Towards Resilience of Jabodetabek Megacity: Developing Local Sustainability Index with Considering Local Spatial Interdependency

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Abstract

Sustainability is a global issue that needs to condense the best efforts of humankind to deal with the goals that it is imposing on our planet and on our society. This study tried to develop indicators to promote sustainable development in the local level, called Local Sustainability Index (LSI) using Factor Analysis (FA) with considering local-scale spatial interdependency by employing Local Indicator of Spatial Association (LISA) statistics. LSI was developed based on 46 local sustainable development indicators which divided into 3 major dimensions: economy, social, and environment. LSI is covering household's economic welfare, public services, local infrastructure, social welfare, local community health and education, physical condition, local environmental sustainability and disaster resilience. Based on LISA results, it was found that local sustainability performance of the small-scale spatial units (villages/*desa*) was strongly influenced by the sustainability conditions in its surrounding areas. The approach developed in this study was able to show the actual condition of local sustainability performance in all dimensions without making it into one composite index so that it could include the trade-off between dimensions.

Keywords: sustainable development; Local Sustainability Index; Jabodetabek megacity; LISA statistics; factor analysis.

Abbreviations:

LSI	: Local Sustainability Index
LISA	: Local Indicator of Spatial Association
FA	: Factor Analysis

1. Introduction

Sustainability is a global issue that needs to condense the best efforts of humankind to deal with the goals that it is imposing on our planet and on our society. Sustainability requires that the well-being of society – the combination of community livability, environmental sustainability, and economic prosperity – is maintained or improved over time. In order to manage sustainability, society has to formulate clear and measurable goals of sustainability that should be continually revised and corrected. The level, at which these goals are implemented, might be measured using sustainable development indicators, i.e. definable and measurable parameters, which show values and trends of development of ecological, economic, and social stability of a particular region [1].

Sustainable development has been the subject of considerable discussion since the publication of The Brundtland Commission Report [2] which has made a great contribution by emphasizing the importance of sustainable development. It has played a catalytic role in the promotion of the concept of sustainable development, both in the developed and the developing world. There are many versions of definitions of sustainable development. According to World Commission on Environment and Development (WCED) definition, development is sustainable if the present generation can satisfy its needs without compromising the ability of future generations to meet their own needs. There are three pillars that support the concept of sustainable development, namely: (1) economy, (2) social, and (3) environment (ecology) [3][4][5], where the three pillars should be mutually supportive and involved in the development process.

The word 'sustainable development' has become popular on the world's policy agenda. Almost all governments have committed themselves to sustainable development by integrating economic welfare, environmental quality and social coherence. As a consequence, there is a strong political desire for the comprehensive assessment of changes in economic, welfare, environmental quality and social coherence.

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As a consequence, there is a strong political desire for the comprehensive assessment of changes in economic, environmental, and social conditions: an issue that cannot be clearly measured will be difficult to improve. Monitoring progress towards sustainable development requires in the first place the identification of operational indicators that provide manageable units of information on economic, environmental, and social conditions [6]. Sustainability assessment currently arises at transparent, comprehensive, integrated, and provident decision-making approach [7]. Sustainability indicators are developed as a simplified tool of communication, which helps to make political decisions for seeking sustainability. In order to achieve this goal, it is necessary to set a limited number of easy understandable indicators [8]. According to World Bank [9], fundamental factor of good indicator is the estimation of relationships between measurement of environmental conditions and practical political possibilities. However, these indicators should not necessarily include all aspects of sustainability because as Hueting and Reijnders [10] argue, in that case they often become very subjective and meaningless.

Based on OECD [11], an “indicator” is a variable which describes one characteristic of the state of a system, usually through observed or estimated data. Some indicators may give information about the position of the system relative to particular sustainability boundaries or goals. Harger and Meyer [12] suggest that indicators should contain the following characteristics: (1) simplicity; (2) (wide) scope; (3) quantifiable; (4) allows trends to be determined; (5) tools that are sensitive to change; and (6) allow timely identification of trends. Indicators are a useful tool used to simplify, determine in quantitative terms and summarize enormous flows of information, develop a useful mechanism of feedback, which highlights spheres where we act properly and where major attention is needed. Actually, indicators are used in order to reduce the amount of complex interrelationships by converting them into simple formulation, which makes assessments easier. When many indicators are used, they are either presented in a framework of categories, or aggregated into an index. An “index” is a quantitative aggregation of many indicators and can provide a simplified, coherent, multidimensional view of a system. Indices usually give a static overview of a system, but when calculated periodically, they can indicate whether the system is becoming more or less sustainable, and can highlight which factors are most responsible for driving the system. Sets of sustainability indicators, and aggregation of these indicators into indices, are increasingly used to make policy decisions [13][14].

There are numerous attempts to move beyond the non-integrated and combine different nature-society dimensions in one indicator or index, such as Living Planet Index (LPI), Index of Sustainable Economic Welfare (ISEW) and General Progress Indicator (GPI), Genuine Savings (GS), Ecological Footprint (EF), Environmental Sustainability Index (ESI), Environmental Vulnerability Index (EVI), Environmental

Policy Index (EPI), Wellbeing Index (WI), City Development Index (CDI), and Human Development Index (HDI). Those sustainable development indicators or indices can be used to: (1) anticipate and assess conditions and trends; (2) provide early warning information to prevent economic, social and environmental damage; (3) formulate strategies and communicate ideas; (4) support decision-making [15][16]. From those explanations, we know that sustainable development indicators/indices have been much discussed at the international, national, and regional level but it would be still very limited at the local level. At the local level, there is spatial interdependency between locations. So, the sustainability performance in a location is affected by the sustainability condition in its surrounding areas. The objective of this study is to develop Local Sustainability Index (LSI) with considering local spatial interdependency. LSI was divided into 3 dimensions: economy, social, and environment. It was developed as an approach for reporting local economic, social, and environmental conditions to support an actual integration of the three dimensions of sustainability as well as to build tools for the evaluation of local sustainability degree, in order to increase people’s awareness about the importance of sustainable development at the local level.

2. Jabodetabek Megacity as A Case Study

Cities and megacities (or urban developed areas with more than 10 million population) are important worldwide because human social and economic activities have been concentrating here. Cities and megacities of the developing world will absorb 95% of urban growth in the next two decades, and by 2030, will be home to almost 4 billion people [17]. Cities and megacities play a significant role in social and economic activities, but they perform poorly in terms of environmental conservation because of externalities. In the Brundtland Report [2], the awareness has grown that many environmental problems have a local origin, while global environmental decay often manifests itself at a local level [18]. It is significant to evaluate sustainability in cities or megacities in order to appropriately manage human activities there. Scipioni et al. [19] mentioned that the local and the urban dimensions of sustainability are becoming prevalent in international literature and the definition of specific local urban context indicators is of great interest.

The Greater Jakarta or Jabodetabek megacity was chosen as the study area of this research. Jabodetabek (stand for: Jakarta, Bogor, Depok, Tangerang and Bekasi) consists of 13 regencies/municipalities (Figure 1) which located in 3 different provinces (DKI Jakarta, West Java and Banten Province). Jabodetabek can be divided into 178 districts/kecamatan and 1,495 villages/desa. Jabodetabek consists of only 0.35% of total Indonesia’s area and inhabited about 11.3% of national population. Total population of Jabodetabek was 27 million in 2010, with the

rate of annual growth of 2.62% per year over the period 2000–2010.

From various indications, Jabodetabek - as the second largest megacity after Tokyo Metropolitan Area [20] - was experiencing very serious environmental deterioration in the last two decades. Most of the recent global environmental and social problems such as loss of agricultural land, pollution, crises in water availability, poverty, anthropogenic disasters, were found and experienced in Jabodetabek as the consequence of rapid urban development and increasing population growth [21][22][23]. These problems are becoming common in other parts of Asia and worldwide and spreading fast due to rapid global growing population. Thus, the urgency of the environmental considerations is indispensable in the development mainly because of rapid growth population and increasing human activities, so it takes efforts to maintain the balance and sustainability of resources. Recognizing the importance of consideration of economic, social, and ecological as an important component in the concept of sustainable development, we conducted this study, especially to develop LSI with considering local spatial interdependency - that can be used for measuring sustainable development performance at the local level of Jabodetabek as well as the other megacities.

Figure 1 Location map of Jabodetabek megacity

3. Methods and Materials

The LSI was developed by employing Factor Analysis (FA) to select the variables/indicators. FA was used since it can eliminate the redundancy of a set of correlated variables and replace these variables with a smaller set of variables generated and orthogonal, called as “factors”. The factors which have eigenvalue (E) more than 1 were selected as common factors that forming LSI. The key variables were determined in each factor which have dominant/significant contribution forming LSI. In this study, 46 variables were used ($V_1, V_2, V_3, \dots, V_{46}$) to be analyzed by FA (see the list of variables forming LSI in Tables 1). V_1 to V_{16} are variables of the economic dimension. V_{17} to V_{32} are variables of the social dimension. V_{33} to V_{46} are variables of the environmental dimension. All variable data were collected from the PODES datasets on village (*desa*)-

level statistics provided by the Central Bureau of Statistics (BPS) in 2011.

The FA model we used in this study can be written as follows:

$$LSI_{ki} = \sum_{m=1}^n E_{km} \cdot S_{kmi} \quad (1)$$

Where: LSI_{ki} = LSI for k -th dimension on i -th village (*desa*); k = Dimension ($k=1$: economy; $k=2$: social; $k=3$: environment); E_{km} = Eigenvalue for k -th dimension on m -th factor; S_{kmi} = Factor score for k -th dimension, m -th factor on i -th village (*desa*); $i = 1, 2, 3, \dots, n$. To standardize LSI value ($LSI_{ki}(std)$) in scale 0–100, we used this formulation:

$$LSI_{ki}(std) = (LSI_{ki} - LSI_{ki}(\min)) * \left(\frac{100}{LSI_{ki}(\max) - LSI_{ki}(\min)} \right) \quad (2)$$

In this study, the FA was conducted using principal component analysis (PCA) and varimax normalized rotation method in Statistica 8.0 software. To identify spatial interdependency of LSI between locations in Jabodetabek, we employed Local Indicator of Spatial Association (LISA) statistic using GeoDa software. LISA or Local Moran’s Index developed by Anselin [24] is a local spatial autocorrelation statistic based on the Moran’s I statistic. Spatial association (SA) refers to the correlation of a variable with itself in space. It can be positive (spatial clusters for high-high (HH) or low-low (LL) values) and negative (spatial outliers for high-low (HL) or low-high (LH) values). Positive SA exists when high LSI values (LSI_{ki}) correlate with high LSI neighboring values (LSI_{kj}) or when low LSI_{ki} correlate with low LSI_{kj} . Negative SA exists when high LSI_{ki} correlate with low LSI_{kj} and vice versa. Global SA (Moran’s I) captures the extent of overall clustering that exists in a dataset, whereas local SA indicates the location of local clusters and spatial outliers.

A weights or contiguity matrix is used to impose a neighborhood structure of the data to assess the extent of similarity between locations and values. There are two basic categories of neighbor definitions: contiguity-based weights (shared borders and/or vertices) and distance-based weights. In this study, queen contiguity was used as spatial weighting methods to detect SA of LSI in Jabodetabek region. Under the queen criterion, areas are neighbors if they share either a border or point (e.g., on a grid, in addition to the four cells included under rook, the four cells sharing a corner with the central location are also counted as neighbors).

The formula of Global and Local Moran’s I or LISA statistic can be seen as follows [24][25]:

$$I = \frac{\sum_{i=1}^n \sum_{j=1}^n W_{ij} (LSI_{ki} - \overline{LSI_k}) (LSI_{kj} - \overline{LSI_k})}{Z_{LSI_k}^2 \sum_{i=1}^n \sum_{j=1}^n W_{ij}} \quad (3)$$

$$I_i = \frac{\sum_{j=1}^n W_{ij} (LSI_{ki} - \overline{LSI_k}) (LSI_{kj} - \overline{LSI_k})}{Z_{LSI_k}^2 \sum_{j=1}^n W_{ij}} \quad (4)$$

Where: I = Global Moran's Index; I_i = Local Moran's I or LISA statistics; LSI_{ki} = the value of LSI for k -th dimension on i -th village (*desa*); $\overline{LSI_k}$ = the average value of LSI_{ki} ; W_{ij} = contiguity matrix; representing the proximity of i -th village (*desa*) i 's and village (*desa*) j 's locations; n = the total number of villages (*desa*); $Z^2_{LSI_k}$ = the variance of the LSI_k .

Table 1 List of variables forming LSI

Code	Variables
ECONOMY (k=1)	
V_1	Percentage of households that work in the agricultural sector (%)
V_2	Percentage of households that use electricity (%)
V_3	Percentage of households subscribe to cable phone (%)
V_4	Percentage of households that live along the river (riparian) (%)
V_5	Percentage of households that live in the slum area (%)
V_6	Distance to the market (km)
V_7	Distance to the bank (km)
V_8	Distance to the central business district (CBD) (km)
V_9	Distance to the nearest city (km)
V_{10}	Ratio of industry per 1,000 population
V_{11}	Ratio of markets, minimarkets, shops, and grocery shops per 1,000 population
V_{12}	Ratio of food stalls and restaurants per 1,000 population
V_{13}	Ratio of hotels, hostels, motels, and inns per 1,000 population
V_{14}	Ratio of co-ops and banks per 1,000 population
V_{15}	Percentage of built-up/urban land per total area (%)
V_{16}	Local infrastructure index (scalogram index)
SOCIAL (k=2)	
V_{17}	Ratio of formal education institutions per 1,000 population
V_{18}	Ratio of informal education institutions per 1,000 population
V_{19}	Average distance to the education facilities (kindergarten to university) (km)
V_{20}	Number of educational development facility types (school buildings and education facilities)
V_{21}	Number of health facilities (hospitals, clinics, health centers, doctors, pharmacies)
V_{22}	Average distance to the health facilities (hospitals, clinics, health centers, pharmacies)
V_{23}	Ratio of medical personnel per 1,000 population
V_{24}	Percentage of people suffering from diarrhea and vomiting (%)
V_{25}	Percentage of people suffering from respiratory tract infection (%)
V_{26}	Percentage of people suffering from tuberculosis (%)
V_{27}	Percentage of people suffering from malnutrition (%)
V_{28}	Ratio of toddler death per 1,000 population
V_{29}	Ratio of maternal mortality per 1,000 population
V_{30}	Number of types of residential facilities development (sanitation, clean water)
V_{31}	Number of non-profit organization/institutions
V_{32}	Number of criminals
ENVIRONMENT (k=3)	
V_{33}	Percentage of waterbody per total area (%)
V_{34}	Percentage of forest per total area (%)
V_{35}	Percentage of rice field per total area (%)
V_{36}	Percentage of other greenery area per total area (%)
V_{37}	Slope (%)

Code	Variables
V_{38}	Are there any irrigation canals? (1 = yes; 2 = no)
V_{39}	Are there any reservoirs or small lakes? (1 = yes; 2 = no)
V_{40}	Is there any water pollution? (1 = yes; 2 = no)
V_{41}	Is there any soil pollution? (1 = yes; 2 = no)
V_{42}	Is there any air pollution? (1 = yes; 2 = no)
V_{43}	Have there been landslide disasters? (1 = yes; 2 = no)
V_{44}	Have there been flood disasters? (1 = yes; 2 = no)
V_{45}	Have there been windstorm disasters? (1 = yes; 2 = no)
V_{46}	Have there been drought disasters? (1 = yes; 2 = no)

4. Results and Discussions

We employed FA to select key performance indicators/variables forming LSI for each dimension: economy (LSI_1), social (LSI_2), and environment (LSI_3). Table 2 showed that FA selected 5 factors from 16 variables which representing LSI for economic dimension (LSI_1). Based on factor loading's values, factor 1 is represented by the percentage of households which work in the agricultural sector (V_1), percentage of households which subscribe cable phone (V_3), and percentage of built-up or urban land per total area (V_{15}). These indicators are showing household's economic welfare. This factor is the most important/principal component which forming LSI_1 . Factor 2 is represented by ratio of economic facilities per 1,000 population (food stalls and restaurant - V_{12}) and (cooperation and bank - V_{14}). Factor 3 is represented by the percentage of households which living along the river/riparian (V_4) and slum area (V_5). Factor 4 and 5 are represented by accessibility to the nearest city (V_9) and ratio of industry per 1,000 population (V_{10}).

Table 2 Factor loading of economic factor analysis

Var	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
V_1	-0.747	0.006	0.043	-0.022	-0.041
V_2	0.236	-0.055	-0.198	0.284	0.467
V_3	0.736	0.036	0.067	0.206	0.118
V_4	-0.073	-0.050	0.730	-0.105	-0.079
V_5	-0.073	0.020	0.740	0.107	0.036
V_6	-0.643	-0.020	0.076	0.355	0.048
V_7	-0.627	-0.032	0.060	0.397	0.081
V_8	-0.579	0.011	0.120	0.135	-0.053
V_9	0.018	0.013	-0.004	0.779	-0.118
V_{10}	0.077	0.040	-0.086	0.150	-0.813
V_{11}	-0.015	0.623	-0.045	0.002	-0.012
V_{12}	0.015	0.714	-0.002	0.011	-0.014
V_{13}	0.007	0.237	-0.036	-0.058	0.342
V_{14}	0.020	0.773	0.040	-0.001	0.122
V_{15}	0.753	0.030	0.043	0.206	0.064
V_{16}	0.610	-0.034	0.119	0.087	-0.074
Expl.Var	3.258	1.567	1.181	1.134	1.071
Prp.Totl	0.203	0.097	0.073	0.070	0.066
Eigenvalue	3.275	1.586	1.202	1.119	1.028
% Total	20.472	9.917	7.518	6.993	6.427
Cumulative	20.472	30.390	37.909	44.903	51.330

Table 3 showed that FA determined 6 factors from 16 variables which representing LSI for social dimension (LSI_2). Factor 1 as the most important/principle component are

represented by the ratio of formal (V_{17}) and informal education facilities per 1,000 population (V_{18}), as well as ratio of health facilities (V_{21}). Factor 2 is represented by the percentage of people suffering from diarrhea and vomiting (V_{24}) and respiratory tract infection (V_{25}), which reflected the local community health. Education development (V_{20}) and residential facilities development (V_{30}) are being the representative indicators of factor 3. Whereas, factor 4, 5 and 6 are represented by the ratio of toddler's death per 1,000 population (V_{28}), average distance to the education facilities (V_{19}), and ratio of medical personnel per 1,000 population (V_{23}) respectively.

Table 3 Factor loading of social factor analysis

Var	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
V_{17}	0.819	0.091	-0.052	-0.111	0.215	-0.087
V_{18}	0.719	-0.038	0.026	0.023	-0.011	0.038
V_{19}	-0.127	-0.032	0.032	0.064	-0.714	0.130
V_{20}	0.073	0.110	0.816	0.046	-0.154	0.024
V_{21}	0.810	0.054	-0.040	-0.076	0.217	0.008
V_{22}	-0.292	-0.005	-0.029	0.258	-0.645	0.119
V_{23}	0.029	-0.110	0.015	0.051	-0.148	0.775
V_{24}	0.050	0.824	0.012	-0.014	-0.058	0.113
V_{25}	0.030	0.780	-0.020	0.041	0.039	-0.054
V_{26}	-0.117	0.363	0.003	-0.062	0.095	0.621
V_{27}	-0.354	0.102	0.113	0.437	0.234	0.068
V_{28}	-0.096	0.001	-0.024	0.745	-0.033	0.021
V_{29}	0.150	-0.021	0.017	0.586	-0.165	-0.025
V_{30}	-0.070	-0.123	0.790	-0.011	0.187	0.002
V_{31}	0.433	0.018	0.094	0.133	0.270	-0.005
V_{32}	0.133	-0.066	0.038	0.083	0.483	0.316
Expl.Var	2.339	1.490	1.323	1.218	1.507	1.150
Prp.Totl	0.146	0.093	0.082	0.076	0.094	0.071
Eignvalue	2.803	1.568	1.379	1.203	1.042	1.032
% Total	17.520	9.803	8.619	7.520	6.515	6.455
Cmulative	17.520	27.323	35.942	43.462	49.978	56.433

V_{42}	-0.112	-0.043	0.715	0.025	0.045	0.177
V_{43}	-0.016	0.463	-0.020	-0.082	0.017	0.477
V_{44}	0.020	-0.113	0.105	-0.736	-0.186	0.022
V_{45}	-0.020	0.204	0.013	0.199	-0.234	0.664
V_{46}	0.128	-0.193	0.126	-0.144	0.133	0.706
V_{47}	0.110	0.118	-0.042	-0.726	0.156	-0.015
Expl.Var	1.645	1.495	1.476	1.249	1.131	1.321
Prp.Totl	0.109	0.099	0.098	0.083	0.075	0.088
Eignvalue	1.912	1.742	1.471	1.101	1.075	1.017
% Total	12.750	11.616	9.808	7.341	7.167	6.784
Cmulative	12.750	24.367	34.175	41.516	48.684	55.468

In Table 4, the percentage of rice fields per total area (V_{35}) and slope (V_{37}) are important indicators of Factors 1 and 2 representing the LSI for the environmental dimension (LSI_3) by showing physical conditions. In Factor 3, there is soil pollution (V_{41}) and air pollution (V_{42}), which appear as key environmental indicators. Factor 4 represents disaster resilience through flood disaster (V_{44}) and drought disaster (V_{46}) indicators. Factors 5 and 6 are represented by the existence of a reservoir or small lake (V_{39}) and windstorm disaster (V_{45}).

Table 4 Factor loading of environmental factor analysis

Var	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
V_{33}	-0.189	-0.058	0.098	-0.038	0.525	-0.104
V_{34}	-0.096	0.694	0.119	0.054	-0.155	-0.094
V_{35}	0.855	-0.079	0.003	-0.097	-0.052	0.016
V_{36}	-0.558	0.317	-0.003	0.038	0.373	0.175
V_{37}	-0.108	-0.708	0.054	0.026	-0.029	-0.090
V_{38}	0.687	0.266	0.071	-0.044	0.091	0.171
V_{39}	0.108	-0.042	-0.016	0.057	0.727	0.047
V_{40}	0.102	0.027	0.633	-0.280	-0.066	0.092
V_{41}	0.085	0.067	0.707	0.105	0.102	-0.145

The distribution values of LSI_1 , LSI_2 and LSI_3 can be shown spatially in Figure 2. The higher value of the LSI_1 (Figure 2(A)) concentrated in the central part of Jabodetabek region (located in all municipalities, including Jakarta city, Bekasi, Tangerang, Tangerang Selatan, Depok and Bogor municipality). It means that these regions have a better economic performance compare with the others. On the other hand, those urban regions have lower local environmental index (Figure 2(C)).

Figure2 Spatial distribution of (A) LSI_1 , (B) LSI_2 and (C) LSI_3

Figure3 Spatial association of LSI_1 , LSI_2 , and LSI_3 based on LISA

Thus, there is a trade off between economic growth and environmental quality [26]. However, these two topics are often pitted against each other, framing prospective policy decisions as a choice of one over the other. Some people

view actions taken in order to protect the environment as constraining economic productivity, while others see some modes of economic production as particularly destructive to the environment. Compared with LSI_1 and LSI_3 , LSI_2 have the lowest value and mostly distributed in the whole area of Jabodetabek (Figure 2(B)). Then, Figure 3 showed the spatial association of local economic, social, and environmental index based on LISA statistics. In Figure 3, the spatial distribution of all dimensions LSI value were showed with considering the influence of the neighboring villages. The local economic sustainability index (LSI_1), which has the highest Global Moran's I (0.63), tends to configure spatial clusters, whereas the social indicators (LSI_2) are more randomly distributed (low Global Moran's I (0.23)). The HH spatial associations of the LSI_1 are clustered in the central part of the region (Jakarta city), whereas Jakarta city and the surrounding urban area have LL spatial associations for the LSI_3 . Then, those locations have good economic performance but low environmental quality. Applying the LISA technique to show the LSI (Figure 3) can better simplify and capture the spatial phenomena by considering the spatial association than by using a conventional approach (Figure 2).

Based on the LISA results shown in Figure 3, we produced a composite map that combined the HH and LL category for the LSI in all dimensions (LSI_1 , LSI_2 , and LSI_3) into four categories (Figure 4). The first (1st) category shows the best local sustainability performance conditions (i.e., with an HH index value for all dimensions: economic, social, and environmental), and the last (4th) category includes the worst local sustainability performance conditions (i.e., with an LL index value for all dimensions).

Figure 4 The combined map between High-High (HH) and Low-Low (LL) categorize for LSI_1 (eco), LSI_2 (soc), and LSI_3 (env)

The areas included in first (1st) (HH_{eco}-HH_{soc}-HH_{env}) and second (2nd) categories (HH_{eco}-HH_{soc}-LL_{env}; HH_{eco}-LL_{soc}-HH_{env}; and LL_{eco}-HH_{soc}-HH_{env}) have better local sustainable development conditions, but the areas categorized in third (3rd) category (HH_{eco}-LL_{soc}-LL_{env}; LL_{eco}-HH_{soc}-LL_{env}; and LL_{eco}-LL_{soc}-HH_{env}) and the last (4th) category (LL_{eco}-LL_{soc}-

LL_{env}) face severe conditions in terms of their local sustainability. The local government can use this approach to evaluate the local sustainability conditions in the region considering local spatial interdependence. Merging the LISA results into a single map as shown in Figure 4 will help decision makers take action with spatial dimensions perspectives. This study approach can show the actual condition of local sustainability performance without turning it into one composite index so that it does not eliminate the trade-off between dimensions. This is the benefit of using this approach.

5. Concluding Remarks

The LSI was developed as an approach for reporting local economic, social, and environmental conditions to support the integration of the three dimensions of sustainability. Developing the LSI is a new approach to evaluating the degree of local sustainability in order to increase people's awareness about the importance of sustainable development at the local level. This index can be very powerful tools for sustainability if it is used appropriately. Without a clear understanding of how the indicators interact with each policy other and influence the index results, policy decisions could increase economic disparities and environmental damage and decrease the possibilities for long-term sustainability. Based on the spatial distribution map of LSI_1 , LSI_2 , and LSI_3 , it was found that the areas with a higher local economic sustainability index are located in the center of Jabodetabek Megacity and are the core of economic activity, whereas the hinterland areas have a low LSI_1 value. In contrast, the local environmental sustainability index shows the opposite situation. This means that the approach developed in this study was able to show the actual conditions of local sustainability performance in all dimensions without making them into one composite index so it could include the trade-off between dimensions. Based on the LISA statistics analysis in this study, we found that local sustainability performance of the small-scale spatial units (villages/desa) is strongly influenced by the sustainability conditions in its surrounding areas. A high LSI value in one location is meaningless if its surrounding areas have a low index value (i.e., HL categories), because it might be affected by negative externalities from poor economic, social, or environmental quality conditions. On the other hand, a location with low values of LSI receives positive externalities only if its surrounding areas have high LSI value. LSI is a very effective method to indicate hotspot locations for sustainable development issues, and it can be used as an effective tool for spatial-based decision-making processes. The approach used in this study can be further developed by creating several policy scenarios and modeling simulations to improve the local sustainability performance toward the resilience of Jabodetabek Megacity.

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