# APPLICATION OF GIS IN BUILDING ENVIRONMENTAL IMPACT ASSESSMENT IN HONG KONG

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## ABSTRACT

With the deterioration of environment, the environment of human life has been facing a serious threat. Environmental protection and environmental impact assessment have become important research directions. Effective tools for evaluating environmental impact of construction activities also have increasing concerns by researchers. This paper reviewed some assessment methods of environment impact and the development of GIS applications in this field in world and in Hong Kong. The paper proposed a model of GIS based environmental impact assessment platform and did some simulations to proof its advantages and effectiveness. Finally, some problems had been proposed for further works.

## KEYWORDS

Environmental Impact Assessment, GIS based platform, EIA Ordinance

## INTRODUCTION

With the rapid development of industry, the pollution caused by industrial emissions has become a major impact on the human living environment. The environment changes which brought by this impact have affected all aspects of human life. Environmental protection has become the one of the most important missions in the 21st century. In research area, the issues related to environmental protection are significant increased in recent years.

Attention to the environment of mankind began in the 60s of last century. The United States began to investigate the hazards of high toxic pesticides in early 60s, and thus led to the widespread attention to the environmental impact of production process. Finally in 1970s, the US established Environmental Protection Agency. In June 1972, first United Nations Conference on Human Environment held in Stockholm, Sweden. This conference proposed the establishment of environmental protection organization by government in all member states. Hong Kong government established the Environmental Protection Group in this period, and was formally transferred to Environmental Protection Department in 1986.

The definition of environmental pollution is very broad, and the protection methods are multiple. However, the emission produced in construction has become a major factor of environmental pollution. The main possible impacts in construction conclude the following aspects: air, soil, water, noise and the social effect such as economy and culture. Therefore, for the sustainable development, people must evaluate the environmental impact of construction projects.

## BUILDING ENVIRONMENTAL IMPACT ASSESSMENT

Building environment is a natural science which reflected the relationship among people, building and environment (Cole, 1999). Building Environment is a cross-system subject which involves construction technology, environmental monitoring, facilities management, medicine and health, environmental psychology, living psychology and other subjects.
Environmental impact assessment refers to analysing, forecast and evaluating the possible environmental impact of planning and implementation phases in construction projects, proposing policies and measures to prevent or mitigate adverse environmental impacts and methods for tracking and monitoring environmental changes. This is the concrete embodiment of "prevention first" principle in pollution prevention and ecological protection. And it is also an effective way to avoid "pollution first, treatment later or the destructing first, recovery later"

situation (Zhang et al, 2004).

For evaluating the environmental impact of construction projects, many countries published their own environmental impact assessment (EIA) methods. For example, the laws of environmental protection in US, the Hong Kong Environmental Impact Assessment Ordinance (EIAO), etc. In fact, environmental protection is a wide range concept, any issues which are related to the environment or affect environmental may be concerned as environmental problems. However, not every environmental issue has a law or an ordinance as environmental protection principle. Different environmental laws or ordinances also have different application scopes. Hong Kong for example, the EIAO by EPD is only adapted to the large construction projects which have great impact on environment. This EIAO do not support all new buildings or renovation projects, especially the residential buildings, office buildings, commercial buildings and others which were accounted for a large proportion of constructions. Therefore, a wide range adapted environmental assessment method has been gradually concerned in recent years.

Currently, the building environmental assessment methods and definitions have not completely unified. In addition, different researchers identified the environmental assessment factors are also emphasis on different aspects. Crawley and Aho (1999) proposed the assessment of the building environment that can be divided into two parts of environmental impact assessment and life cycle assessment, as figure below:

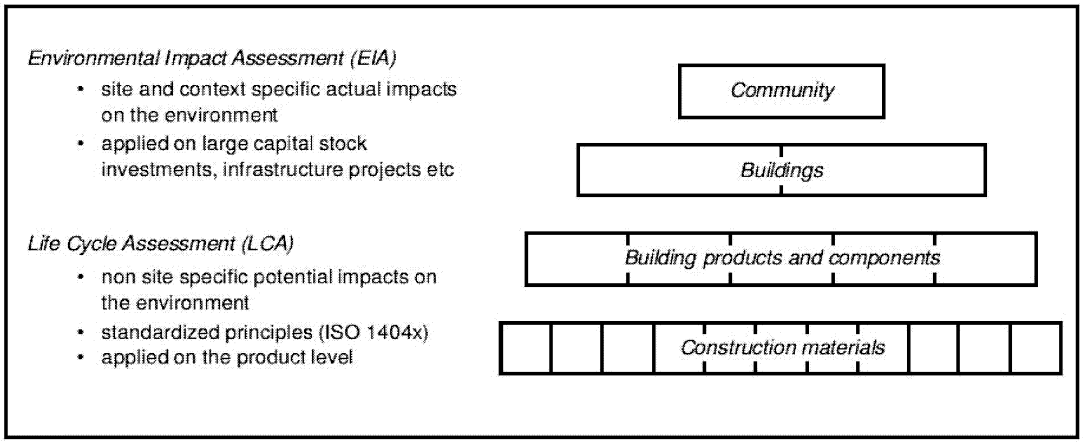


Figure 1 Conceptual difference between EIA and LCA
(Source: Drury Crawley1 and Ilari Aho, 1999)

Jay et al (2007) claimed that the project environmental impact assessment should not only focuses on energy and emissions, etc., but also includes strategic impact assessment, planning impact assessment, traffic impact assessment and regional economic impact assessment. The building projects occupied a large proportion of construction project. Therefore, building environmental impact assessment was given a richer meaning.

Therefore, Yang (2009) summarised that Building Environmental Impact Assessment means: assessment of buildings which may impact on the surrounding environment, including natural environment, transportation environment, economic environment and living environment. Implementation of BEIA is following considerations for humane care, social responsibility and policy requirements.

The U.S. Green Building Council proposed the concept of Green Building in 1993 and established the LEED system to evaluate the building environment in 2003. The basic content of green building can be summarized as: to reduce building emission, to save energy and resources and to provide a safe, healthy, comfortable living space. The LEED evaluation system consists of five aspects and a number of indicators constituted its framework: includes sustainable construction sites, water use, energy saving, atmosphere, resources or materials and indoor air quality. The LEED is a comprehensive study of buildings and assesses its environmental impacts. It gives a score to each indicator, and then composite score results by assessing the building. The final result is divided into platinum, gold and silver certification levels to reflect the green building level (USGB, 2006).

Except Hong Kong EIAO by EPD, Hong Kong has another Building Environmental Assessment Method (called HK-BEAM) published by a non-profit organization named HK-BEAM Society in 2003, which seeks to:
• To enhance the quality of buildings in Hong Kong;
• To stimulate demand for buildings in more sustainable and to give recognition for performance improvement

and to minimize false claims;
• To provide a comprehensive set of performance standards that can be pursued by developers and owners;
• To reduce the environmental impacts of buildings throughout their lifecycle; and
• To ensure that environmental considerations are integrated right from the onset rather than retrospectively.
In the system of BEAM, HK-BEAM identified the environmental factors in six main aspects including more than 70 indicators. It is a very detailed building environmental assessment method which provided a series indicators to evaluate both building's external and internal impact on environment and issues on sustainability.

Although there are many methods to assess the environmental issues, but the assessment tools are still very simple and inefficient. Most of assessment works had done with two-dimension media, like assessment reports were normally written in papers. There is lack of electrical tools to help assessment process and to give a visual view of environment.

## HOW DID GEOGRAPHIC INFORMATION SYSTEM HELPED BUILDING IN ENVIRONMENTAL ASSESSMENT?

Geographic Information System (GIS) is one of many techniques developed by scientific geographers to facilitate their analytic spatial reasoning (Rodriguez, et al, 1995). GIS has the following three features:(1) the capability of collection, management, analysis and output of variety geospatial information;(2) the powerful capability of spatial analysis, multi-factor comprehensive analysis and dynamic prediction;(3) computer system support is an important feature of geographic information systems, which makes GIS fast, accurate and comprehensive in spatial and dynamic analysis of complex geographical systems. GIS software automates many of the spatial processes performed by quantitative geographers, even it can complete works that human beings could not do. (Tomlinson, 2007). It is designed to work with data referenced by spatial or geographic coordinates. GIS software contains both a database manager and a set of spatial functionalities that allow the analysis of data across a desired geographic landscape. Zhou, 1995 defined GIS as a collection, storage, analysis and display of geographic information computer system. It is a common technology to deal with large number of geographic data and a tool for analysis. He divided GIS in two parts:
Geographic Information System (GIS) = Geographic Information (GI) + Information System (IS)
This definition can be a good description of the composition and methods of geographic information system. GI includes all the necessary geographic information of GIS, including maps, DEM, remote sensing information and location information. IS indicates computer-based information management system. This provides a foundation for understanding and development of GIS. Building environment data contains large amount of information. GIS provides a basis for BEIA by its powerful ability of information management. However, GIS in the early stage was not beginning at environmental information storage, but more served urban planning and the related urban affairs.

In the urban information management, GIS is popular for its powerful information storage, management, analysis, dynamic tracking and search features. For example, the City of Niagara Falls, New York, built a real estate map based multi-purpose urban geographic information system by using Arc info in 1989. This became an effective aiding tool of urban real estate property, property register, real estate transactions and management, urban Housing and construction update plans; Longley (1992) successful used GIS for the tax department to formulate a grade distribution map of real estate tax levy rate; Higgs et al (1992) used GIS technology in real estate appraisal matters directly. Thrall and Marks (1993) provide a detailed discussion of the application of GIS to real estate research. Wyatt (1997) by using GIS network analysis and overlay functions established the real estate price differentiation map of United Kingdom Huo Samu region on 1:1250 digital cadastral maps, and provided the basis for the real estate management. The development of GIS technology changed the concept of urban management (Goodchild and Michael, 2010). In addition to the storage and management of a large amount of information, GIS offers an urban management decision-making support system. It integrates buildings' geographical attributes of space, natural attributes, social and human attributes, making property management toward a direction to scientific, standard and intelligent and creating a multi-directional multi-level network and automated property management system.

Consideration of environmental issues in urban planning is the early stage of GIS application in environmental assessment. Accompany with the rapid development of GIS technology, some researchers began used GIS to solve some part of environmental issues. Dai, et al used GIS to combine geo-environmental evaluation and urban land-use planning in 2001. Goodchild, et al discussed the research direction of GIS application in environmental assessment in 1996. They thought narrow natural air, water and other elements into a small scale and pollution level to simulate in GIS is a research trend in the future. Sharma, et al (2010) developed a noise model for area transportation noise and successful used the model for simulation. Except noise, the air pollution

and water contamination were also established a simulation models by some researchers by using GIS. Some large projects were used GIS to assess the impact to the environment. However, using GIS in small scale projects is still lack of research.

Hong Kong government used GIS to simulate surrounding environment of some large construction projects for public supervision. The environmental protection department established a 3D visualization system by integrated GIS and 3D models in 2003. This system implemented the use of GIS to view the surrounding environment of a construction project. But it did not use GIS to assess the environment. And the system still used for large projects which may had a wide range impact on environment, it did not focus on small scale such as building level.

## RESEARCH DATA AND METHODOLOGY

The remote sensing maps for this research were sourced from the Google Earth (all rights reserved Google TM). All the simulation works have been done were based on the ArcGIS software, which was donated by ESRI Hong Kong Corporation for education use for Department of Building and Real Estate, The Hong Kong Polytechnic University.

This paper is a review of early works of my research. The main research methodologies are literature review, computer-aided simulation and case study. A case study was taken on a construction site of Hong Kong Polytechnic University for simulation of the surrounding environment. This research used ArcGIS as the GIS software platform.

## GIS BASED BEIA APPLICATION

In Hong Kong EIAO, sensitive receiver is an important concept. The ordinance specifically defined sensitive receivers in different level and in different conditions for each environmental impact factors. For example, the residential buildings and education site are very sensitive to the noise. But the sensitivities of these buildings are quite different in day time and night. The ordinance defined maximum acceptable decibel in different area and different time, as the tables show:

Table 1 Noise Standards for Daytime Construction Activities

| Uses | Noise Standards | |
|---|---|---|
| | 07:00 to 19:00 hours on any day bot being a Sunday or general holiday (dB) | Other time |
| All domestic premises including temporary housing accommodation | 75 | See Table 2 |
| Hotels and hostels | 75 | |
| Educational institutions including kindergartens, nurseries and all others where unaided voice communication is required | 70 | |
| | 65 (During examinations) | |

Table 2 Basic Noise Level
(Source: Environmental Impact Assessment Ordinance, EPD)

| Time Period | Area Sensitivity in urban area |
|---|---|
| | Affected dB |
| All days during the evening (19:00 to 23:00 hours), and general holidays (including Sundays) during the day-time and evening (07:00 to 23:00 hours) | 50 |
| Night (23:00 to 07:00 hours) | 40 |

Traditional method to identify sensitive receivers was based on documents. Normally, the documents were

composed of two parts: a site drawing and some files included related information such as building attribute and environmental sensitivity. These two part cannot combined together because the limited space on the documents which made by paper material cannot stored too much information. In addition, a document with too small size of font on it would affect people to read and understand. These documents were very hard to understand because people needed to move their eyes quickly between two or more documents to find useful information that can support decision-making. Typically, such work would cause fatigue quickly, thereby affecting the judge! But this problem would no longer exist with GIS solution. Sensitive receivers can be easy to find in GIS software. Figure 2 shows a GIS project with a noise source (the grey one in the middle) and all sensitive receives (all marked as yellow, including residential buildings, office buildings and educational buildings).

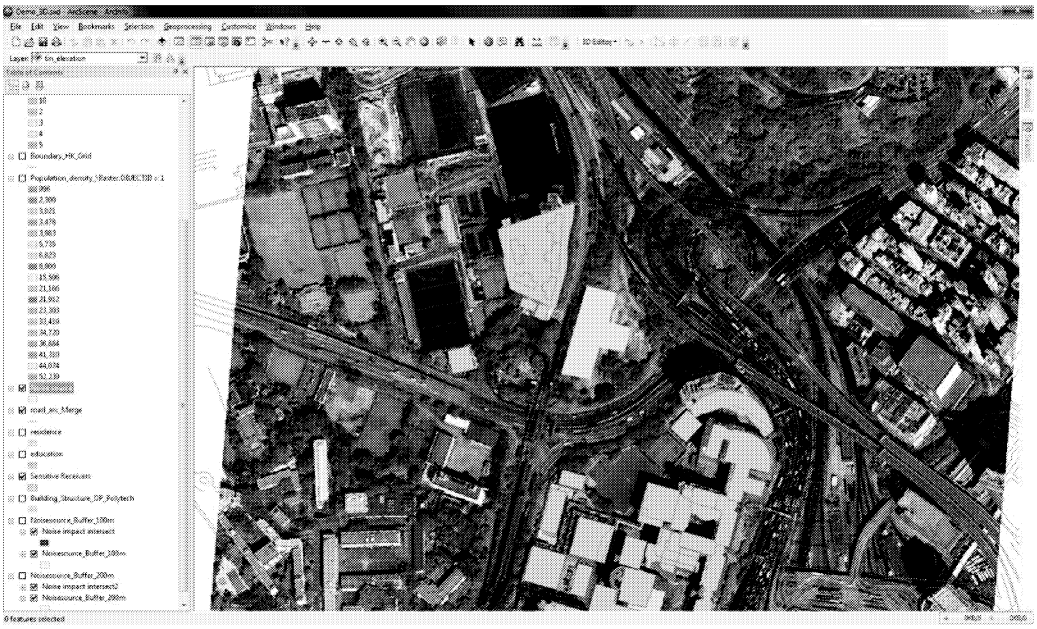

Figure 2 Sensitive Receiver in GIS

People can mark sensitive receivers in different colours, different symbols and even in multi-style in GIS. However, GIS was not only an advanced drawing in computer, and the marked sensitive receivers were not only advanced polygons on the remote sensing map too. Actually, this GIS project combined digital map, buildings and road information together. The sensitive receivers in this project were some identified components with specific attribute which automatically selected by the GIS. Therefore, people can save a lot of time from work of data processing.

All related information was also stored in this GIS project. Still take sensitive receivers for example, all of the polygons on the map had related information stored in a geo-database. People can view the information in an attributes table, as figure 3 shows:

Table

Sensitive Receivers

| FID | Shape * | FID_reside | OBJECTID | STRUCT_ID | CASENO | YEAR | BLK_TYPE | OP_NO | UNDERGROUN | DEMOLISHED | CERTIFIED_ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Polygon | 0 | 276344 | 5240833 | 4006 | 99 | TOW | KN24/2002(OP) | | | <Null> |
| 1 | Polygon | 1 | 353895 | 5243857 | 7907 | 00 | OTH | PR5/2003(OP) | | | <Null> |
| 2 | Polygon | 2 | 53867 | 5240833 | 4006 | 99 | TOW | KN24/2002 | | | <Null> |
| 3 | Polygon | 3 | 353896 | 5243866 | 7907 | 00 | OTH | PR5/2003(OP) | | | <Null> |
| 4 | Polygon | 4 | 51992 | 201852 | 4489 | 66 | TOW | K3/69 | | | <Null> |
| 5 | Polygon | 5 | 93457 | 5169982 | 4057 | 84 | TOW | K32/85 | | | <Null> |
| 6 | Polygon | 6 | 31290 | 219245 | 4029 | 82 | TOW | K31/85 | | | <Null> |
| 7 | Polygon | 7 | 49670 | 219763 | 4029 | 82 | TOW | K31/85 | | | <Null> |
| 8 | Polygon | 8 | 60181 | 219360 | 4029 | 82 | TOW | K31/85 | | | <Null> |
| 9 | Polygon | 9 | 353894 | 5243868 | 7907 | 00 | OTH | PR5/2003(OP) | | | <Null> |
| 10 | Polygon | 10 | 79109 | 1543541 | | | TOW | K11/82 | | | <Null> |
| 11 | Polygon | 11 | 39750 | 219498 | 4029 | 82 | TOW | K31/85 | | | <Null> |
| 12 | Polygon | 12 | 93489 | 288895 | 4069 | 88 | TOW | K52/91 | | | <Null> |
| 13 | Polygon | 13 | 46822 | 204191 | 4029 | 82 | POD | K31/85 | | | <Null> |
| 14 | Polygon | 14 | 58137 | 219646 | 4029 | 82 | TOW | K31/85 | | | <Null> |
| 15 | Polygon | -1 | 0 | 0 | | | | | | | 0:00:00 |
| 16 | Polygon | -1 | 0 | 0 | | | | | | | 0:00:00 |

1 (0 out of 99 Selected)

Sensitive Receivers

Figure 3 Attribute table with information of sensitive receivers

In this project, each polygon was a model of an independent building. It stood for an existing sensitive receiver, and included name, year of completion, building category, height, area, position, environmental sensitivity and so on. However, some models might be the 3D models; they also could be storage as an attribute in this table.

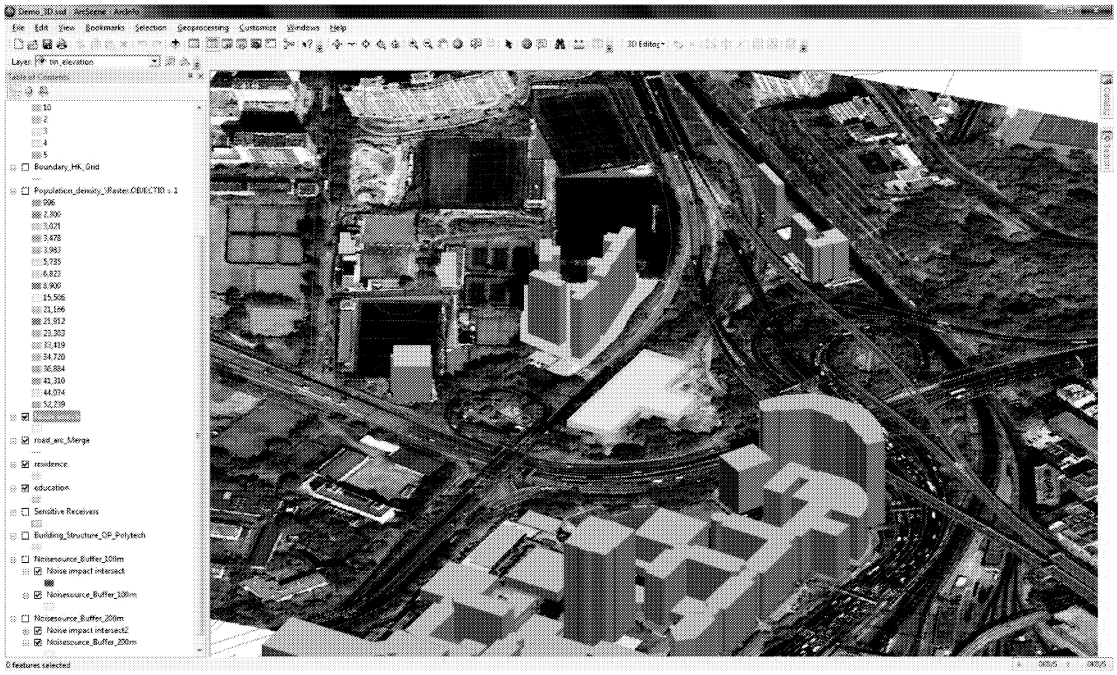


Figure 4 3D models of sensitive receivers

It can easily find from the above figure that residential buildings (yellow) and education site (blue) were separated from sensitive receivers. Moreover, these two parts were showed as 3D performance. People could identify specific building more easy and could see the shape and height of building in an intuitive way. It would be helpful to make right decisions in environmental assessment.

Another benefit of 3D GIS is that people can do 3D analysis and simulation in GIS. Directly doing simulation on 3D GIS can save a lot of time and process. GIS can automatically analyse environmental impact buffers and simulate the affected situation in an intuitive way. Figure 5 shows a simulation of two noise impact buffers. As a noise source, the construction site made noise when it in construction process. Generally, the power of noise will reduce in dissemination process. Based on this, construction noise was divided into different distance levels. Besides, vertical distribution on the space of noise is completely different at the same distance level. (Liu, et al. 2009)

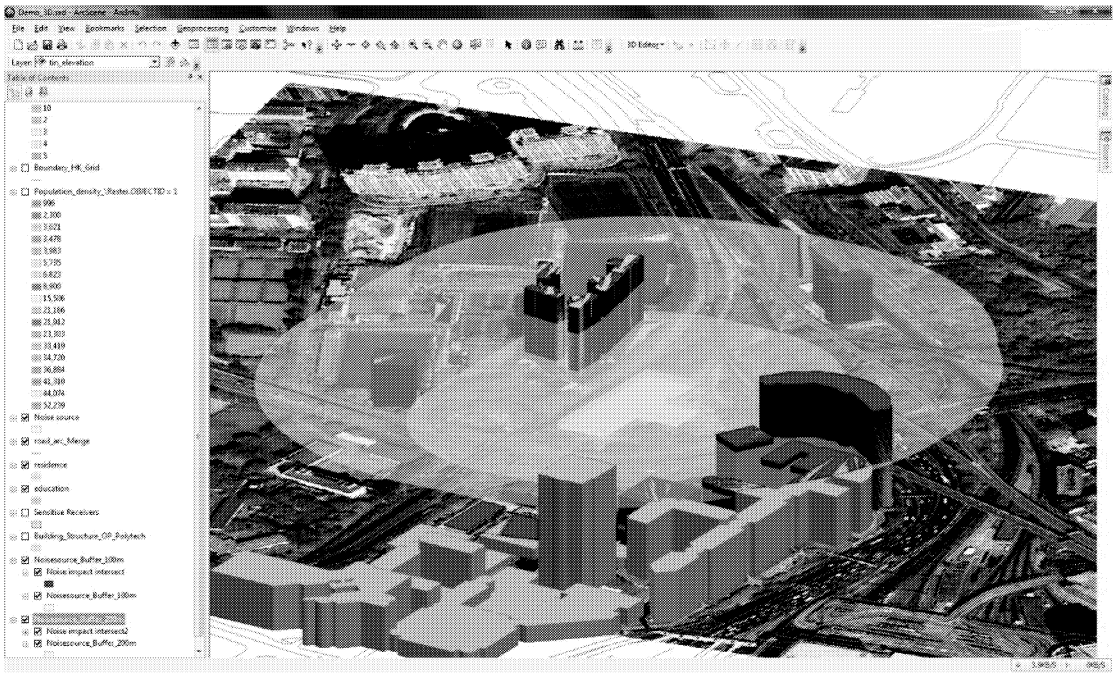

Figure 5 Construction noise impact buffers in different levels

The first buffer was 100 metre range around noise source which covered three residential buildings on the northwest of the source and a part of the most northern building in the education site. The impact of noise at 100 metre level normally concentrated on the ground height, lower than 10th floor. The intersect parts of sensitive receivers and 100 metre buffer were signed with dramatic red to highlight the affected parts. The second buffer was the 200 metre range around noise source. As same as 100 metre buffer, it covered some parts of residential buildings and education site, but wider range. However, there was a difference between the two buffers. Construction noise in 200 metre range normally concentrated on above 30 metre to 40 metre height, upper than $10^{th}$ floor. By the analysis and simulation functions of GIS, people can get an accurate analysis result and can easy to find it in GIS. Especially in group buildings with complex spatial structure, such as the education site in this project, the advantages of using 3D GIS to assess environmental impact are more obviously.

## FURTHER WORKS

One of objectives of this research is to achieve a GIS based environmental impact assessment. In this process, more models will be established to support the assessment work. Meanwhile, 3D models are very important components in the GIS based assessment system. However, common 3D model cannot contain any building's information in it; both the information and the model itself are stored in geo-database as a whole. It means that the building model cannot be separated. However, in the last released version of ArcGIS added support to building information modelling (BIM), which can include huge information related to building. Integration of GIS and BIM models is an important part in the future works.

## CONCLUSIONS

Since the 21st century, Accelerating human development has led to environmental problems highlighted. If people do nothing in environmental protection will accelerate the deterioration of the environment. The life and health of people will be significantly affected. Even cause more serious consequences. Therefore, environmental protection has become one of the most important problems. As a major pollution factor, the impact to environment of construction process must be controlled. Environmental impact assessment is the main measure to supervise and control construction pollution in an acceptable level.

Definitely, computer aided based environmental impact assessment will be a trend in the future. This paper main reviewed some application of GIS in environmental protection in world and in Hong Kong. A simple model of GIS based environment assessment platform had been established. This model included a construction site and surrounding environment. There is large amount information which related to this system contained in the model. Based on the environmental models and related information, the GIS based model can analyse and simulate possible impacts of each environmental impact factors in multi scale. We can also view the result in different perspectives. However, there are still some problems need to be solved. The GIS based model will continuous improving and the assessment methods in GIS based platform are also need to be improved.

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