An integrated assessment of spatial planning towards the multi-hazard risk in Surakarta City

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Abstract. The urban development is correlated to urban economic growth. This situation often produces negative impacts on the environment, such as the emergence of disaster risks. Oftentimes, disaster risk existence is not sufficiently considered in spatial planning. Consequently, urban development does not support the efforts of urban disaster risk reduction and adaptation. This paper discusses the synchronization between spatial planning, and multi-hazard risk reduction and adaptation. Surakarta City was selected for the research case. This city has a multi-hazard risk including flood, fire, and traffic accidents. This paper evaluated the synchronization of the multi-hazard risk to the spatial planning of Surakarta City. This research used a deductive approach, and it is documentary research. The main data were based on urban institutional documents. Furthermore, the descriptive analysis technique was used for exploring the data and information. The research result explains that the procedural evaluation shows the most part of the integration process of the multi-hazard risk assessment that has been conducted, although, on another side, the substantive evaluation indicates that the lack of criteria integration for the multi-hazard risk and the urban spatial planning takes place.

1. Introduction
Indonesia is one of the archipelago countries having high disaster risks. In the last two decades, several natural disasters took place in this country, such as tsunami, earthquake, flood, volcano, fire, landslide, liquefaction, and drought. The occurrences of the tsunami in Aceh (2004), and the earthquake in Yogyakarta (2006) produce governmental awareness concerning the efforts of comprehensive disaster risk management from the national scale to local scale. The national government created the law of disaster management (2007) as a national regulation to anticipate the high-risk disasters in Indonesia. Furthermore, the law of spatial planning (2007) stated the consideration of disaster risks must be accommodated in the spatial planning from the national scale to the local (municipality) scale. Recently, the national government leads the municipalities to have a disaster management master plan. In fact, oftentimes, the urban disaster risk assessment is less considered to spatial planning. Furthermore, the disaster management master plan and the spatial planning are less correlated, and consequently, the disaster risks took place in the high-density areas of buildings and population. The spatial planning that is based on the environmental approach produces positive impacts for society, particularly, the disaster risk reduction [1]. The innovative land use
planning for natural hazard risk reduction is needed for urban development [2]. The spatial planning that accommodates disaster risk becomes one of the key elements to achieve urban sustainability. The risk of spatial planning and vice-versa should be recognized and implemented to enhance urban resilience [3,4].

Surakarta is one of the Indonesian cities which have composed the disaster management master plan in 2018. Although this master plan has not been officially implemented for the municipality regulation, it has become the guidance for urban disaster management. Meanwhile, this city has the spatial planning for 2011-2031, so that the urban development must refer to this plan. The documentation of the disaster management master plan mentioned that Surakarta City has four disaster risks including flood, building and settlement fire, technological failure (traffic accident), and social conflict [5]. The flooding is a natural disaster, meanwhile, the building and settlement fire and the traffic accident can be categorized as non-natural disasters. The social conflict is related to the social disaster. The assessment of the risk in spatial planning can be implemented for natural and non-natural disasters. However, the assessment of social disaster risk in spatial planning is difficult to be explained. Based on the information, the assessment of multi-hazard risk in spatial planning of Surakarta City will focus on flood risk, building and settlement fire risk, and traffic accidents.

![Figure 1. Surakarta City. Modification of Disaster Management Master Plan (2018)](image)

**2. Multi-hazard risk and spatial planning**

2.1. Multi-hazard risk

Indonesian acts no. 24/2007 describes that the potential losses are due to the disaster in a region happening during a certain time, and it can affect death, the person injured, illness, the threat for people, sense of insecurity, evacuation, damage, or loss of property, and disturbance for society [6]. Meanwhile, United Nation Office for Disaster Risk Reduction (UNDRR) defines disaster risk as a potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity [7]. Based on the definition, disaster risk reduction should be considered in urban planning and development. Furthermore, the multi-disaster risk is often recognized as the multi-hazard risk. Hazard is a cause of disaster occurrence. It is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation [8]. The multi-hazard risk describes the potential disaster occurs due to the multiple causes (sources) including natural phenomena and human activities and errors. It describes different hazards affecting the same exposed
elements in a given area [9,10]. These perspectives describe disaster risk in certain spaces, such as area (zones), city, region that should be observed through the existing multi-hazard risk, so that the comprehensive approach of mitigation efforts could be achieved. All possible hazard interactions among different hazards are considered in multi-hazard risk assessment. It can effectively fill the gap in current multi-hazard risk assessment methods which to date only consider domino effects [11].

Indeed, the assessment of multi-hazard risk is not implemented easily. This condition is related to the lack of a precise definition of terms generally agreed by all different communities, and also the data availability limitations [12,13]. However, the assessment method of multi-hazard risk is very general, but the multi-hazard risk assessment should be conducted in the local context. Inappropriate hazard risk assessment causes the space more vulnerable due to the limitation of appropriate mitigation efforts. Although the disaster-related data availability is limited, the risk assessment should be implemented in local scales carried out by the local authorities.

2.2 Assessment of multi-hazard risk to spatial planning

One of the systematic and comprehensive institutional efforts for disaster risk reduction is spatial planning. It is a form of mitigation besides structural (construction) mitigation, and community empowerment and institutional capacity for reducing the disaster risk. The spatial planning approach including regional and urban planning approaches is a key to disaster risk management to achieve urban resilience. Spatial planning plays a significant role in enhancing climate change adaptation, especially within urban areas by improving their resilience [4]. It remains a relevant tool to manage the impacts of climate change; hence, the need to incorporate climate change issues in local policies and plans is necessary [14]. The lack of spatial planning has a consequence of disaster risk increase. It is related to urban growth and development, so when it does not describe the urban risk management clearly, there is a possibility that the urban development produces the increasing of disaster risk. On the other hand, the extent of physical growth and its impact on increasing disaster risk occurs in plot (local) level and area-level [15]. Meanwhile, the integration of climate change adaptation into disaster risk reduction and urban planning is still left behind the advances made in the environmental management field [16]. Climate change and increasing urbanization create huge challenges in managing urban planning for a sustainable future [17]. These situations indicate that the integration of spatial (urban) planning and disaster risk management is not easily implemented. In the city context, the existence of multi-hazard risk should be covered in urban planning. The comprehensive approaches are needed for the integration of multi-hazard risk assessment to urban planning.

3. Method

This study uses a deductive approach, in which several selected variables are used for understanding the integration of multi-hazard risk to spatial planning. It is documentary research seeking the exploration of institutional documentation relating to the multi-hazard risk and spatial planning. Furthermore, the analysis techniques are supported with descriptive analysis for assessing the figures, statistical data, and information relating to multi-hazard risk and urban spatial planning. The assessment of the multi-hazard risk level is based on the number of hazard risk in an area.

Table 1. Assessment of multi-hazard risk level.

| Multi-hazard risk | Level  | Indicator                                           |
|-------------------|--------|----------------------------------------------------|
|                   | Zero   | No existed risk                                    |
|                   | Low    | - one risk                                          |
|                   |        | - low intensity of risk (frequency, and capacity)   |
|                   | Medium | - one or two risks                                  |
|                   |        | - from low to medium intensity of risk (frequency, and capacity) |
|                   | High   | - more than two risks                               |
|                   |        | - from medium to high intensity of risk (frequency, and capacity) |
The useful data supports the urban and spatial planning in post-disaster recovery including the available data such as cadastral maps, risk and hazard maps, base maps, statistical data, and special surveys, and the post-disaster damage data such as public authorities’ data, citizens’ and volunteers data, private organizations data, and international organizations [18]. Furthermore, the comparison between disaster resilience and urban planning can be conducted through a mix of the diversity of public open spaces, plan for everyday life with adequacy, design of loose spaces, getting the highest and best use of urban space, and plan networks of public open space [19]. These elements will be considered as the variables of research.

The evaluation of integration between multi-hazard risk and spatial planning can be understood by assessment criteria. The framework of criteria to measure impact assessment effectiveness includes procedural, substantive, transactive and normative[20, 21]. Other arguments explained the effectiveness of the impact assessment, identifying three dimensions: substantive, procedural and incremental [22]. Our research explains the evaluation of multi-hazard risk and spatial planning integration by the assessments of substantive and procedural criteria. These criteria are commonly used for the evaluation process.

Table 2. Criteria of the integration of multi-hazard risk and spatial planning.

| Variable | Procedural criteria | Substantive criteria |
|----------|---------------------|----------------------|
| Cadastral and based maps | Available and synchronized detailed maps of the multi-hazard risk in spatial planning | |
| Statistical data from public authorities, communities, and private organizations. | Available and synchronized detailed statistical data of the multi-hazard risk in spatial planning | |
| Special surveys | Primary data and information from communities about multi-hazard risk are used for composing spatial planning. | |
| Public open space in a risk area | - Public open space is a minimum of 30% | |
| Built-up area in a risk area | - The low density of the built-up area in the high multi-hazard risk area. - The high density of built-up areas in no existed or low multi high-risk area. | |
| Urban activities and concentration of population in a risk area | - Low urban activities in a high multi-hazard risk area. - High urban activities (urban centers) in no existed or low multi-hazard risk area. - The low number of population in the high multi-hazard risk area. - The high number of population in no existed or low multi high-risk area. | |
4. Analyses and discussion

4.1 Lack of multi-hazard risk identification in the disaster management master plan

The disaster Management Master plan is the essential documentation for urban disaster risk reduction. The appropriate master plan produces the effectiveness of urban disaster risk reduction. The first disaster management master plan of Surakarta City needs an assessment to explore the quality of achieving urban disaster risk reduction. The procedural evaluation is used for assessing that documentation. Several criteria for this evaluation include the cadastral and base maps, the statistical data availability, and the primary surveys concerning the existing multi-hazard risk. The identification of documentation shows that the limitation of the cadastral and base maps identify and analyze the existing multi-hazard risk. The maps of multi-hazard risk are presented inappropriately. The delineation of hazard risk is based on the administrative boundaries, not on the risk impacted areas. This situation produces obscurity of hazard risk area delineation, and consequently, those maps cannot support proper mitigation efforts.

Furthermore, there is a lack of statistical data and information supporting the spatial analysis for the multi-hazard risk. The statistical data only describe the number of disaster risk occurrence, without the clear description of disaster risk delineation area. It indicates the difficulty of urban disaster risk identification, and it produces the limitation of multi-hazard risk assessment. In addition, the limited primary data concerning multi-hazard risk influences the lack of spatial analysis. The primary data is only results of interviews with several subjects who are considered to recognize the existence of multi-hazard risk. The interviews did not produce the spatial data of multi-hazard risk existence. These data and information were used for the assessment of multi-hazard risk; consequently, the assessment of the multi-hazard risk level is only based on the frequencies of disaster occurrences. It indicates the ambiguous of multi-hazard risk analyses, thus, these analyses will be difficult to be integrated with spatial planning.

Figure 2. Multi-hazard risk including flood, fire, and traffic accident in Surakarta City. Modification of Disaster Management Master Plan of Surakarta City (2018)
4.2 Limitation of multi-hazard risk identification and strategies in the urban spatial planning

The discussion is based on a procedural evaluation to identify the existence of multi-hazard risk assessment in the institutional documentation of urban spatial planning. The exploration of the spatial planning documentation (final report and regulation of municipality) shows that disaster risk management is attempted to integrate the spatial planning. The integration of multi-hazard risk is found in the related regulation for composing spatial planning, the urban plans relating to urban risk adaptation (anticipation) such as the evacuation plans to anticipate the disaster occurrences. The disaster risk being explained in the spatial planning documentation includes flood hazard risk and geological hazard risk. However, the identification of those risks is limited. The identification of geological hazard risk is only the predictive disaster that may occur in Surakarta City, and it is not supported by the appropriate statistical data and cadastral maps so that it seems just an assumption. Meanwhile, the identification of flood hazard risk is better than that of geological hazard risk. It is described from the history of flood occurrences, and the delineation of existing flood risk. Furthermore, the urban plan for multi-hazard risk management only focuses on the general plan of evacuation for communities. The evacuation plan was made for all disaster risks, and there is no evacuation plan for specific disaster risk. In addition, the urban spatial planning documentation mentions that the improvement of roads and new roads are needed for the development of evacuation routes. Nevertheless, it does not mention explicitly, the areas needing the improvement of roads or new roads. These situations indicate that the procedure of the integration of single hazard risk (flood risk) was conducted in urban spatial planning, but the substantive evaluation remains questioned. Limitedness of multi-hazard risk assessment is only complementary information in urban spatial planning.

![Evacuation routes plan for disaster anticipation](image_url)

**Figure 3.** Evacuation routes plan for disaster anticipation in the Spatial Planning of Surakarta City. Modification of Spatial Planning of Surakarta City (2011)

4.3 Unsynchronized spatial planning for multi-hazard risk reduction

The exploration of this part is conducted by the substantive evaluation. It seeks to correlate the existing urban spatial planning and the existing urban disaster management master plan. Several criteria of identification are conducted to be compared and be analyzed based on those documents.
Figure 4. Spatial Planning of Surakarta City for 2011-2031. Modification of Spatial Planning of Surakarta City (2011)

Note:
- Light yellow: settlement with low density of built up area
- Yellow: settlement with medium density of built up area
- Orange: settlement with high density of built up area
- Red: Office zone
- Pink: educational zone
- Mauve: commercial zone
- Clay: warehousing zone
- Purple: Health zone
- Dark green: greenbelt of river
- Light green: green urban zone
- Green yellow: heritage zone
- Blue: river or lake
- Black: Military zone
**Table 3.** Assessment of the integration of multi-hazard risk and spatial planning.

| Variable                  | Disaster management master plan                                                                 | Urban spatial planning                                                                 | Integration                                                                                     |
|---------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Type of disaster risk     | The existence of the multi-hazard risk including flood, fire, and traffic accident               | It describes the multi-hazard risk includes flood and geological hazards.               | It is only a flood risk being mentioned in both documents. The spatial planning does not discuss urban fire, and traffic accidents as the multi-hazard risk in Surakarta. |
| Public open space in the risk area | It mentions only the plans of the relocations of settlements located along urban rivers as the efforts for the increase of public open space. However, it does not describe explicitly the locations of settlement relocations. | The number of public open spaces is planned to increase, but it remains less than 30% of the city area. | There is no specific analysis and strategies indicating the spatial plan and design of public open space in the risk areas. The addition of green open space in spatial planning relating to disaster management is only the providing of green belt around urban rivers. |
| Built-up area in the risk area | It does not describe explicitly the arrangement of built-up area for disaster risk management. | The southeast of the city is recognized as the flood risk impacted areas, but it remains planned as the settlements with a medium density of a built-up area, although there is the plan of green belt along the urban rivers. It indicates that disaster risk assessment is less considered in urban spatial planning. Furthermore, there are no spatial plans for the reduction of urban fire and traffic accident risk. | Both documents do not clearly explain the arrangement of the built-up area in the risk area. |
| Urban activities and concentration of population in the risk area | It does not explicitly describe the consideration of urban activities and the concentration of population in risk areas for disaster risk management. | The spatial plans of concentration of population and urban activities are not based on the existence of multi-hazard risk. There is the explication of urban activities and populations in multi-hazard risk areas including flood, fire, and traffic accidents. | There is no consideration of urban activities and concentration of population related to urban risk reduction through spatial planning. |

5. Conclusion
This article concludes that there is the disintegration of multi-hazard risk and the urban spatial planning of Surakarta City. Indeed the procedural evaluation shows that the most part of the integration process criteria of multi-hazard risk to urban spatial planning has been conducted. Although the master plan of disaster management describes the different hazard risks (urban fire risk, and traffic accident risk) from the document of urban spatial planning, it still indicates the procedure of the multi-hazard risk assessment implemented into the urban spatial planning. Nevertheless, the substantive evaluation explains that the majority of substantive criteria including disaster risk type, public open space in the risk area, the built-up area in the risk area, and urban activities and concentration of population in the risk area, for the integration of multi-hazard risk into the urban spatial planning which has not been correlated. This study recommends to the city authority that the revision of urban spatial planning with the consideration of the proper multi-hazard risk should be conducted. However, the appropriate multi-hazard risk assessment must be supported by adequate cadastral and based maps, the detail statistical data and information, and the proper surveys for detail primary data concerning the multi-hazard risk in Surakarta City.

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