Frontiers of Architectural Research (2016) 5, 39–51

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Frontiers of Architectural Research

RESEARCH ARTICLE

A GIS-based methodology for safe site selection of a building in a hilly region

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Received 14 January 2015; received in revised form 1 January 2016; accepted 4 January 2016

KEYWORDS
Construction safety;
GIS;
Site selection;
Spatial safety aspects;
Topography;
Safety code provisions

Abstract
Worker safety during construction is widely accepted, but the selection of safe sites for a building is generally not considered. Safe site selection (SSS) largely depends upon compiling, analyzing, and refining the information of an area where a building is likely to be located. The locational and topographical aspects of an area located in hilly regions play a major role in SSS, but are generally neglected in traditional and CAD-based systems used for site selection. Architects and engineers select a site based on their judgment, knowledge, and experience, but issues related to site safety are generally ignored. This study reviewed the existing literature on site selection techniques, building codes, and approaches of existing standards to identify various aspects crucial for SSS in hilly regions. A questionnaire survey was conducted to identify various aspects that construction professionals consider critical for SSS. This study explored the application of geographic information systems (GIS) in modeling the locational and topographical aspects to identify areas of suitability. A GIS-based methodology for locating a safe site that satisfies various spatial safety aspects was developed.

1. Introduction

Site selection, as one of the key principles of building planning, plays an important role and has a huge impact on the design of a proposed building (Cheng et al., 2007). The relation of a site to its surroundings significantly influences the decisions of architects and engineers. The site requirements for buildings depend on the type of occupancy. For example, a site that is suitable for residential buildings may not be suitable for buildings with some other purpose. Thus, buildings proposed for different purposes have different requirements and considerations in their site selection.

Architects and engineers play a major role and contribute significantly to site selection. Their expertize depends upon their depth of knowledge and experience, which results in

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Peer review under responsibility of Southeast University.

http://dx.doi.org/10.1016/j.foar.2016.01.001

variations in location-based decisions. Generally, their decisions about site selections are based on an analysis in terms of simple calculations, past experience, or even preference. The traditional approach to site selection requires efforts from a number of experts from various fields to select the best alternative by considering the available information and geographic variables (Molenaar and Songer, 1998).

The purpose of site selection is to determine the best possible site for a building within a specific region (Ghobarah, 1987). Site selection significantly influences the success or failure of a project. In many instances, especially in developing countries, project failure is caused by the unsuitable site of a building (Ghobarah, 1987). The best site is the location in which a building can be established with a minimum use of resources (manpower, material, machines, money, and time) and which is logistically and economically viable, adequate, and safe for future expansion (Paradis and Trans, 2013).

In recent years, sustainability has increasingly become a priority of building projects. Sustainable construction begins with suitable/safe site selection (Paradis and Tran, 2013). The location of a building affects a wide range of factors, such as environment, safety, security, accessibility, and energy consumption, for commuting the impact on the local ecosystem and the use/reuse of existing infrastructure (Carsjens and Ligtenberg, 2007). Architects and engineers involved in site selection should understand sustainability concepts and their effects on the overall safety and performance of a building. Hence, the need for professionalism in SSS assumes a special significance.

Site selection of a building involves the evaluation of various aspects with different degrees of importance or percentage influence. It depends upon the importance of locational and topographical aspects that remain in a continuous state of change because of changes in building size, technology, building requirements, topological factors, and safety provisions. To ensure that the critical aspects influencing site selection are not overlooked, a methodology has to be evolved for the SSS of a building.

2. GIS in site selection

SSS involves measuring the needs of a proposed facility against the merits of potential locations (Vahidnia et al., 2008). It involves the selection of a piece of land for any building in accordance with prevailing safety codes. The inclusion of safety in site selection is recognized as imperative for sustainability (Rajendran, 2006). Rajendran and Gambatese (2009) suggested that the best way to enhance the sustainability of buildings is to consider site safety from inception. This approach is a step toward drawing the maximum benefit of project objectives in terms of time, cost, quality, and safety (Rajendran, 2006). Several studies (Bennui et al., 2007; Cheng et al., 2007; Hernández et al., 2004; Li et al., 2005, Özdağoğlu, 2012) indicate that minimum research and knowledge exist in SSS.

The basic aim of SSS is to integrate a building with the natural environment with the least damage to nature, as well as to harness all natural resources (MoEF, 2006). To utilize natural resources such as light, air, and water inside the building without damaging the natural environment, the exploration and evaluation of site characteristics during site selection are important. Given the varying site conditions from place to place, no single method of SSS is applicable; it largely depends upon the analysis of information concerning a specific region and the spatial safety parameters for a particular building. A clear, complete, and practicable safe site should be in strict compliance with safety provisions. Selecting a site as per safety provisions means better adherence to schedules, lower developmental and constructional cost, higher quality, and improved safety during construction (Ghobarah, 1987).

In the last three decades, various techniques to solve site selection problems have been developed. In literature (Vahidnia et al., 2008; Özdağoğlu, 2012; Erensal et al., 2006; Tomić et al., 2014; Awasthi et al., 2010; Forzieri et al., 2009; Dinler et al., 2015;Ugo, 2015; Huifeng and Aigong, 2008; Koçak, 2010), various techniques of site selection have been presented. Depending upon the complexity of the location problem, selection techniques vary from heuristic to exact methods. Prescribed standards, handbooks, and other defined practices by CPWD (2014) and NHAI (2006), among others, are also adopted in developing countries, such as India. In site selection, two-dimensional (2D) maps, plans, and sketches are widely used. To represent the ideas of architects or engineers, solid three-dimensional (3D) models and CAD-based 3D models are also used (Waly and Thabet, 2002). CAD-based 3D modeling focuses mainly on the visualization. However, site selection requires other capabilities of geospatial analysis where CAD-based systems are lacking.

SSS in hilly regions needs to consider aspects such as landslides, slope stability, topography, and drainage in addition to ensuring minimum adverse impact on the fragile environment. These considerations also have a strong impact during the construction stage (NBC, 2005). Furthermore, architects and engineers need spatial information about the neighborhood of a building to know its dependence on existing facilities/utilities. Such dependence cannot be easily modeled in the absence of GIS. The use of GIS allows for viewing and analyzing the effects of locating a proposed facility in the neighborhood of existing facilities/utilities (Tardie et al., 2003). Increasing the accessibility of GIS provides new ways and means for researchers and construction professionals (Greene et al., 2011). GIS is also useful to promote the spatial navigation of infrastructure planning and sustainability of the region (Chang et al., 2014).

Locational and topographical aspects of a region play a key role in site selection. Keeping in mind the importance of these aspects, architects and engineers create, store, and share 3D models of a building along with its surroundings in GIS (Bansal, 2011b; Bansal and Pal, 2008). Literature suggests the use of GIS for site selection of real estate projects (Li et al., 2005), shopping malls (Cheng et al., 2007), and large wind turbines (Bennui et al., 2007) to assess the impact of buildings on landscape in site selection (Hernández et al., 2004). The applicability of building information modeling in the geospatial environment has also been investigated to support the site selection process (Isikdag et al., 2008). Karan and Ardeshir (2008) suggested that GIS is an effective tool for safety assessment and for