

# **A Study on Regional/Local Sustainable Development Indicators**

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## Foreword

The Republic of Korea ranks 122nd in the 2005 ESI (Environmental Sustainability Index) out of 146 countries, published by the World Economic Forum. To be sure, such a result hardly seems to indeed reflect the reality of sustainability in this country, since indicators/indices are merely regarded as an attempt to quantify conditions. However, there is value to try to measure and diagnose, making it possible to find appropriate ways to advance.

Thus SDIs (Sustainable Development Indicators) have received increasing amounts of attention in the last decade since the 1990's. In Korea, national indicators have been studied comprehensively since the early 2000's by this institute and Korean PCSD (Presidential Commission on Sustainable Development). Moreover, SDIs in regional and local levels are strongly needed at this time when regional/local autonomy is settled down sufficiently.

This study thus aims at developing a set of SDIs for regions and localities in Korea as well as understanding how indicators and relevant policy measures affect the goal of sustainable development and our society. This study firstly reviews theoretical and empirical approaches to SDIs including several domestic and foreign cases. A series of prototype SDIs are secondly derived by the case analysis and statistical feasibility. Finally, a system model of SDIs is suggested to encourage viewing the holistic effect of individual indicators or policy measures.

I hope that this study will be an important step toward regional/local sustainable development and the facilitation of their own indicators. I would like to thank the authors, Dr. Hoi-Seong Jeong, Dae Uk Jeon, and Prof. Young Keun Chung for their hard works. I also wish to express my sincere thanks to the reviewers for their helpful comments and suggestions on this study.

Suh Sung Yoon  
President  
Korea Environment Institute

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## Chapter 1. Introduction

It is generally accepted that SDIs comprise all of our concerns related to the following four sectors: our economy, society, institutions and the environment. Economic, social and environmental indicators in the past have been separately developed and applied to measure how far communities progress toward growth or development in each respective area.

*Economic indicators* emerged early in the 1940's. The fascination with single indicators carried over to economics and national development. However, economic indicators such as GNP (Gross National Product) and GDP (Gross Domestic Product) have been recognized as how fast economy grows, rather than develops. As a result, the rate of resource use is squandered and converted into money flow, irrespective of their effect on society.

*Social indicators* followed to compensate for these deficiencies in the 1960's. The concept of balanced growth was emphasized in that time and indicators of social development emerged. It normally deals with human norms, social welfare and quality of life, which are all ambiguous. Thus, a necessity to elaborate the theoretical definition as well as operational measurement developed.

During 1970-80's, pollution and environmental degradation in urban areas came to light due to industrialization and urbanization. Indicators of environmental conditions were consequently considered to address the quality of the urban environment and furthermore, the comprehensive approach to the quality of life. *Environmental indicators* were developed and cascaded into various environmental media, such as air, water, waste and etc.

Since the Brundtland Commission in 1987 and the Rio Summit in 1992 defined sustainable development, indicators have been incorporated into SDIs with the introduction of the concept of environmental carrying capacity. Some of systematic approaches to SDIs, such as the PSR (Pressure-State-Response), DSR (Driving Forces-State-Response), have

## 2 A Study on Regional/Local Sustainable Development Indicators

been suggested and adopted. Other relevant concepts are often presented to capture the impact of and the interactions between our economy, society and the environment.

In Korea, nationwide ESI (Environmental Sustainability Index) or SDIs have been studied comprehensively since 2001 jointly by KEI (Korea Environmental Institute) and the KPCSD (Korean Presidential Commission on Sustainable Development). In the meantime, SDIs for regional and local communities have been rarely examined, except for some cases introduced by city/local governments and the LA21 (Local Agenda 21). Currently, local/regional SDIs are strongly needed, not only because regional/local autonomy and policies have settled down since the mid 1990's, but also because local actions like LA21 have been prosperous.

Therefore, the aim of this study is to develop a set of prototype SDIs (Sustainable Development Indicators) for regions and localities in Korea. This study also aims to help local/regional governments and other organizations like LA21 introduce and facilitate the indicator system. Thus, a comprehensive set of guideline of SDIs will to be presented.

In Chapter 2, recent research related to SDIs is reviewed. Following this theoretical background, empirical case studies on SDIs are performed throughout Chapter 3. This study furthermore suggests, in Chapter 4, for the local executive bodies, a set of guidelines desired during the introduction and operation of SDIs, based on the holistic and systematic models mentioned above. In Chapter 5, this study investigates and suggests a set of prototype SDIs for regions and localities after the following procedures: 1) a comparison/contrast analysis of the cases, 2) a PCA (Principal Component Analysis) method in the statistical factor analysis, and 3) a consultation from field experts regarding LA21 to make indicators more future-oriented.

This study conclusively suggests a system dynamics model of SDIs to help understand the impacts and interactions between economic, social and environmental indicators and find relevant policy instruments using system thinking.

## Chapter 2. Literature Review in SDIs

In this chapter SDI theories are reviewed as summarized in Table 2-1 where indicators/indices are distinguished by their domain and type. As mentioned in the previous chapter, the domains are: the environment /ecology, society/economy and an integration of both. The type refers to whether SDIs are in the form of indicator sets or a single index.

In some recent studies, one interesting point of SDI derivation hinges on a system approach. The key features and discussions of system approaches related to SDIs follow the single indicator/index approaches.

**Table 2-1. The Approaches to SD Indicators/Indices**

	Environmental /Ecological	Social/Economic	Environment Socio-economy Integrated
Families of Indicators	Environmental indicators (air, water, waste, ecology)	Economic indicators (GDP, etc.), Social indicators	Quality of life, DSR, PSR, Sustainable indicators
Single Indices	PP, EF, EmSI, LPI, etc.	Green GDP, Genuine Saving, ISEW, HDI, etc.	ESI and other sustainability indices
Indicators in System & Dynamics	Predator-Prey systems, Environmental models, etc.	Macroecon models (Dynamic CGE, etc.), Industrial dynamics, Urban dynamics	World Dynamics, Sustainable development models, etc.

### 1. Single Indicator/Index Approach

Sustainable development is a policy target that is complex and extensive. It is normally said that sustainable development policies encompass all of our concerns related to economy and society as well as the environment.

Thus, it is easy to find that people try to include appropriate items, as many as possible, to measure their interests or considerations in

sustainable development. At the same time, people desire to shorten long lists of indicators, to select sets of headline indicators or aggregate them for the creation of unique integrated indices, such as the ISEW (Index of Sustainable Economic Welfare), ESI (Environmental Sustainability Index), Genuine Saving, EF (Ecological Footprint), and EmSI (Emergy Sustainability Index).

The latter two, EF (Wackernagel & Rees, 1996) and EmSI (Odum, 1996) and others, Maximum Sustainable Yield (Schaefer, 1954) and Primary Productivity (Tyler & Miller, 1996) could be classified as the *ecology- or environment-oriented approach*. The reason for the categorization is that these indices mainly focus on the concept of environmental carrying capacity, rather than the quality of life.

Social and economic indicators covering quality of life also can be condensed into a single index, such as the ISEW (Daly & Cobb, 1989) and Genuine Saving (Hamilton, 2000), categorized as the *social/economic approach*. ISEW and Genuine Saving are both regarded as attempts to broaden conventional measurements of saving to account for environmental, natural resource and human capital factors.

## 2. Systematic Approach in Impact Analysis

In the meantime, people may think that their efforts to create an index from their headline indicators are not significant, if they understand the relative priority or urgency of each indicator. Their final action must be to question themselves: what policies are necessary? How do policy measures primarily and eventually affect the ultimate goal and other parts of our community? Such questions imply that indicators are not only desired from a policy viewpoint, but that indicators also help to specify policy instruments.

The well known PSR model (OECD, 2002) and/or DSR (UN, 2001) may be one of the answers for the above question. The reason is that the PSR prior to Rio de Janeiro was a new conceptual framework based on *straightforward causalities to the environment*.

The famous ESI (WEF, 2005), based on the PSR system, is an example of

the third category of the previous single index approach, named as the *comprehensive sustainability-oriented approaches*.

The DSR model following the Rio Principles was presented to solve the incompatibility problem of the PSR with the social and economic system by introducing the concept of driving forces.

Both models and their on-going extension forms, however, seem to be sufficient only for the working groups on environmental indicators, who must devote themselves to the primary task of completing their indicator sets. It can be said that such approaches are hardly regarded as a provider of policy measures or instruments necessary for the utilization process of that completed list.

The most serious objection to the PSR/DSR is that they isolate causes and effects, fail to chain them into feedback loops, and neglect the nature of inherent system dynamics.

### **3. Systematic Approach in Dynamic Analysis**

The four *Daly's principles* seem to be easily accepted as a milestone to find policy targets/instruments for sustainable development (Daly, 1991). The four conditions for a sustainable development model can be mentioned in terms of flows: 1) impact to be less than carrying capacity, 2) renewables used to be less than reproduction rate, 3) waste less than natural sink, and 4) non-renewables less than the resource substitution rate.

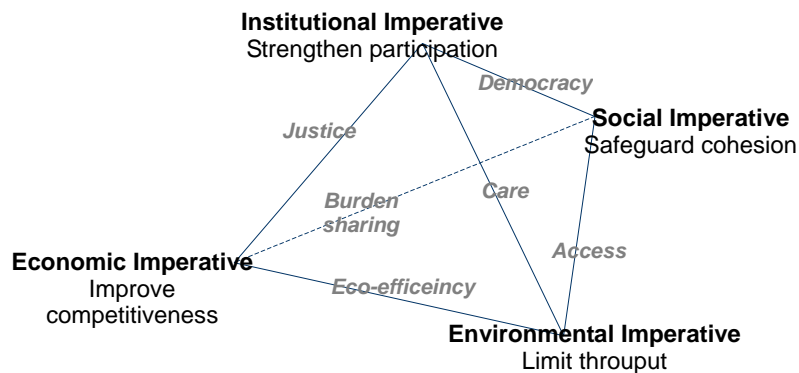
The principles also seem to be helpful, since it reminds one of some important aspects of inherent dynamics and evolution between the environment and our society. With such a dynamic way of thinking, more specifically, a system model simulating such an evolutionary path, one can easily measure the impacts and overall system effects of each policy instrument and understand how to improve the situations individual indicators depict.

The principles, however, overshadow the quality of life that is currently recognized as an irreducible sector in the sustainable development

model. Consequently, some recent studies try to restore the evolutionary and dynamic point of view within indicator models and simultaneously highlight the holistic domain areas of the sustainable development system, including the environment, economy, society, and institution.

The system approach adopting the concept of *System Orientor* by Bossel (1999) is very influential. Ronchi et al. (2002) explain ISSI (Italian Sustainability Index) that is based on headline indicators in three domains (welfare, environmental quality and resource use) using a system modeling approach, while Valentin & Spangenberg (2000) suggest the well-designed system model, *Prism of Sustainability*. As illustrated in Figure 2-1, its vertices represent environmental, economic, social and institutional imperatives each edge that represents the interlinking components between them.

**Figure 2-1. Prism of Sustainability**



Source: Valentin & Spangenberg (2000)

It is unfortunate that almost no further contribution could be made to the implementation of system- and/or dynamic-oriented indicator models following the literature, especially in Korea.

In the following chapter this study therefore tries, after elaborating a set of prototype SDIs, to present a system dynamics model and to make possible an integration those prototype indicators. With the model, policy makers expect to find their appropriate policy instruments with

the system model, which is consistent with the evolutionary dynamics that can assess impacts and find policy measures for a region.

#### **4. Systematic Approach in Developing and Executing SDIs for a region/locality**

In the research community, policy makers possess a general awareness of the interlinkages/causalities between individual indicators and inherent evolutionary dynamics. It led to the formulation of the *Bellagio's Principles* (Hardi, 1997) as guidelines for the practical assessments of progress toward sustainable development.

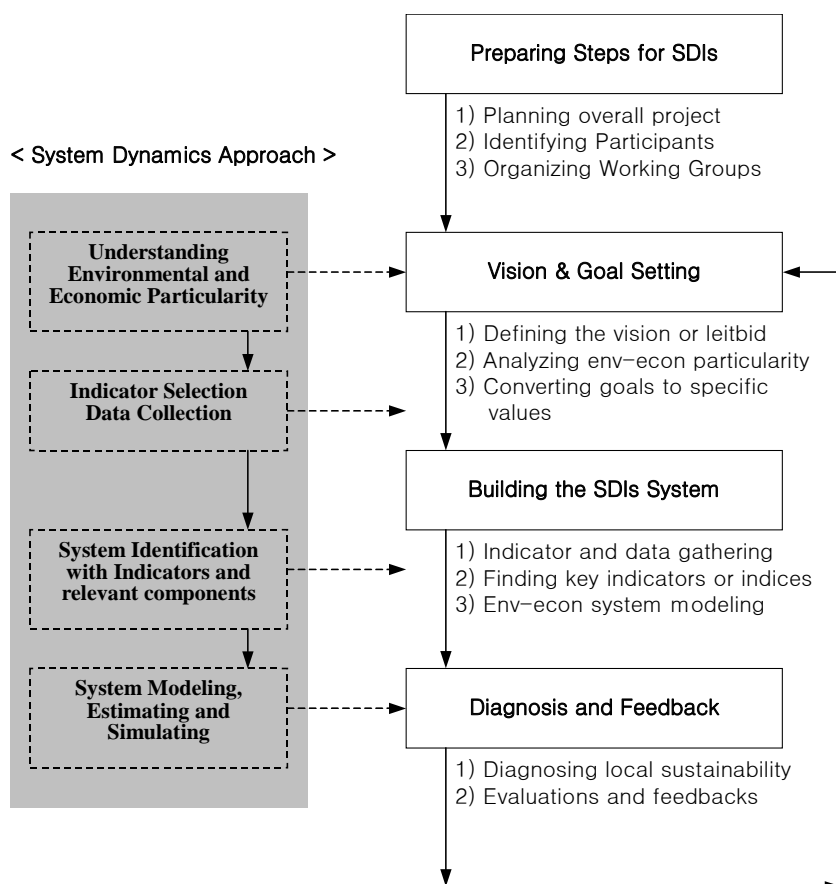
Following the principles and realizing the inadequacy of current approaches to SDIs, their developers and executors must analyze the entire complex of problems and tasks more carefully (Bossel, 1999). This requires a reasonably detailed model of the total system and its components. This study suggests by integration and a review of literature a means to accomplish the following four tasks:

- 1) To identify the total system boundary and its subsystems relevant to the context of sustainable development.
- 2) To develop an approach for identifying system components, which are directly and indirectly converted to SDIs.
- 3) To think about causal relations among the components and estimate comprehensive and longer-term effects by linking the causalities throughout the overall system.
- 4) To search which policy instruments are eventually appropriate to latent or estimated problems.

Practical guidelines for regional/local SDI participants are also suggested by Valentin & Spangenberg (2000). The process of developing and using indicators is schematically outlined in Figure 2-2, which is adjusted by the authors for Korean regions/localities with guidelines from the literature.

In Figure 2-2, it must be highlighted that the feedback process is the most important step in the execution of SDIs. The goals, indicators and consequent actions must be adjusted continually.

**Figure 2-2. Practical guidelines for Building and Running the system of regional/local SDIs**



The following chapters are directed by the systematic procedures suggested in this study (Figure 2-2). The process of data availability and indicator selection is dealt with in Chapter 3, and System thinking including the modeling process and feedback thinking is also covered in Chapter 4.

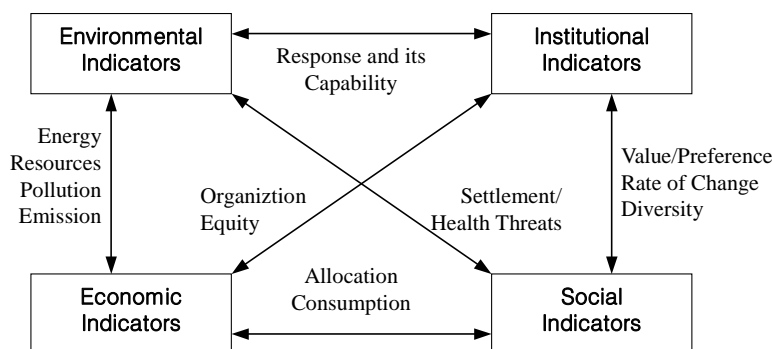
## Chapter 3. Prototype of Regional/Local SDIs

In this chapter, authors perform empirical case analysis and the PCA (Principal Component Analysis) so as to complete a set of key indicators among various SDIs. The set is presented as the prototype SDIs for Korean regions and localities.

### 1. Domestic and Foreign SDIs for Regions/Localities

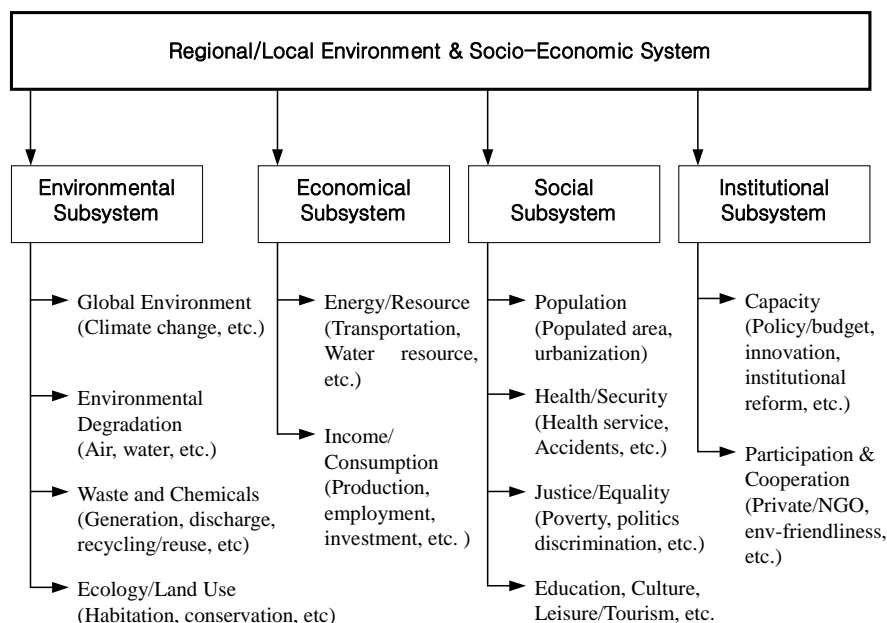
The first step, in order to elaborate a set of prototype SDIs for regions/localities, is to define the system boundaries of the regional/local environment and socio-economy. Latent subsystems are then sought to find major system elements within the system boundary. An example of subsystem definition and relevant system components are depicted in Figure 3-1.

Figure 3-1. Regional/Local System Boundary for SDIs



In order to identify specific subsystem components, the authors collected some cases of regional/local SDIs in domestic and foreign, especially developed regions/localities. In addition, the authors analyzed cases and extracts prerequisite to each subsystem, as presented in Fig 3-2. Each item in the figure is selected after a comparison of and contrast to domestic and foreign cases.

Figure 3-2. Regional/Local System Components for SDIs



The foreign cases analyzed include all three levels of SDIs: national, regional and local, respectively. The foreign cases are as follows:

- 1) National indicators/indices proposed worldwide: PSR (OECD, 2002), DSR (UN, 2001), and ESI (WEF, 2002, 2005)
- 2) U.K.: *Headline SDIs in Quality of Life Count for the nation, regions, and localities* (UK DEFRA, 2004; UK NS, 2004), *London's Quality of Life Indicators* (LSDC, 2004)
- 3) U.S.: National SDIs (Lee et al, 2004), *Sustainable Seattle's indicators* (SS, 1998), and *Santa Monica Sustainable City indicators* (SM, 2003)
- 4) Japan: *National Basic Environment Plan's indicators* (Lee et al, 2004), *Kanakawa LA21's SDIs* (Harashima, 2003)
- 5) Germany: National SDIs (Lee et al, 2004), *Berlin LA21's indicators* (BAF, 2004)

- 6) Taiwan: *Island-Taiwan and Urban-Taiwan Indicators* (Yeh et al., 2003)

The domestic SDIs are normally considered following the type category of their respective developers. The type is divided into two groups: ones are regional/local governments and the others are LA21 organizations. They are listed as follows:

- 7) National level SDIs by Korean PCSD (Chung, 2002; PCSD inbound documents, 2005)
- 8) Seoul Metropolitan Region: *Seoul Survey Indicator and Vision 2006* indicators by the Seoul Metro Government<sup>1</sup> (Lee et al. 2005), Seoul LA21's indicators<sup>2</sup>
- 9) Daejeon Metro Region: *Vision 2020's* indicators by the Daejeon Metro Government (Lee et al. 2005), Daejeon LA21's indicators<sup>3</sup>
- 10) Gyeonggi Province *Vision 2020's* indicators by Gyeonggi Regional Government<sup>4</sup>, Gyeonggi LA21's indicators (Gyeonggi LA21, 2005)
- 11) Suwon City: Suwon LA21's indicators<sup>5</sup>
- 12) Ansan City: Ansan LA21's indicators<sup>6</sup>
- 13) Yeongi County: Yeongi LA21's indicators<sup>7</sup>

## 2. Empirical Feasibility of SDIs

The subsystems and components in Figure 3-2 are identified by the most common categories in the above cases. The key elements on the figure may be regarded as generalized core SDIs, that is, they are easily converted to indicators for sustainability since the source of the figure is used in the sets of SDIs in the cases.

The *generalized indicators* are tested if a sufficient amount of statistics supports individual indicators for use and also if SDI users feel that the

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<sup>1</sup> [http://www.seoul.go.kr/2004brief/2005\\_vision/target.html](http://www.seoul.go.kr/2004brief/2005_vision/target.html),  
<http://www.seoul.go.kr/seoul/summary/statistics/index.html>

<sup>2</sup> [http://env-app.seoul.go.kr/green/green\\_02\\_s06\\_03.htm](http://env-app.seoul.go.kr/green/green_02_s06_03.htm)

<sup>3</sup> <http://www.tjla21.or.kr/>

<sup>4</sup> [http://www.gg.go.kr/ki/ki\\_future\\_new/2020\\_new\\_1\\_3.pdf](http://www.gg.go.kr/ki/ki_future_new/2020_new_1_3.pdf)

<sup>5</sup> [http://suwon21.jinbo.net/action\\_3.htm](http://suwon21.jinbo.net/action_3.htm)

<sup>6</sup> <http://www.asag21.or.kr/>

<sup>7</sup> <http://www.ygagenda21.or.kr/info04.html>

indicators are meaningful in the real world. Therefore, empirical feasibility of generalized indicators was measured in the following three ways:

- 1) Assessing the availability of statistics related to the generalized indicators, and gathering statistics to complete a list of *statistically available indicators*
- 2) Finding a set of *representative indicators* among the statistically-available indicators, using the PCA (Principal Component Method in the statistical Factor Analysis)
- 3) Reselecting and adjusting the representative indicators to suggest the final result of this indicator selection process, *prototype indicators* after some consultation workshops including LA21 indicator experts in Korea.

As for the statistics collection, the authors attempted to search all the statistical publications in central and local public institutions, those especially related to sustainable development. Some examples are: the *KOSIS database* in the National Statistics Office, the database and *Statistical Year Books* published by the Local Administration Information Bank, the local/regional governments, Ministry of Environment, the Ministry of Commerce, Industry and Energy, the Ministry of Construction and Transportation, and etc.

After investigating the statistical publications, authors completed a list of *statistically available indicators*, including almost 270 statistics varied by regions. In addition, the authors performed the PCA eight times for the total 8 domains in the subsystems of economy, society, and institution. About 30 statistical indicators for each domain were tested, and the final 16 *representative indicators* were selected. And then, two workshops were held and a total of 12 SDIs experts attended to discuss the results of the *representative indicators*.

### **3. Complete List of the prototype SDIs for Regions and Localities in Korea**

Throughout the workshops, the final 27 prototype selected indicators are presented in Table 3-1.

Table 3-1. The Prototype SDIs for Korean Regions/Localities

Sub-system	Domain	Key indicators
Environment	Air & Water Quality	<ul style="list-style-type: none"> <li>Concentration of CO/CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, O<sub>3</sub>, PM<sub>10</sub>, TSP, VOCs</li> <li>BOD Concentration: river, stream, lake, coastal, and ground water</li> </ul>
		[Sub] Emission: CO/CO <sub>2</sub> , NO <sub>x</sub> , SO <sub>x</sub> , VOCs, BOD, COD, etc.
	Waste	<ul style="list-style-type: none"> <li>Amount of general waste generated</li> <li>Recycling rate</li> </ul>
[Sub] Recycling rate of food waste, Amount of specified waste generated by industry		
Land Ecology	Land Ecology	<ul style="list-style-type: none"> <li>Biomass size of or number of particular species</li> <li>Length of natural meander/river streams</li> </ul>
		[Sub] Percentage of forest/green, Wood accumulation rate, Conservation area, Percent of populated land area
Economy	Income Production	<ul style="list-style-type: none"> <li>GRDP (per capita)</li> <li>Unemployment rate</li> </ul>
		[Sub] Corporate environmental programs, Fund size for SMEs, Operation rate in manufacturing, Direct sales rate of primary products
	Primary Production	<ul style="list-style-type: none"> <li>Rate of water supplied per person</li> <li>Rate of sewage disposal per person</li> <li>Observational chemicals per urban citizen</li> <li>Pesticide/fertilizer usage per cultivated land</li> </ul>
[Sub] Per capita amount of water used, Disposal rate of Sewage/ night soil/livestock waste water		
Resource Energy Transport	Resource Energy Transport	<ul style="list-style-type: none"> <li>Amount of total energy per capita (per GRDP)</li> <li>Percent of new &amp; renewable energy consumed per capita (per GRDP)</li> <li>Rate of fossil fuel used per registered car</li> </ul>
		[Sub] Rate of commuters by public transport and bicycle, Length of bicycle drive, Capacity of transportation security facilities

(Continued)

**Table 3-1. Prototype SDIs (Continued)**

Sub-system	Domain	Key indicators
Society	Population Urbanization	<ul style="list-style-type: none"> <li>Density: population per populated area</li> <li>Percent of impermeable land area</li> </ul>
	Health Security	<ul style="list-style-type: none"> <li>Death/damage by natural disasters/car accident</li> <li>Health care capacity per thousand people</li> </ul>
		[Sub] Death rate by non-disease accident, crime, and natural disaster
	Equality Welfare	<ul style="list-style-type: none"> <li>Income distribution (Gini index)</li> <li>Capacity of welfare facilities for women, aged, and handicapped</li> </ul>
[Sub] Rate of young patriarch/matriarch, Economic participation rate of women, aged, and handicapped		
Education Culture		<ul style="list-style-type: none"> <li>Teacher-student ratio</li> <li>Revenues of contents/cultural/tourism industry</li> </ul>
		[Sub] Participation rate of cultural society and activities, Cultural area for teenagers
Institution	Response Capacity	<ul style="list-style-type: none"> <li>Public expenditure for the environment</li> <li>Establishment of regulations related to sustainable development</li> <li>ISO14001 approval of local governments</li> </ul>
		[Sub] Formation of local SD Commission, Production of environmental industry, Number of employees in the sector of new & renewable energy, Percent of women and handicapped in the public sector, Number of international cooperation, etc.
	Participation Cooperation	<ul style="list-style-type: none"> <li>Participation of residence/NGOs, eco-friendly consumption</li> <li>Amount of time participating environmental education programs by residents/students</li> <li>Number of eco-labeled products/companies</li> </ul>
		[Sub] Participation rate of NGOs, Consumption rate of eco-labeled product/services, etc.

## Chapter 4. Regional/Local SDIs in System Thinking

In the last chapter the authors suggest a system dynamics model with the *prototype SDIs* in the previous chapter. System thinking via this model is expected to help not only understand the underlying relations among the indicators, but also find appropriate policy leverages, which are the final product of SDIs.

### 1. System Thinking of SDIs by Causal Loops

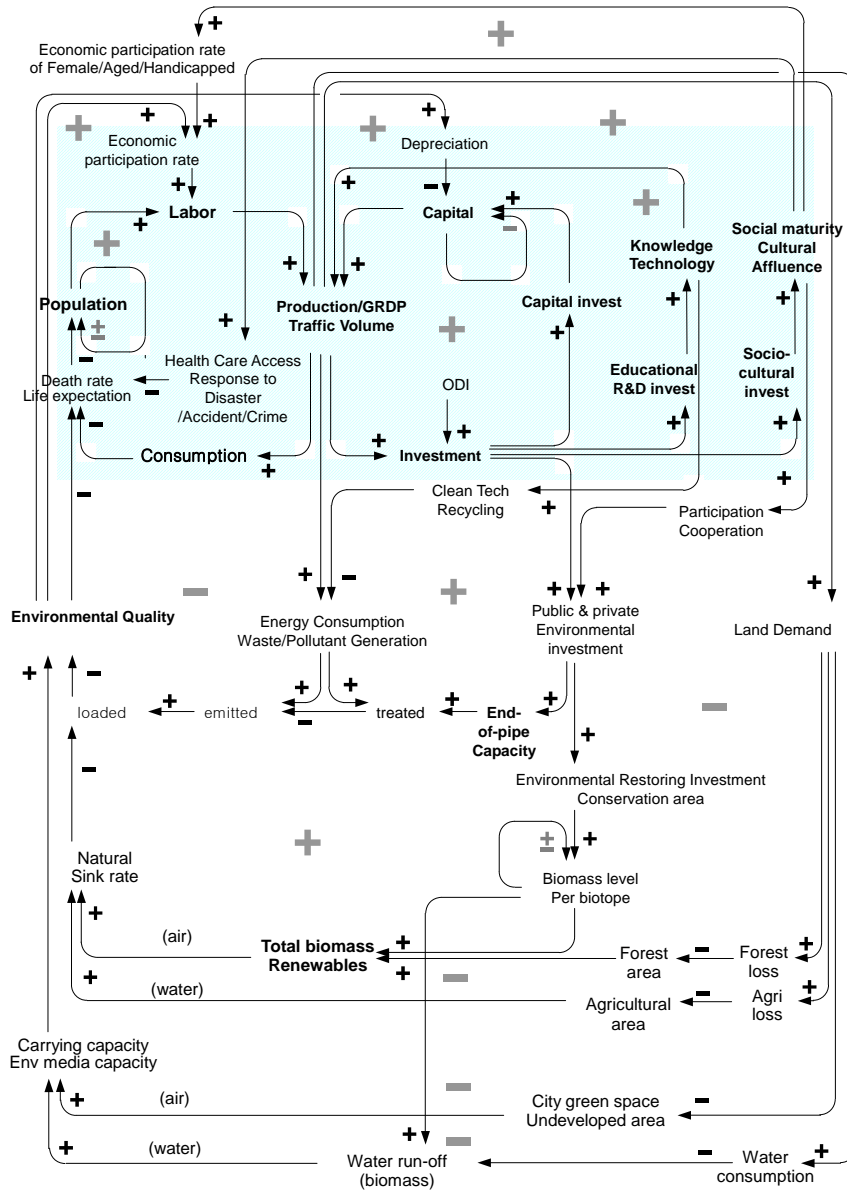
Causal relations between the elements in Figure 3-2 and Table 3-1 must be investigated with scientific evidence. Of course, one of the latent limitations of this modeling approach hinge on the existence of affluent information on causality itself, as well as its functional form which builds a system of simultaneous differential equations.

By this reason, the authors try to model only variables widely accepted in the field of economics and policy science, even though the variables modeled seem to be on a macro-level. As well, the authors express the flow equation of each state variable (stock or level), strictly following one of the basic flow structures provided by the principles of System Dynamics (Sternman, 2000).

Figure 4-1 presents the causal loop diagram covering most of variables in Figure 3-2 and Table 3-1. Each arrow mark and its polarity represent the causal relationship and its direction between the dependent and independent variables. Causal relations are chained in this picture, such that a variable gets feedbacks from itself or others via the coupled loops. Each loop also has a polarity, which symbolizes the feedback.

Basically, a causal loop diagram plays an important role in model building and system thinking. The final math model will be transformed from this map, the mental model with distinguishing stock or levels from variables in the mental model. In Figure 4-1, the shaded area in the upper part corresponds to the socio-economic sector while the lower part denotes the environmental sector. One can also find institutional variables within the socio-economic and environmental sector.

Figure 4-1. Causal loop diagram of a regional/local Sustainable Development system

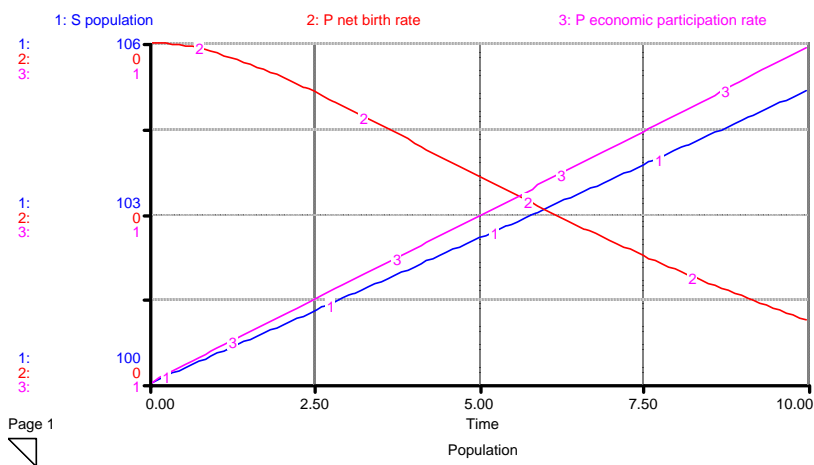


## 2. Dynamic Behaviors of SDIs

The overall structure in Figure 4-1 follows the typical environmental and macroeconomic way of modeling with Cobb-Douglas technology. But, the production is closely related to the social, environmental, and institutional variables. Figure 4-2 to 4-5 illustrate the result of a numerical example of dynamics behavior in the regional sustainable development systems.

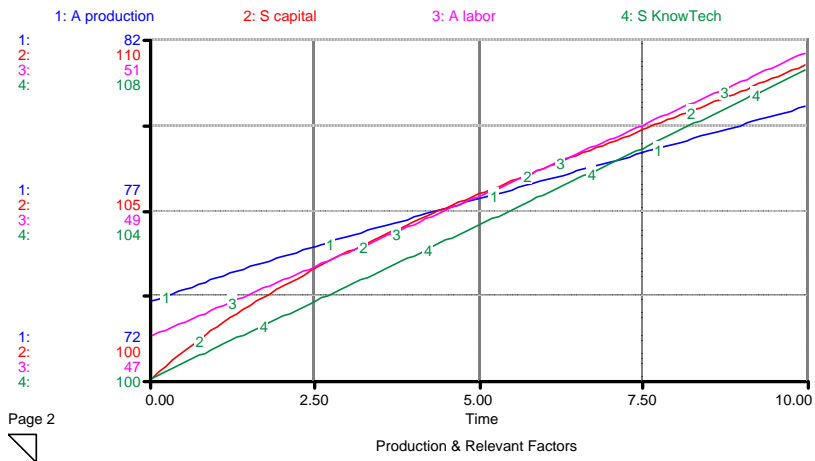
In Figure 4-2, population (line 1) steadily increases with a slightly declining net birth rate (line 2). The economic participation (line 3), however, increases at a higher rate than population because the economic participations of women, old and handicapped are increasing due to the rising socio-cultural level.

**Figure 4-2. Dynamic Behavior: Population**

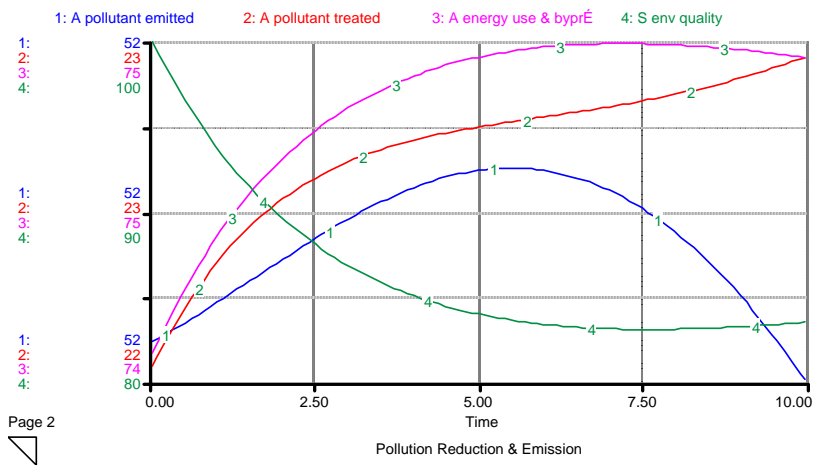


In Figure 4-3, production (Line 1) seems to be steady, but the contributions of its factors are different. The factors are capital (Line 2), labor (Line 3), and knowledge/technology (Line 4) in this model. Labor moves steadily, capital grows faster in its early stages, but its rate declines soon, and technology accumulation accelerates.

**Figure 4-3. Dynamic Behavior: Production**



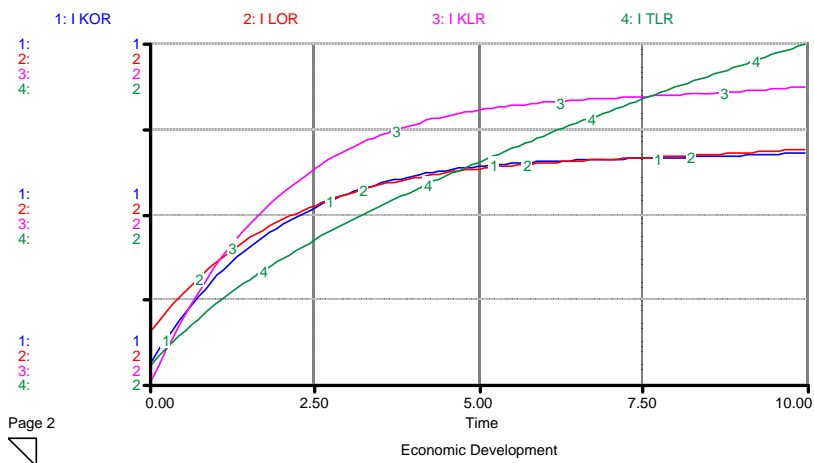
**Figure 4-4. Dynamic Behavior: Pollution & Environmental Quality**



Thus the contribution of capital to production is outstanding in the early stages. Nevertheless, technology will lead production in the later stages as well. This result is normal because, as an economy develops, labor-based production moves to capital-based, back to knowledge and technology-based.

This trend can also be seen in Figure 4-5, the increment rates of Kapital- (Line 1) and Labor-Output Ratio (Line 2) as well as Kapital-Labor Ratio (Line 3) diminishes, while the Tech-Labor Ratio (Line 4) inclines at a steady rate.

**Figure 4-5. Dynamic Behavior: Socio-economic Development**



However, this trend results from the assumption of steady knowledge/tech and socio-cultural investment. Without either one, technological advancement or a sufficient labor supply cannot be expected, and the production may not be sustainable. Thus, adequate investment on knowledge/tech and socio-culture should be proposed as policy leverage that literally *levers* sustainable development.

The same argument can be made in the case of environmental

protection. In Figure 4-4, the behavior of pollutant emissions (Line 1) seem to overshoot and drastically collapse. The behavior is likely to lead in the early stage by the end-of-pipe treatment (Line 2), and the leading role is shifted to a reduction in pollutant generation (Line 3) near the later stages. As a result, when referring to environmental quality (Line 4), environmental degradation ceases just before the end.

As before, this behavior comes from the assumption of steady investments in the environment, society, culture, and knowledge. Thus steady interest and investment can act as policy leverage for the environment and society in the form of intangible assets, in order to achieve balanced development.

## Chapter 5. Conclusion

Economic, social and environmental indicators in the past were separately developed and applied in each respective area. Meanwhile, SDIs have incorporated indicators with introduction to the conceptualization of environmental carrying capacity since the early 1990's.

Recently, SDIs studies tend not to aim simply at suggesting a more-sophisticated list, but at investigation of the interactions between SDIs, seeking a holistic, systematic and dynamic model that makes possible the assessment of long-term development and social evolution.

Based on a theoretical background, this study performs an empirical case study of SDIs. The cases cover national-, regional- and local-level SDIs in Korea and foreign countries including U. K., Germany, Japan, Taiwan and U. S. In the cases, SDIs are considerably different by differing levels and locations, although the definitions of sustainable development are similar generally. The differences are attributed to the consequence of considering the specificities of the environment and society.

Moreover, prerequisite SDI domains are selected after a comparison/contrast analysis of the cases. The list is then condensed into representative indicators by the PCA. After, the list refines the data to complete the prototype SDIs via consultation from LA21 indicator experts to include more future-oriented indicators.

It is confirmed that, when applied to a specific community, these prototype SDIs should be adjusted according to the local and social circumstances of the community. It is obvious that the subsystems and their coupling structures in the community will differ from one another.

Conclusively, this study recommends SDI executives to find sustainable development policies with system thinking. In this model sustainable development can be achieved only by the balanced growth of the economy, society, institution and environment. The whole system can collapse, if one of the subsystems fails to function properly.

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Sustainability can be regarded as the long-term stability of the whole system coupled by its subsystems.

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