serious disadvantages is that the macro-level data usually do not contain the information about the quality of environmental management.

For future research issues, we first emphasize the importance of developing some process model for social capacity development because environmental management system is a temporally changing system and consequently such temporal dynamics bring about the differing interaction structure for all the actors, reflecting the influence of development stages. In line with such research stream, for example, Fujiwara *et al* (2005) developed a simplified dynamic structural equation model in order to capture complex cause-effect relationships existing in the measurement of sustainability over time, considering data availability in developing countries. Dynamic evaluation is realized by introducing the concept of state dependence, which refers to the influences of the dependent variables in the past on the ones in the present. Senbil *et al* (2005) also proposed an integrated process model of SCEM, which divides the development process of SCEM into system making, system working and self-management stages. Next, to incorporate the quality issue of environmental management into the measurement of capacity indicators, we need to develop some new survey method to collect the micro-level (disaggregate) data at the city level. Such survey method should properly reflect the genuine casual relationships and the target cities should cover both the developing and developed cities for comparisons. Finally, policy analyses based on the developed indicators are required in the future.

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