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Assessing social vulnerability to seismic hazard through spatial multi criteria evaluation in Bantul District, Indonesia

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Introduction

Natural disaster has become irrefutable research problem in modern science. One of too many research objectives is to test different predictive measurements to minimize future damages due to the natural disaster. Herein, the research aims to test spatial multi criteria evaluation (SMCE) for social vulnerability assessment (SV) in seismic prone areas ofBantul, Indonesia. In essence, the SMCE is a method which allows diverse input criteria to explain unstructured condition such as vulnerability. Given to seismic hazard potential among dynamic social economic condition causes certain degree of the social vulnerability towards particular hazard type, which off course cannot solely described by one exact criteria. Cutter (1996) proposed place based vulnerability to quantify vulnerability. She argued that natural (physical) – social interplay within specified geographic and temporal boundaries constructs certain degree of vulnerability. Cardona (2003) expressed that 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. This has differed vulnerability into social and physical vulnerability. Herein, the social vulnerability towards seismic hazard is an important indicator to predict pre-existing condition of being unfavorable due to seismic hazard expressed on a scale 0 (no loss/damage) – 1 (lethal/full damage). If an area within specified time subjects to social vulnerability indices up to 1, it means that the area suffers from potential lethal loss or full damage and vice versa. Based upon place based vulnerability, the research selected several input criteria to conduct SMCE for SV, such as physical, social-economic, demographic, and damage-loss, also hazard criteria. In disaster management cycle, the social vulnerability assessment is apparently plays formidable role within mitigation phase together with hazard assessment to come up with risk assessment.

The research focuses on the absence of vulnerability assessment in Indonesia which entails for scientific endorsement. Indonesia has strived to mainstream disaster mitigation strategy – including risk assessment – to attain better and safer future development (Act Nr 24/2007 on Disaster Management). It has thoroughly opted hazard assessment, but yet completed the vulnerability assessment, thus it has shortened risk assessment (Hizbaron et al., 2010). So, there is gap between national endorsements with local praxis. Based upon this regional problem, the research delineates works upon method selection to conduct the vulnerability assessment.

Research area coverssix sub-districts (Banguntapan, Kasihan, Sewon, Jetis, Pleret and Sedayu), which is vested in Bantul, D.I. Yogyakarta – Java Island, Indonesia. It is located between 7º 44' 50'' - 8º 37' 40''South Longitude and 110º 18' 40'' - 110º 34' 40'' East Latitude. It is adjacent to active subduction zone of south Java Island – a part of Indo-Australian tectonic plate that subducted beneath Eurasian plate (Irsyam et al., 2007). Bantul District experienced 6.2 Mw earthquakes in May 27th, 2006 which caused damages to nearly 80% out of the 508 km^2 total area, nearly 5.700 people died, and total economic loss was up to 3.134 million US$ (Bappenas; Local Governments of D.I Yogyakarta, 2006). Given to critical geologic setting towards seismic hazard, Bantul happened to be home formore than 823.000 in 2004 and up to 954.000 people in 2010, while the six sub-districts inhabits by nearly 425.057 inhabitants(Bappenas; Local Governments of D.I Yogyakarta, 2006; BPS

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Bantul, 2008; Disdukcapil Bantul, 2010). The research area depicts physical rural-urban expression and dominates by low to medium income group earn living from agriculture sector (42%) and non-agriculture sector (58%)(BPS Bantul, 2008). Apparently, there is rapid land conversion in the research areasince early 2000s which occursto 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(Bappeda Bantul , 2010).The long term development plan of Bantul 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.

This research employs inductive logics to empirically test some input criteria for the social vulnerability. It works based upon temporal and spatial boundaries as unit analysis. This research addresses this following question to attain the research objective: how to conduct SMCE application and how to justify SMCE application in terms of analytical unit, input criteria, generated scenarios, sensitivity criteria and weighting consistencies. The expected outputs are vulnerability indices and justification towards method feasibility.

Research method

There are various analytical methods to conduct the social vulnerability assessment to date. The SMCE is an applied science based method that combines spatial analysis using geographic information system (GIS) and multi criteria evaluation (MCE) to transform spatial and non-spatial input which generates output decision. There are several phases to conduct the SMCE, such as problem tree analysis, standardization, weighting and map generation.The problem tree analysis adopts multi goals and multi criteria to expose relationship among relevant criteria for main objective which generally clusters into group factors or constraints (Sharifi & Retsios, 2004). Problem tree analysis covers setting up main goals, criteria and factors. As it employs multi criteria, thus each criterion holds certain range scale value. 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 (Malczewski, 2004). Furthermore, he noted that 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 confirm validity of each generated scenarios and strengthening decision-making. The following figure and table indicates research flow (Fig.1).

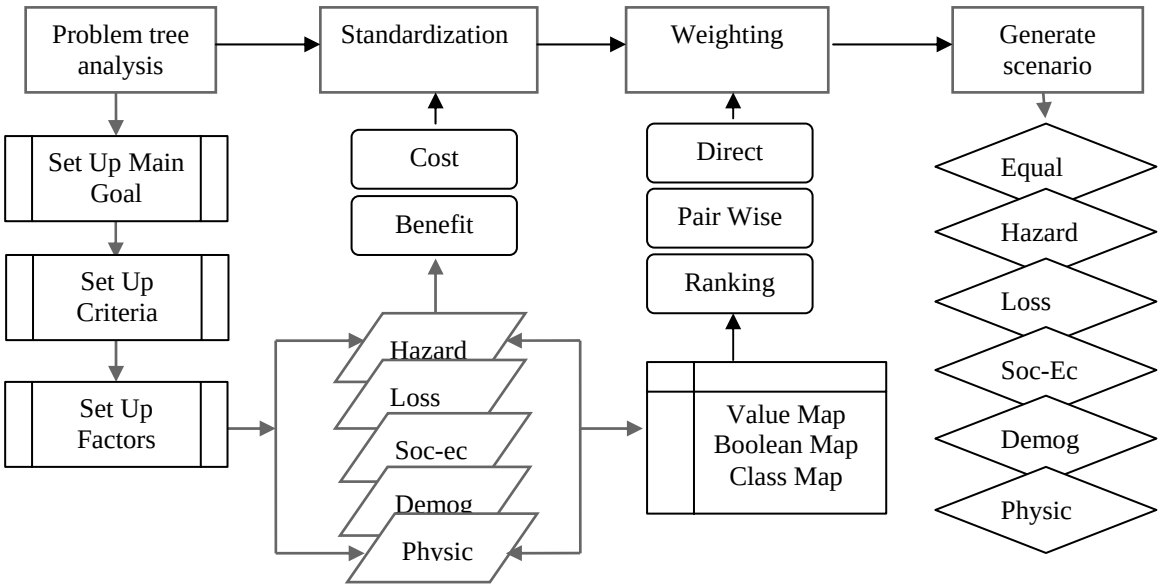

Fig.1 Research flow

The research has selected factors to describe criteria based upon data availability in the research area. 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. 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. There are thirteen factors within social-economic criteria, such as people with clean water access, electricity access and communication access, number of poor people (by household), people without saving, insurance and low income group, pension group, labor group also number of people with building asset, vehicle assets, cattle stock assets and productive land assets. There are two factors to describe damage-loss such as ration for immaterial loss and ration for damaged house. Lastly, seismic zonation factor explains hazard criteria.

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. Thus, physical scenario for example, assigns more weight to physical criterion (0.40) and equally assigns other criteria (0.15) since it expects that there is dynamic physical condition which contributes to vulnerability. Each factor requires different standardization method, and set in particular weighting scheme to generate six scenarios, such as physical, demographic, social-economic, losses, hazard and equal scenarios.

Result and discussion

Arguably, the SMCE method for SV requires two preliminary stages and four main stages. The preliminary stages are screening process and surveying phase. Screening process is important process to delineate prone areas towards specified hazard since hazard information is pivotal input within this exercise. This research selects hazard information from authoritative format published by Geologic Agency of Republic Indonesia which consists of deterministic scenario as noted above. Surveying phase is a follow up phase to conduct field survey if any required datasets are not available. The preliminary stages generally take more resources since data availability is not easily accessible. Meanwhile, four main stages such as problem tree, standardization, weighting and generated maps require skill, fair decision, and adequate scientific knowledge.

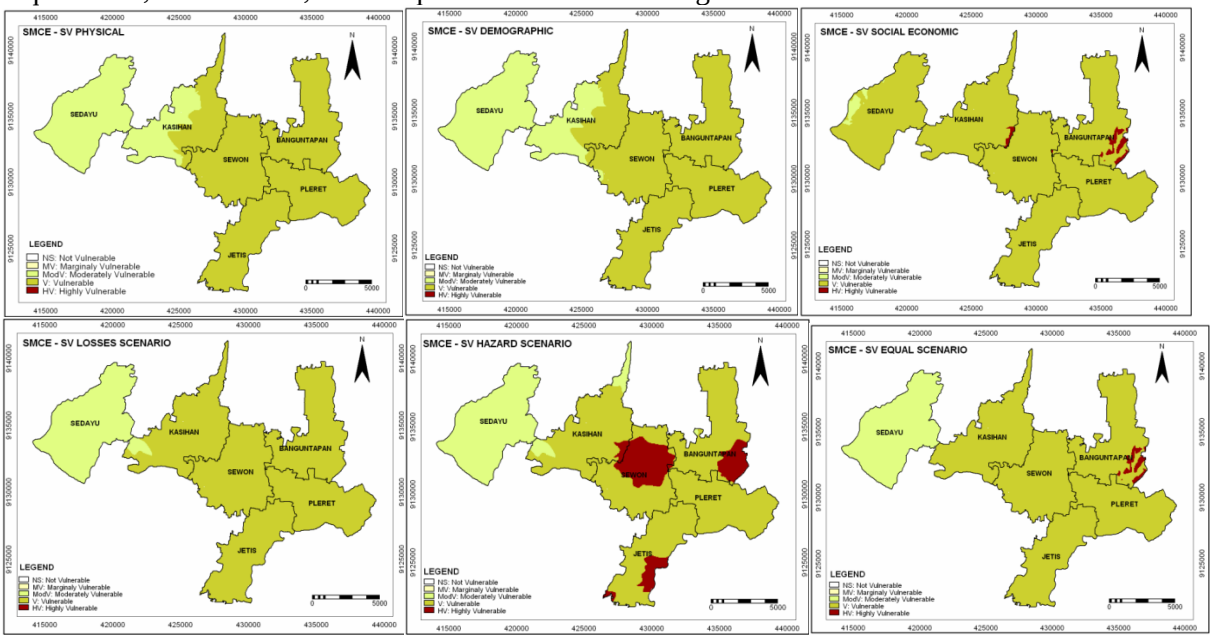

Fig.2 SMCE-SV Scenarios

The SMCE-SV has generated six deterministic scenarios pertains with these scenarios: if the research area likely to experience seismic activity originates from Opak fault – the most active fault in the research area – ornearby active fault structure, magnitude < 5 S.R, attenuation < 0.15 g, recurrence period between 2009 - 2059 and expose to major perturbation to physical/social-

economic/demographic/settlement unit/hazard/loss characteristics,thus the likelihood of the social vulnerability are spatially discern as depicted in the Fig.2. The other scenarios have similar logical thinking. The equal scenarios represents 'if scenario' expects for equal perturbation of all criteria.

The generated six scenarios indicate consistencies. Each scenario consists of composite map with indices value from 0.51 to 0.79 (Fig. 2). The social vulnerability indices is set into five categories, 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). 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). Some areas in Sewon, Banguntapan and Jetis are considerably high vulnerable area because it is posited in high seismic zone, and socially-economically vulnerable. Overall, Sewon, Banguntapan, Jetis, Pleret and part of Kasihan are subjected to vulnerable areas due to social-economic assets accumulation. Accumulation of people and their assets seemingly become major cause of the social vulnerability, while given potential seismic hazard apparently predominant for Jetis and Pleret. The more moderate vulnerable area is Sedayu, since it has less potential of seismic hazard although it has rapid assets accumulation and less recorded potential loss or damage from previous occurrences. The research argued that the social-economic criterion is the most sensitive criteria among others since it has generated slightly different spatial pattern of vulnerability compare to other scenarios.

Concluding remarks

The research finding has indicated that the SMCE-SV best operates in spatial unit, although it falls into ecological fallacies. In some sense, the SMCE operates using deductive logics, i.e. input criteria selections and standardization depends upon user's knowledge to control bias subjectivity. Despite its limitation, this method has promotes early awareness towards vulnerable areas. It also contributes towards better and safer spatial utilization and spatial management for future sake.

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