Article

Urban Vulnerability in Bantul District, Indonesia – Towards Safer and Sustainable Development

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Abstract

Assuring safer and sustainable development in seismic prone areas requires predictive measurements, i.e. hazard, vulnerability and risk assessment. This research aims to assess urban vulnerability due to seismic hazard to strengthen safer and sustainable development through risk based spatial plan. This research highlights hazard, vulnerability and risk as constituent part of mitigation process in urbanized area. The idea of urban vulnerability assessment is to indicate current and future potential of losses due to specified hazard in given spatial and temporal unit, although it is extremely dynamic. Herein, the urban vulnerability refers to classic separation between social vulnerability assessment and physical vulnerability assessment. In mere sense, both assessment refers to pre-existing condition of being unfavorable due to seismic hazard expressed on a scale from 0 (no loss/damage) – 1 (lethal/full damage) within specified time. The research area covers six sub-districts in Bantul, Indonesia. It experienced 6.2 Mw earthquakes in May, 27th, 2006 and suffered from 5.700 death tolls, economic losses up to 3.1 billion US$ and damaged nearly 80% out of total 508 km^2 area. Overall, it has experienced three major environmental issues, i.e. (1) seismic hazard, (2) rapid land conversion and (3) dominated by low income group. Based upon existing research problem, this research employs spatial multi criteria evaluation (SMCE) for social vulnerability (SMCE-SV) and for physical vulnerability (SMCE-PV). It is a method which allows diverse input criteria to explain unstructured condition such as vulnerability. There are several phases to conduct the SMCE, such as problem tree analysis, standardization, weighting and map generation. The research reveals two important findings. First, SMCE-SV and SMCE-PV are empirically feasible to indicate urban vulnerability indices. Second, integrating vulnerability assessment into risk based spatial plan requires broad dimension, from strategic, technical, substantial and procedural integration process. In summary, without adequate knowledge and political will to integrate urban vulnerability into risk based spatial plan, thus manifestation towards safe and sustainable development claimed meager and haphazard.

Keyword: vulnerability, sustainability, spatial plan, seismic hazard, Indonesia.

1. Introduction

Assuring safer and sustainable development has been under intense debate, especially if it corresponds to hazard prone areas due to natural disaster. Natural – technological disaster is partly consequences of unsustainable development with misleading cultural behavior to balance natural, economic and social setting [12-13]. Furthermore, the preventive measurement i.e. risk based spatial plan, land use control and other preventive measure are recently critical to minimize future impact due to the disaster [12]. Herein, the research aims to assess the urban vulnerability due to seismic hazard in order to strengthen safer and sustainable development. The idea is to integrate urban vulnerability information together with hazard information into risk based spatial plan. The risk based spatial plan is a legally binding document to allocate spatial pattern and spatial structure in safe and sustainable manner by integrating hazard, vulnerability and risk information [8]. It keeps people and their properties away from hazardous zone [12-13]. Unfortunately, some people have resided in some hazardous zone beforehand and had become socially-economically reluctant towards future risk.

This research employs several terms, i.e. hazard, vulnerability, and risk as an integral part of disaster mitigation strategy. Mitigation is any action taken to reduce or avoid future risk or potential damage/loss far before disaster occurrences [12-13]. In broader sense, risk is a convolution between hazard and vulnerability to quantify the expected damage and loss from all level hazard severity [15]. Hazard in here refers to probable extreme natural event within specified period time in given area which expressed in certain measurement i.e. magnitude, frequency, recurrence period and potentially causing damage. The vulnerability definition derives from place based vulnerability concept [6]. She argued that natural (physical) – social interplay within specified geographic and temporal boundaries constructs certain degree of vulnerability. She noted that vulnerability is degree of potential of losses and damage towards certain degree of hazard severity and it involves adverse reaction of social and natural system [6]. Thus, the urban vulnerability we discussed here regards myriad criteria exists within specified spatial boundaries, i.e. physical, demographic, social-economic and build-up setting. Meanwhile, some other expressed vulnerability as severity level of one's being hit by hazard and fragility of an element at risk (i.e. building, infrastructure) being exposed to it [4]. Herein, he revealed that within spatial – temporal boundaries there are various elements at risk, which indicates different responds behavior towards disaster. Hence, the urban vulnerability employed within this research is a function of the social and physical vulnerability. It delineates classic separation between social vulnerability assessment (represents pre-existing condition of people per se which potentially experiences losses during future hazard scenarios) and physical vulnerability assessment (represents pre-existing condition of urban settlement unit which potentially damaged during future hazard scenarios). In more details, this research perceives urban vulnerability as an important urban indicator to predict pre-existing condition of being unfavorable due to seismic hazard expressed on a scale from 0 (no loss/damage) – 1 (lethal/full damage) within specified time.

The research focuses on absence of vulnerability assessment within risk based spatial plan in Indonesia especially in seismic prone areas of Bantul District. This research values the urban vulnerability assessment as one among too many mitigation strategies that possible to be integrated within risk based spatial plan. Indonesian government has strategically mainstreamed disaster risk reduction into development agenda through Act Nr. 24/2007 on Disaster Management and Act Nr. 27/2007 on Spatial Plan. In recent praxis, Indonesia has opted hazard assessment, but it has not yet completed vulnerability assessment, which has caused risk assessment shortcoming [9]. To delineate research scope this research shall not conduct hazard assessment but apply existing hazard map and generate vulnerability scenarios. Evidently, D.I Yogyakarta government has enacted latest (risk based) spatial plan for regional scale, which address that seismic hazard potential is likely concentrated along Bantul District. The remaining challenge is to assess vulnerability in multi-scale, i.e. district and sub-districts level.

The research area addresses six sub-districts (Banguntapan, Kasihan, Sewon, Sedayu, Pleret and Jetis) which are vested in Bantul District, D.I Yogyakarta Province – Java Island, Indonesia (see Figure 1).
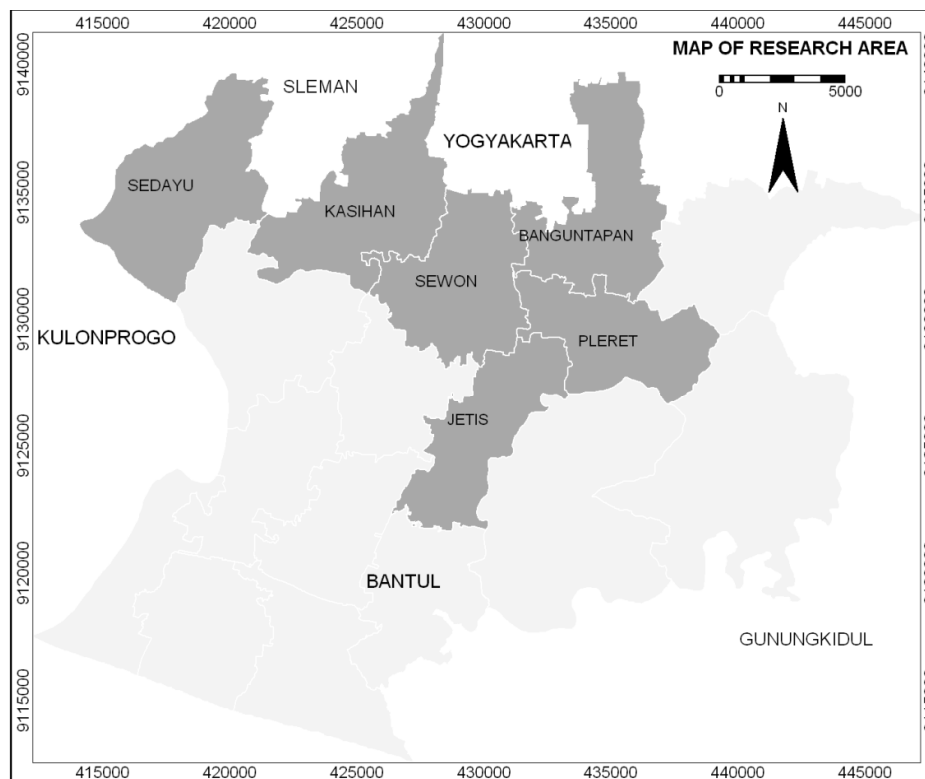

Figure 1 Research area

Overall, the research area have experienced three major environmental issues, i.e. (1) diverse seismic intensity level, (2) rapid land conversion and (3) dominated by low income group. Geologically, it is adjacent to active subduction zone of south Java Island – a part of Indo-Australian tectonic plate that subducted beneath Eurasian plate [10]. It experienced 6.2 Mw earthquakes in May, 27th, 2006 which epicenter was located nearby the active fault lines. The research area suffered from 5.700 death tolls, economic losses up to 3.1 billion US$ and damages nearly 80% out of total 508 km^2 area [2]. Bearing such critical geologic setting towards seismic hazard, Bantul District has expected to experience earthquake with high intensity level within recurrence period of 50 years. It happens to be home for more than 823.000 in 2004 and up to 954.000 people in 2010, while the six sub-districts inhabits by nearly 44% out of total inhabitant or 425.057 inhabitants [2-3-7]. The research area depicts sub urban expression and dominates by low to medium income group earn living from agriculture sector (42%) and non-agriculture sector (58%) [3]. Apparently, there is rapid land conversion in the research area since early 2000s which occurs to accommodate rapid population growth and urbanization phenomena from neighboring city – Yogyakarta City – and also because economic transition from agriculture based economy to industrial based economy in Bantul Districts [1]. The long term development plan of Bantul District has enlisted prone areas towards seismic hazard derived from physical aspect, however it has not yet evaluated social, economic, and other potential vulnerability criteria.

Suffice to say, the research area has given to complex environmental burden either originated from natural hazard potential and or rapid man-land relation potential. Given to such scale of problem, there are two important research questions to attain the research objective, such as: (1) how to assess urban vulnerability and (2) how to integrate it into risk based spatial plan.

2. Research Method

The research endeavors to integrate urban vulnerability into spatial plan. Among too many analytical method of vulnerability assessment, this research selects Spatial Multi Criteria Evaluation (SMCE) for these following grounds. First, risk based spatial plan generally aims to tackle multiple spatial problem derives from multiple spatial attribute using spatial analysis, thus, urban vulnerability assessment requires spatial approach. The SMCE offers spatial analysis using geographic information system (GIS) and multi criteria evaluation (MCE) to transform spatial and non-spatial input [5]. It possible to explain multi-level analysis, i.e. spatial scale and household scale, which in fact corresponds to real condition in the research area whereas data are commonly available in multiple proxies. Second, risk based spatial plan generates multiple scenarios to accommodate future possibilities and selects modest scenario using decision-making tools, thus, the urban vulnerability entails decision-making tools which able to select series of modeling scenarios and ascertains it using mathematical logics. The SMCE allows diverse input criteria to explain unstructured future condition based upon mathematical logics using problem tree analysis, standardization, weighting scenarios and map generation to generate multiple scenarios [11]. The following figure indicates research flow using the SMCE procedure (see Figure 2). The problem tree analysis adopts multi goals and multi criteria to expose relationship among relevant criteria for main objective – herein assessing social vulnerability (SV) and physical vulnerability (PV) – which generally clusters into group factors or constraints [16]. As it employs multi criteria, thus each criterion holds certain range scale value which requires standardization. Standardization is a process to offer membership value based upon utility for each factor using Boolean Logics and or Fuzzy Logics. The Fuzzy Logic allows membership of factors in continuous scale from 1 (full membership or full utility) to 0 (full non membership or zero utility) to the main goals. Boolean logic has introduced strict binary options as True or False, or value of 0 (excluded from preference) or 1 (contribute high utility to main goal) to express preferences [11]. Furthermore, weighting is a process to assign relative importance to each factors contribute to multi goal, it also generates multiple scenario which at the same time confirms validity of each generated scenarios and strengthening decision-making. In summary, the research selects the SMCE since it accommodates spatial approach, includes decision-making tools and employs mathematical logics which are commonly adopted within spatial plan.
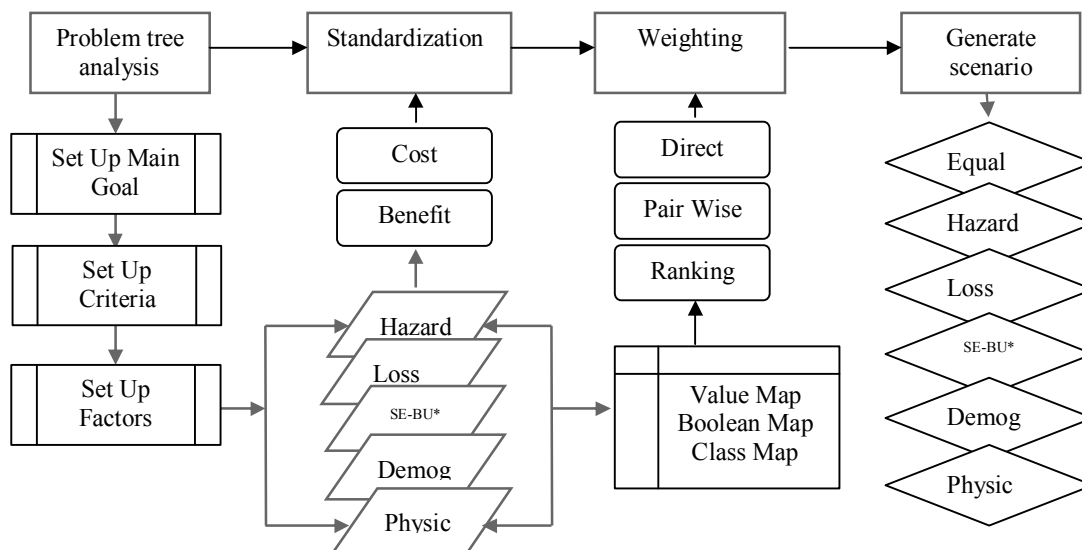

Figure 2 Research Flow

*SE-BU: Social – economic (for social vulnerability) or Build-Up (for physical vulnerability)

There are several input criterion employed for urban vulnerability assessment (see Table 1). In order to selects criteria, the research re-routed previous research and considered data availability in the research area. The SMCE-SV employed hazard, physical, demographic, social-economic, and losses criteria. The SMCE-PV employed similar criteria except for social-economic criteria and included build-up criteria. There are five factors to describe physical criteria, such as land use distribution, distance to stream, distance to fault structure, distance to road network and slope. For example, the land use indicates developed areas, which in this case the more it developed thus the more it contributes to SV or PV. Additionally, there are eight factors to describe demographic criteria, such as population density, agriculture density, number of elderly people, children, illiterate group, high educated group, occupant during day time, and occupant during night time. These factors relatively shares similar logics, whereas more population contributes more to vulnerability. Demographic criteria commonly attaches to social economic attributes, which in this research denotes to household proxies. There are thirteen factors within social-economic criteria, such as household with clean water access, electricity access and communication access, number of poor household, household without saving, insurance and low income group, pension group, labor group also household with building asset, vehicle assets, cattle stock assets and productive land assets. Their social-economic attributes contribute more to vulnerability, as more assets refer to more properties to loose, while low economic supports and less access to basic services profoundly increase vulnerability. Critically, this research added build-up characteristics using location factors and occupancy rate. In order to document previous trend, this research added losses criteria which described damage-loss such as ration for immaterial loss and ration for damaged house. Lastly, seismic zonation factor explains hazard criteria which holds formidable role to delineate sensitive zones.

Table 1 SMCE-SV & SMCE-PV Criteria

No	Criteria	Factor	Description	Data source
1	Physical	Land use, Faults, Road network, Stream network, Slope	built up areas (+) distance to fault lines (+) distance to road network (+) distance to river (+) mountainous area (+)	Secondary Data (Bappeda, 2009)
2	Demographic	Population density, Population by education, by age, by income, by occupation	High density (+) Low education (+) Elderly (+),children (+)	Secondary Data (BPS, 2009) Primary Data
3	Socio-economic	Asset, access, economic background, etc.	Low economic assets (+) Low wages (+)	Secondary Data (BPS, 2009) Primary Data
4	Built-up	Distribution of building, Building type*, Building structure*; Building occupants*	High value (+) Poor structure (+) Permanent type (+) High occupancy (+)	Primary Data Satellite image interpretation (Ikonos 2006, Google images 2009) *Fieldwork observation
5	Losses	Material loss ratio, immaterial loss ratio	High ratio (+)	Primary Data (Bappeda, 2009)
6	Hazard	Distribution, Magnitude, Frequency, Intensity	High frequency, high magnitude, high intensity, wider distribution (+)	Secondary Data (Geological Agency, 2009)

Note: (+) contribute more or have high utility to construct vulnerability

As noted earlier, the research has set up weighting scenarios to generate multiple scenarios. Weighting scenarios within this research is set up in random-rank order weight using direct method which assigns weight based upon importance ranking of qualitative assessment from decision maker. The research expects to generate six scenarios for SV and PV, such as physical scenario, demographic

scenario, social-economic scenario (for SV) and build-up scenario (for PV), loss scenario, hazard scenario and equal scenario (see Table 2).

Table 2 Weighting Scenarios

Scenarios	Physical Factors	Demographic Factors	Socio econ/Build-up Factors	Affected Loss Factors	Hazard Factors
Physical	0.40	0.15	0.15	0.15	0.15
Demographic	0.15	0.40	0.15	0.15	0.15
Social-Economic/Build-up	0.15	0.15	0.40	0.15	0.15
Losses	0.15	0.15	0.15	0.40	0.15
Hazard	0.15	0.15	0.15	0.15	0.40
Equal	0.20	0.20	0.20	0.20	0.20

In details, the physical scenario for example, assigns more weight to physical criterion (0.40) and equally assigns other criteria (0.15) since it expects dynamic physical condition which contributes more to vulnerability rather than other factors. As for equal scenario, it regards equal change in each factor which equally contributes to vulnerability, thus it assigns equal weight.

3. Result & Discussion

The research has revealed two important findings. First, SMCE-SV and SMCE-PV are feasible to assess urban vulnerability from multi-scale observation and best to operate in spatial manner. Second, spatial pattern of social and physical vulnerability are possible to be integrated within spatial pattern and spatial structure within spatial plan. Evidently, this research has generated the SMCE-SV for macro scale (1: 250.000) and the SMCE-PV for micro scale (1: 50.000). The macro scale vulnerability assessment is suitable to be integrated within large scale spatial plan, i.e. regional spatial plan, while micro scale vulnerability assessment is suitable to be integrated within detailed scale spatial plan, i.e. sub-district spatial plan. The social vulnerability through SMCE-SV represents household proxies, while the physical vulnerability through SMCE-PV represents settlement proxies. Herein, the different proxies entail different input data, which cause slightly different technique. Clearly, data availability for household proxies is excessive therefore it is possible to conduct social vulnerability for macro and micro level. Meanwhile, availability data for settlement proxies is unfortunately difficult to obtain, thus it is quite difficult to generate macro scenarios for physical vulnerability. Despite slightly different technique, both exercises require two preliminary stages (screening and surveying) and four main stages (problem tree, standardization, weighting and generated scenarios). The screening process is an important process to delineate prone areas towards specified hazard since hazard information is pivotal input within this exercise. The surveying phase is a follow up phase to conduct field survey if any required datasets are not available, i.e. building occupants, building types etc. The remaining four stages require skill, fair decision, and adequate scientific knowledge to construct logical scenarios for vulnerability. Albeit strong sense of subjectivity, this exercise evidently generates accurate and consistent results as follow.

The SMCE-SV has generated six deterministic scenarios to represent household proxies. It pertains with these scenario: if the research area likely to experience seismic activity originates from active faults or nearby active fault structure, magnitude < 5 S.R, attenuation < 0.15 g, recurrence period between 2009 - 2059 and expose to major perturbation to physical/demographic/social-economic/losses/hazard criteria, thus the spatial pattern of social vulnerability are depicted in the following figure (Figure 3a-f). The research set vulnerability indices into five categories, as follow:

not vulnerable (0), marginally vulnerable (0.01 - 0.25), moderately vulnerable (0.26 – 0.50), vulnerable (0.51 – 0.75) and highly vulnerable (0.76 – 1.00). The generated six scenarios from the SMCE-SV consist of composite map with indices value from 0.51 to 0.79. This indicated that the research area falls into highly vulnerable area (red zone), vulnerable areas (darker green zone) and moderately vulnerable areas (light green zone) for social vulnerability. It means that people who resided within that area are subjected towards that certain level of social vulnerability.
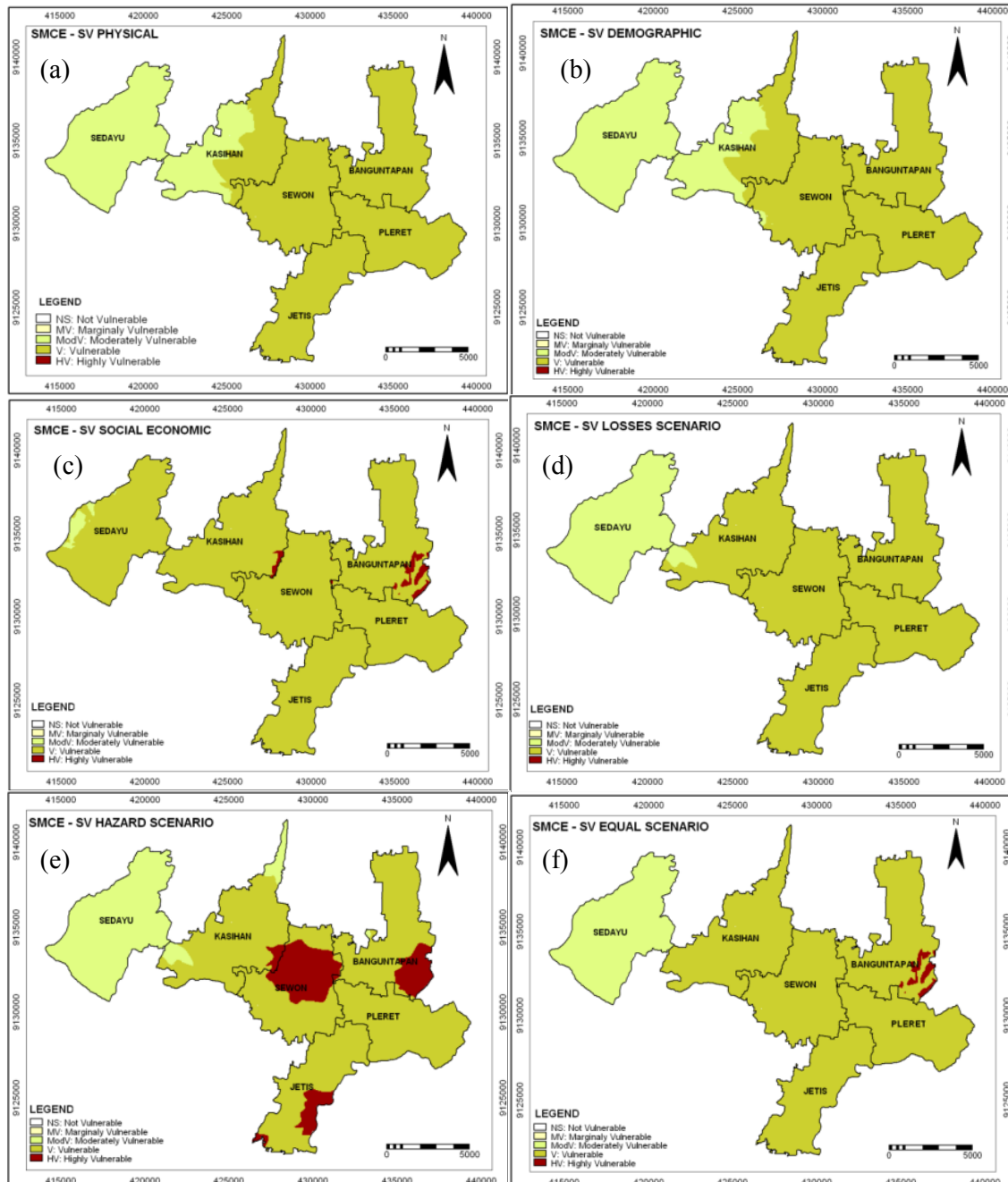

Figure 3 (a) SMCE-SV Physical Scenario; (b) Demographic Scenario; (c) Social Economic Scenario; (d) Losses Scenario; (e) Hazard Scenario; and (f) Equal Scenario

First, the physical scenario of the SMCE-SV aims to identify contribution of physical criteria towards vulnerability (Figure. 3a). The idea is to introduce the spatial pattern of the social vulnerability if the physical criteria (land use, transportation network, fault structure, rivers, and slopes) experiences

dynamic changes due to many reason, i.e. spatial structure plan. The perturbation discussed here highlight land use and transport network, since these are sensitive towards any modification due to spatial structure plan. Meanwhile, fault structure, river and slopes are not subject to direct perturbation, but these criteria potentially respond to any dynamic change within its surrounding. If there is significant perturbation towards these physical criteria, thus household proxies resided in Banguntapan, Sewon, Jetis, Pleret and partly Kasihan are classified as vulnerable. Meanwhile, the household proxies resided in Kasihan and Sedayu are classified as moderately vulnerable. This scenario is considerably important since the latest spatial plan has designated Banguntapan, Sewon, Kasihan and Sedayu as small town, which potentially developed into urban agglomeration center together with neighboring city – Yogyakarta. This refers to more physical perturbation which might impinge future development.

Second, the demographic scenario aims to expose contribution of demographic figures towards vulnerability (Figure 3b). The idea is to introduce spatial pattern of the social vulnerability if demographic figure experience major perturbation. The research area has experienced rapid onset of demographic figure – population growth less than 2% per year [3]. However, it is possible to experience more rapid demographic variation in the up-coming years due to local migration since some vulnerable areas, i.e. Banguntapan, Sewon and Kasihan are direct periphery areas potential for rapid demographic spillovers from neighboring city, Yogyakarta. According to spatial pattern plan 2010 - 2029, these areas are designated settlement areas together with Pleret [14]. Given to future settlement allocation, it is assumed that these periphery areas are subjected to more demographic accumulation in the up-coming years follow to rapid habitation. Moreover, this future spatial pattern should have strengthened with rigid building codes and or local awareness to avoid future damages and losses. The demographic scenario has generated similar result as the physical scenarios, whereas household proxies resided in Banguntapan, Sewon, Jetis, Pleret and partly Kasihan has more vulnerability than those resided in Sedayu.

Fourth, the losses scenario aims to expose contribution of losses criteria towards vulnerability (Figure 3d). Previous damages and losses pattern perpetuates distribution of elements at risk due to seismic hazard. Arguably, these elements at risk are likely to respond in similar behavior once hazard with similar likelihood strikes. Thus, if the research areas experience rapid urbanization, which indirectly increase population growth, economic growth and development activities, hence the distribution of elements at risk shall increase and induce more vulnerability. Notably, the scenario has presented similar result as physical and demographic scenarios that Banguntapan, Jetis, Pleret, Sewon and some of Kasihan are vulnerable areas, and Sedayu as moderately vulnerable area.

Fifth, the hazard scenario aims to expose contribution of hazard scenario towards vulnerability (Figure 3e). Hazard scenarios become critical since it is subject to change. The hazard map in Indonesia has undergone massive technical improvement recently. In many cases, academics generate clear scenario, unfortunately, it lack of legal consequences. In other extreme, there are some hazard scenarios with legal binding, unfortunately it lack of method elaboration, and can only allow scholar as end user. A selected hazard map should have clear measurement method and have legal consequence. The related institution in charge for the hazard map, i.e. Geologic Agency has continuously elaborated measurement method to generate valid and accurate hazard map scenario, and currently has published microzonation map for Bantul District. This research has employed deterministic microzonation map from Geologic Agency, which has been slightly modified prior to suit with research area. The existing microzonation map has yet cover Sedayu, thus the research has generalized it using spatial analysis to get rough assumption towards seismic likelihood. The hazard scenario has generated 11.39% out of total area as highly vulnerable area which concentrated in Sewon, Banguntapan and Jetis.

Lastly, the equal scenario aims to elaborate contribution of all criteria towards vulnerability (Figure 3f). If Bantul District continuously control land use change, manage urbanization, maintain social welfare, and conduct preparedness to protect communal or individual assets it will promote equal scenario. The equal scenario put all variables into same weight, which means it gives equal opportunity to any change caused by different variables. Arguably, the equal scenario occurs if

research area likely to experience steady growth in demographic, physical and social economic background. Similar to physical and demographic scenarios, this scenario spots Kasihan, Sewon, Banguntapan, Jetis and Pleret as vulnerable areas and leaves Sedayu as moderately vulnerable areas. Meanwhile some areas in Banguntapan considers as highly vulnerable area.

In slightly different setting, this research has conducted the SMCE-PV for micro level. This method is heavily relied on availability of hazard scenarios, impact inventory and building stock inventory. Input data for building stock inventory derives from interpretation of high resolution satellite image which apparently too excessive for the whole research area, hence the research selects detailed spatial unit for Sewon sub-districts.

As noted earlier, these scenarios still pertain with this if scenario: if the research area likely to experience seismic activity originates from Opak Fault or nearby active faults, magnitude < 5 S.R, attenuation < 0.15, occurrence period between 2009 – 2059 and expose to major perturbation to the physical/demographic/build-up/losses/hazard characteristics, thus the likelihood of the physical vulnerability is spatially discern as depicted in Figure 4(a - f). The physical vulnerability indices range from 0.220 to 0.743, which directly set Sewon sub-district into three vulnerable zones: vulnerable (red zone), moderately vulnerable (yellowish red) and marginally vulnerable (green zone). It means that the settlement units resided within this area are subjected to certain level of physical vulnerability. Derives from these scenarios, the most sensitive criteria to generate discern spatial pattern of physical vulnerability is hazard criteria. Despite such dynamic vulnerability setting, the regional spatial plan has allocated Sewon as settlement, services and wet agriculture area. Clearly, this area has assigned to carry numerous human activities in spite of its vulnerability indices.

There are some critical highlights towards the exercises. First, the SMCE method has generated consistent scenarios. Overall, the household proxies in Sewon, Banguntapan, Jetis, Pleret and Kasihan have resided in vulnerable area. Meanwhile Sedayu as moderately vulnerable area, since it has less potential of seismic hazard although it has rapid assets accumulation and less recorded potential loss or damage from previous occurrences. In more detailed observation, settlement unit in Sewon has vested in vulnerable area, moderately vulnerable area and marginally vulnerable area.

Second, despite its consistencies, vulnerability is dynamic in nature thus it is sensitive towards any perturbation. The research argues that the social-economic criterion is the most sensitive criteria among others since it has generated relatively different spatial pattern of social vulnerability, while hazard criterion is the most sensitive criteria to influence the physical vulnerability. Third, the SMCE-SV has fallen into ecological fallacies – a typical error which occurs when scenarios developed from large data proxies to represent individual entities. Thus, the future challenge is to create vulnerability assessment for detailed spatial unit to minimize unambiguous interpretation. This research has conducted the SMCE-PV using different observation scale to critically improve method. It has generated micro scale scenarios to clarify the ecological fallacies from previous SMCE-SV scenarios. Although, it is also consider to have systemic fallacies, which apparently indicates error from input, analysis and data management.

Given to critical social economic and natural condition, the research argues that the existing risk based spatial plan for Bantul District has not yet adequately involve hazard, vulnerability and risk information. It has acknowledged hazard scenarios – yet vulnerability scenarios – as exclusive protected areas due to natural hazard within spatial pattern plan, separated from other plan, i.e. spatial pattern for cultivated areas and spatial structure plan [9-14]. Apparently, this integration method has not yet embedded within overall spatial plan, thus conflicting plan arouses, i.e. settlement areas have designated in highly vulnerable areas. In different point of view, the risk based spatial plan scenarios is designed for 20 years period which is shorter compared to hazard and vulnerability scenarios which is lasted for 50 years. Shorter timeframe for the risk based spatial plan is an advantage as variable control to continuously amend future likelihood of vulnerability.
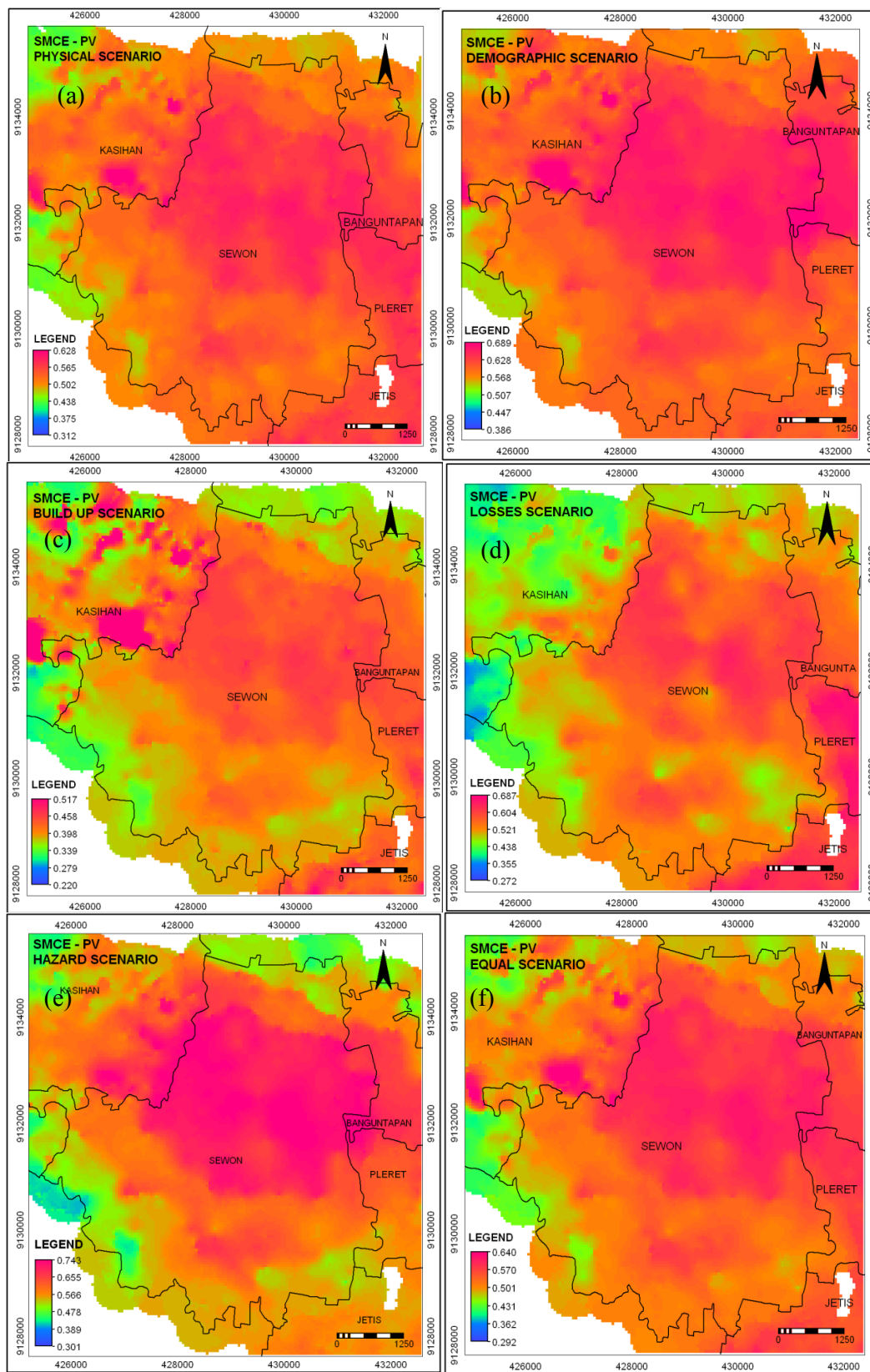
Figure 4 (a) SMCE-PV Physical Scenario; (b) Demographic Scenario; (c) Build-up Scenario; (d) Losses Scenario; (e) Hazard Scenario; and (f) Equal Scenario

The Indonesian government has initiated strategic integration through manifestation of Act Nr. 24/2007 on Disaster Management and Act Nr. 26/2007 on Spatial Plan. In operational level, the regional (provincial) government of D.I Yogyakarta has initiated to integrate hazard map into spatial plan as an exclusive protected areas, which has not yet integrate with other spatial plan. Thus, it is the local government of Bantul District who bears responsibility to carry on technical and procedural integration of vulnerability into overall spatial plan for detailed level. The future challenge is to integrate hazard and vulnerability into overall spatial plan instead of merely attach it as exclusive protected areas without further consideration towards other spatial allocation. Herein, the research has revealed that spatial plan in Bantul has not yet critical to amend future likelihood for vulnerability since it has not yet integrated its information within overall plan.

4. Conclusion

Urban vulnerability comprises from complex assessment towards different types of element at risk. Herein, the research presented the urban vulnerability which only limited to human vulnerability and settlement fragility towards seismic hazard using SMCE method. This method is fairly feasible to be implemented in Indonesian cases for three reasons: (1) employ multi criteria input, which allow as many as possible data to explain vulnerability; (2) assess vulnerability in spatial manner as it suitable to be integrated into risk based spatial plan and (3) generate several scenarios to assist decision-making process. Despite its ecological and or systemic fallacies, this method has promoted better mitigation system for vulnerable areas. It has also contributed towards manifestation of better and safer spatial utilization and spatial management for future sake.

Arguably, the integration of vulnerability into spatial plan entails observation from larger scope, i.e. strategic, technical, substantial and procedural scope. The national government and provincial government of Indonesia have initiated strategic integration, while this research has contributed to substantial and technical integration towards spatial plan. Unfortunately, in order to integrate new input into an established spatial plan method entails more than scientific knowledge and political will. Once again, the manifestation towards safer and sustainable development calls for more tailor-made initiatives, political endorsement, participative involvement and technical improvement in all sectors.

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