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RESEARCH ARTICLE

A support tool incorporating a district disaster mitigation performance evaluation method for the examination of improvement plans in built-up areas

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Abstract
Approximately 20,000 ha of densely built-up areas still remain in Japan. However, the advance of improvements in these areas has been very slow. Thus, making draft improvement plans through citizen-administration partnerships is indispensable to promote improvements. The planning support tool proposed in this study supports a consensus-building process during the creation of draft improvement plans. We develop a disaster mitigation performance evaluation method (DMPEM) for built-up areas at the district level and incorporate this method into a disaster mitigation support Web-GIS. However, DMPEM requires lengthy calculation time because it uses the probabilistic Monte Carlo computation method. Using this tool in real-time planning is therefore difficult. In this study, we first develop a system that reduces the calculation time required by DMPEM. Second, the support tool is used to make draft plans through citizen-administration partnerships in districts where residents are conducting various disaster mitigation activities. Finally, we investigate the usefulness of the tool for consensus building through the promotion of lively discussions among residents and clarify the issues associated with practical use of the tool.

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1. Introduction

1.1. Background and purpose

Japan has one of the highest earthquake risks of any country in the world. The country has already experienced large-scale earthquakes, such as the Kanto Earthquake in 1923, Hanshin/Awaji Earthquake in 1995, and Tohoku Earthquake in 2011. Thus, there is an urgent need to increase disaster preparation and planning efforts to enhance the safety of those who may otherwise become victims of urban earthquake disasters. A large number of densely built-up areas that are extremely vulnerable to earthquakes (approximately 20,000 ha) still remain in Japan, and the implementation of corrective measures in these areas has been very slow.

Collaboration between local governments and residents is essential to promoting urban improvements. Building consensus is one of the most difficult planning challenges because of the various stakeholders involved. Consequently, implementing safety measures in densely built-up areas is difficult. The planning support tool proposed in this study is designed to facilitate consensus building through on-site group discussions that involve residents, government officials, and experts in a shared examination of the risks and drafting plans for a target area.

To support this type of group discussion, we have developed a disaster mitigation performance evaluation method (DMPEM) that incorporates a Web-GIS tool for use in built-up areas at a district level. The DMPEM is composed of two methods: a fire spread risk evaluation (FSRE) (Ohgai et al., 2004, 2007; Gohnai et al., 2006) and an evaluation of emergency response and evacuation (EERE) activities (Gohnai et al., 2007), both of which we originally developed. With both methods, evaluating the effectiveness of disaster mitigation activities at the micro level of the areas requires considerable computation time because of the probabilistic Monte Carlo calculation method. Therefore, the availability of DMPEM during group discussions focuses on examining draft improvement plans, which is the most critical issue that needs to be addressed in developing the Web-GIS tool.

This study aims to achieve the following objectives:

1) To develop a Web-GIS tool incorporating DMPEM that will aid consensus building in on-site group discussions focused on examining draft improvement plans.
2) To investigate the usefulness of the proposed tool.

1.2. Perspective for developing a Web-GIS tool

PC performance is the key to reducing the DMPEM computation time. Using a high-performance PC, such as a supercomputer, is a simple method. We assume that local governments use this tool for system construction, management purposes and other practical uses. Considering the financial difficulties of local governments in recent years, using costly, high-performing PCs is not feasible. Therefore, we adopt a method using the type of PCs to which local governments generally have access to distribute the calculation process.

1.3. Review of previous research

The developing Planning Support Systems (PSS) and decision support systems (DSS) aim to facilitate the examination of plans in the field of urban planning. In particular, studies on system developments using the GIS technique have multiplied all over the world since 1960s, along with advances in computer technology. Studies on the development of PSS and DSS that incorporate GIS techniques have been reviewed and organized (Harris and Batty, 1993; Klosterman, 1995, 1997) and recently reorganized (Klosterman and Pettit, 2005).

In Japan, PSS and DSS have been integral to the field of urban planning since the 1980s. In particular, studies incorporating GIS, computer graphics and virtual reality have been conducted since 1990s. For example, a PSS was developed to understand the characteristics of a subject area and evaluate and share townscape images after an improvement is identified through a community workshop using virtual reality (Arima et al., 2007). PSS was developed to promote consensus building among community-based organizations exploring townscape designs and its effectiveness in promoting lively discussions focused on exploring draft plans for townscape images has been verified (Shen and Kawakami, 2010).

Although studies have been conducted on various PSSs, only a few of them consider the development of PSS and DSS for urban disaster mitigation. The development of PSS for disaster mitigation aimed at improving densely developed areas started after the 2000s. Murakami et al. (2001) developed a PSS to improve densely built-up areas. There was the pioneer study on developing PSS for disaster mitigation. Although experts, such as urban planning consultants and local government officials, use PSS, providing DMPEM information on urban areas to community-based participants is important when exploring draft improvement plans for disaster mitigation (Pearce, 2003). A comparison of the DMPEM data that summarize the current conditions and the DMPEM data that summarize the conditions after the improvements is important to understand how safety has been improved, particularly when residents have been involved in discussing the improvement plans (Kato et al., 2002; Karashima et al., 2014). After reviewing previous studies of PSS that incorporate DMPEM in Japan, Kato (2008) developed a PSS that can compare the current conditions with those after the improvements. However, PSS has not been used in on-site discussions, such as workshops, not has it been used to improve densely built-up areas.

Ohgai et al. (2004), (2007) and Gohnai et al. (2006), (2007) sought to develop PSS for use in on-site community-based activities and explore draft plans in venues, such as workshops. Although the fire spread simulation tool enables users to provide simulation results during discussions, the FSRE and EERE tools, which can evaluate quantitative disaster risks, cannot provide results during a discussion. Therefore, the draft plans being explored by the participants must be entered, the urban areas represented in the draft plans must be evaluated, and the analysis results must be provided before concluding the discussion to achieve the