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Analysis of Changing Landscape of World Heritage Site for Heritage Management: Case of Luang Prabang, Lao People's Democratic Republic

by

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ABSTRACT

Heritage preservation has been gaining recognition around the world. World Heritage Site inscription has brought much-needed opportunities and yet poses threats. The challenge is complex in historic cities because the needs of development often contradict those of conservation. Rapid tourism growth, often accompanied by modernization, has degraded World Heritage Sites. Luang Prabang of Lao PDR is, without a doubt, facing similar circumstances. The ancient city is regarded as one of the most significant historic cities in Southeast Asia. It has experienced tremendous change following unprecedented growth in tourism and development pressure. However, there has been a lack of empirical evidence to ascertain how Luang Prabang has changed. In other words, the change in Luang Prabang was unclear.

This study aimed to visualize and analyze significant changes affecting the built environment of Luang Prabang using the mapping tool, Geographic Information Systems (GIS). GIS is applied, alongside considerations of the difficulties of introducing GIS in developing countries. GIS application is designed to deploy GIS technology in a more sustainable manner and tackle local constraints such as a severe lack of data, inefficient data management, and lack of accurate digital base maps. The built environments of 1999 and 2009 were compared, based on seven indicators of building attributes from the Safeguarding and Preservation Plan (PSMV). The analysis of change is supported by an investigation of the reasons behind the changes from local stakeholders. Statistical methods are employed to validate findings and examine relationship between 1) an increase of touristic use and significant changes, and 2) the PSMV and significant changes.

The built environment changed significantly in four aspects. First, there was an evident shift from residential to touristic use, in particular to guesthouses along riverbanks and main roads. Second, Lao traditional architecture replaced modern architecture along riverbanks. Third, modern building materials replaced traditional building materials throughout the peninsula. Fourth, traditional roof materials replaced modern roof materials. Despite the increase of touristic buildings, traditional elements replaced modern elements for architecture and roof materials, contrary to what has been reported in the literature. The change to touristic use is associated with all significant changes identified. Although multiple factors influenced the changes, the strict implementation of the PSMV was the factor prevalent in all significant changes. The PSMV had a significant influence on the built environment. The built environment changed within the limit of preservation regulation. As such, the empirical evidence derived was able to comprehend the state of conservation of Luang Prabang.

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LIST OF ABBREVIATIONS

The following abbreviations are used in this manuscript:

ADB	Asian Development Bank
AFD	French Development Agency
ADUC	Chinon Development and City Planning Agency (Agence de Developpement et d' Urbanisme)
CAD	Computer Aided Design
DBMS	Database Relational Management System
DPI	Department of Planning and Investment
DPL	Department of Luang Prabang World Heritage Site (La Départmente du Patrimoine Luang Prabang)
FOSS	Free and Open Source Software
GIS	Geographical Information Systems
GPS	Global Positioning System
HUL	Historic Urban Landscape
ICOMOS	International Council on Monuments and Sites
ICT	Information and Communication Technology
JBIC	Japan Bank of International Cooperation
LNTA	Lao National Tourism Administration
OUV	Outstanding Universal Value
MdP	Heritage House (La Maison du Patrimoine)
PSMV	Safeguarding and Preservation Plan (Plan de Sauvegard et de Mise en Valeur)
UNDP	United Nation Development Programme
UNESCO	United Nation Educational, Science and Cultural Organization
WHC	World Heritage Committee

CHAPTER 1: INTRODUCTION

Heritage preservation concerns the effort to preserve historical objects, monuments and places which have outstanding value significant to humanity. The global effort to safeguard heritage started with the Great Temple of Abu Simbel in Egypt in the 1960s. In 1972, the UNESCO World Heritage Convention was ratified. This signified an international interest in and consensus on heritage preservation. Since the ratification, local governments and private sectors have increased their involvement, indicating the importance of safeguarding cultural and natural heritage. Once inscribed, World Heritage Sites are expected to experience numerous benefits, such as international recognition, improved heritage management, tourism growth, and social and economic improvement. In World Heritage Sites in developing countries, tourism growth is seen as an opportunity to alleviate poverty and propel development.

It is often the case that the sites are overwhelmed by tourism growth which triggers unplanned development. This causes World Heritage Sites to deteriorate. In particular, World Heritage Sites in Asian developing countries are facing severe strain as they have the highest tourism growth rates in the world (Imon, 2013). Moreover, the approach to heritage conservation has evolved from preserving isolated individual monuments to including the surrounding landscape. This has greatly expanded the scale and scope of conservation. More than 250 cities around the world have been inscribed as World Heritage Sites (Bandarin & van Oers, 2012). The preservation of entire Historic Urban Landscape (HUL) is daunting and complex since development needs often contradict conservation priorities. A HUL is defined as "the urban area understood as the result of a historic layering of cultural and natural values and attributes, extending beyond the notion of historic center or ensemble to include broader urban context and its geographical setting" (UNESCO, 2011, p. 52).

Lessons learned from the devastating effects of unplanned development and overly strict conservation have shown that a historic city needs both continuity and change (Ford, 1978; Karimi, 2000; Imon, 2008; Bandarin & van Oers, 2012). Change is inevitable if historic cities are to thrive and develop socio-economically. Rather than halting change, the flexibility to cope and react to change is vital for the sustainability of the city. Therefore, it is imperative to understand the dynamics of change in historic cities and manage change without undermining the outstanding universal value[1] (OUV).

Preservation of heritage sites requires all relevant information; however, conventional methods are unable to successfully collect, store, and analyze mass data. New analysis methods and concepts are needed. Among them is Information and communication technologies (ICT). Ever since UNESCO first demonstrated the use of computer-assisted management system in Angkor Watt in Cambodia, ICT tools have been progressively used in the heritage context. ICT, too, has shifted from documenting individual buildings to capturing entire landscapes. Documenting landscape for the purpose of urban preservation and historical morphology has introduced the use of mapping tools, especially Geographical Information Systems (GIS). GIS integrates spatial and non-spatial landscape data. It also documents different urban features and models urban processes, as well as their impact on heritage areas. In the case of HUL, maps of

[1] "Outstanding universal value means cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity." (UNESCO, 2005, p. 14)

landscape characteristics are important for policy-makers to manage change because it is difficult to perceive the entire landscape and its evolution without mapping the layout of the landscape (Turner, 2010; Whitehand & Gu, 2010).

Given this background, this study aims to examine the changes affecting the landscape of World Heritage Sites, particularly in developing countries. Luang Prabang of Lao PDR is utilized as a case study because the World Heritage Site is facing similar challenges of unprecedented tourism growth and development. The changes that have occurred in Luang Prabang are examined through visualization, using GIS to identify significant changes affecting the built environment. The examination of changes is supported by interpretation and investigation of the reasons behind the changes from the local stakeholders' perspective.

1.1 The Study Site

1.1.1 Luang Prabang World Heritage Site

Luang Prabang is the biggest town in the Northern Central Region of Lao PDR and has a population of 19,068 (Rural Development and Poverty Reduction Office, 2011). Luang Prabang is an ancient capital city of the former Kingdom of Lan Xang, which was established in the 15th and 16th centuries (ICOMOS, 1995). The peninsula of Luang Prabang is one kilometer long and 250 meters wide. It is located between the confluence of the Mekong River and Nam Khan Rivers in a clay basin and enclosed by limestone mountains, as shown in Figure 1. The city was inscribed as a World Heritage Site in 1995 under the three criteria ii, iv, and v (ICOMOS, 1995, p. 47):

Criterion (ii): *"to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, developments in architecture or technology, monumental arts, town-planning, or landscape design"*;

Criterion (iv): *"to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history"*;

Criterion (v): *"to be an outstanding example of a traditional human settlement, land use, or sea-use which is representative of a culture, or human interaction with environment especially when it has become vulnerable under the impact of irreversible change"*.

Figure 1. Historic Urban Landscape of Luang Prabang

Source: Department of World Heritage (DPL), 2006

Luang Prabang World Heritage Site covers an area of 708.53ha, which encompasses 29 villages, 611 inventory buildings, and 183 protected wetlands (Maison du Patrimoine (MdP), 2001a). Inventory is referred to in Article 11 of the World Heritage Convention, 1972, as documentation of a list of properties forming part of cultural and natural heritage with information on locations and significance (UNESCO, 1972). Luang Prabang is recognized for its unique urban fabric resulting from an overlay of Lao and French influence, a rich fusion of diverse architecture, and the coexistence of built and natural environments. The Lao traditional morphology is heavily influenced by the natural environment and the social role of Buddhism (Ateliers de la Péninsule, 2004). Lao houses clustered around monasteries and grew along rivers. Early settlement in Lao was dependent for its livelihood on the Mekong and Nam Khan Rivers. The houses were built parallel to the rivers and known as the Lao fabric, as illustrated in Figure 2. Alleyways and staircases connected the houses to the rivers for daily needs, trading, transportation, and religious activities. Temples situated on the highest ground became the focal point of the local community for religion, education, and social purposes. With the Royal Palace located in the peninsula, aristocrats, artisans, and traders dwelled in the area surrounding it.

However, from the 19th century, urban characteristics were developed as a result of French influence. The King of Lao asked the French to develop and urbanize the town in 1909. The colonial and urbanization era introduced town planning which formed a rectilinear pattern of roads and blocks, known as the Colonial fabric. Urban development focused on roads. The density of houses increased along the main roads which enclosed the scattered traditional land plots and formed organized urban blocks. This new urban structure integrated harmoniously with the existing Lao traditional fabric.

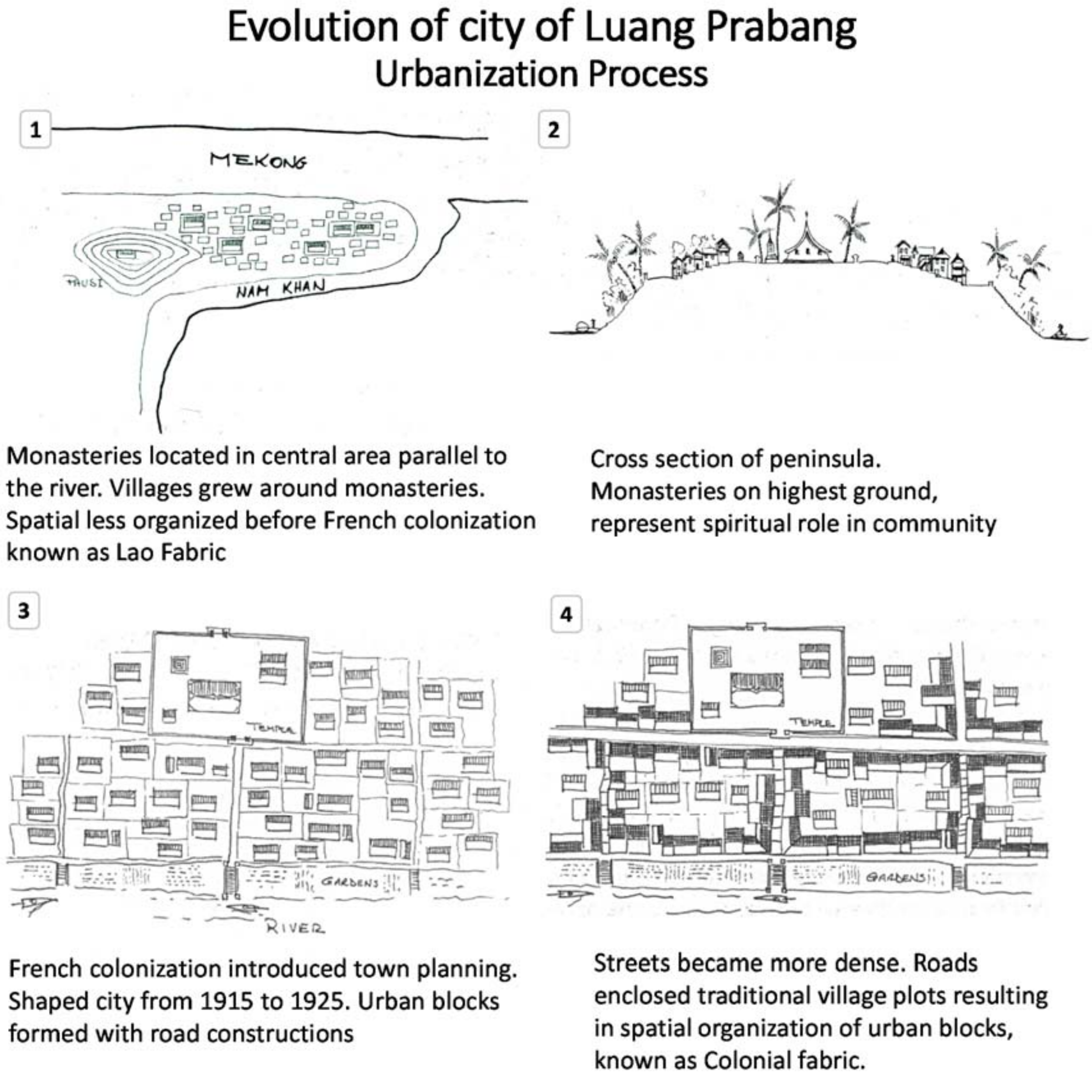

Figure 2. Evolution of the historical urban landscape of Luang Prabang

Source: Adapted from Ateliers de la Péninsule, 2004, p.38-39, Copyright 2004 by Ateliers de la Péninsule Co Ltd. Reprinted with permission.

The World Heritage Committee (WHC) evaluated the overall townscape as being preserved to a high degree of authenticity, with remnants of its pre-colonial appearance still unscathed, which is not seen in other historic cities in South East Asia. The main justification for inscription was stated as being that

> *Luang Prabang represents to an exceptional extent the successful fusion of the traditional architecture and urban structures and those of the European colonial rulers of the 19th and 20th centuries. Its unique townscape is remarkably well preserved, illustrating a key stage in the blending of two distinct cultural traditions* (ICOMOS, 1995, p. 5).

1.1.2 Impacts of Tourism and Development

Luang Prabang has experienced exponential tourism growth since it became a World Heritage Site. The total number of foreign and domestic tourists has risen by 875%, from 62,348 in 1997 to 607,584 in 2015, as displayed in Figure 3 (Department of Planning and Investment (DPI), 2016). Both foreign and domestic tourists have continuously increased over the years. As a result, tourist accommodation and related facilities have been rapidly constructed to meet the growing demand. Touristic buildings increased dramatically, by 779%, from 87 in 1997 to 765 in 2015, as shown in Figure 4 (DPI, 2016).

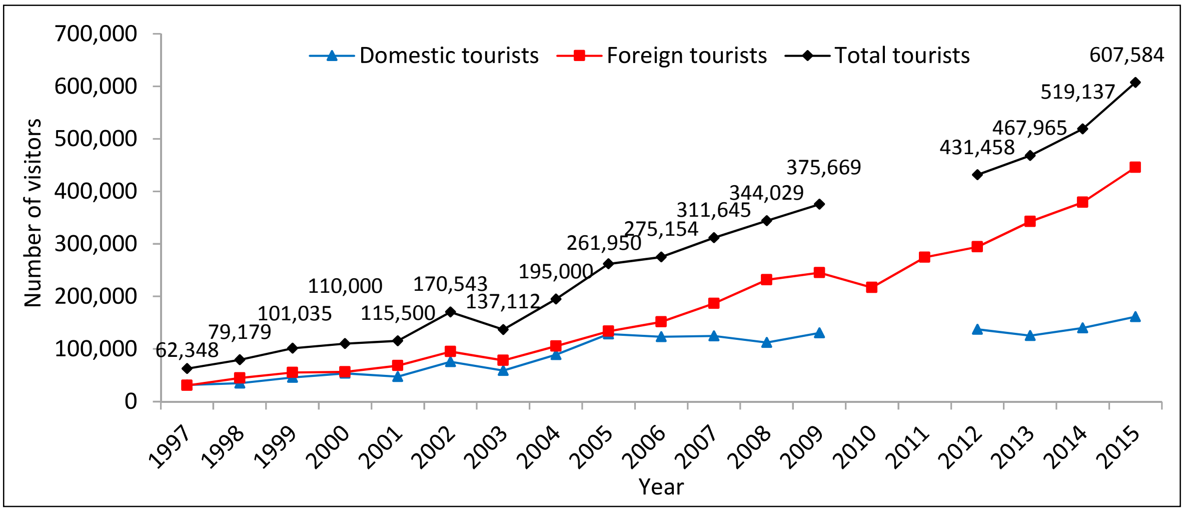

Figure 3. Number of foreign and domestic tourists visiting Luang Prabang (1997 - 2015)

Note: Data on domestic tourists are not available for years 2010 and 2011.

Source: Summary based on data from the DPI, 2016.

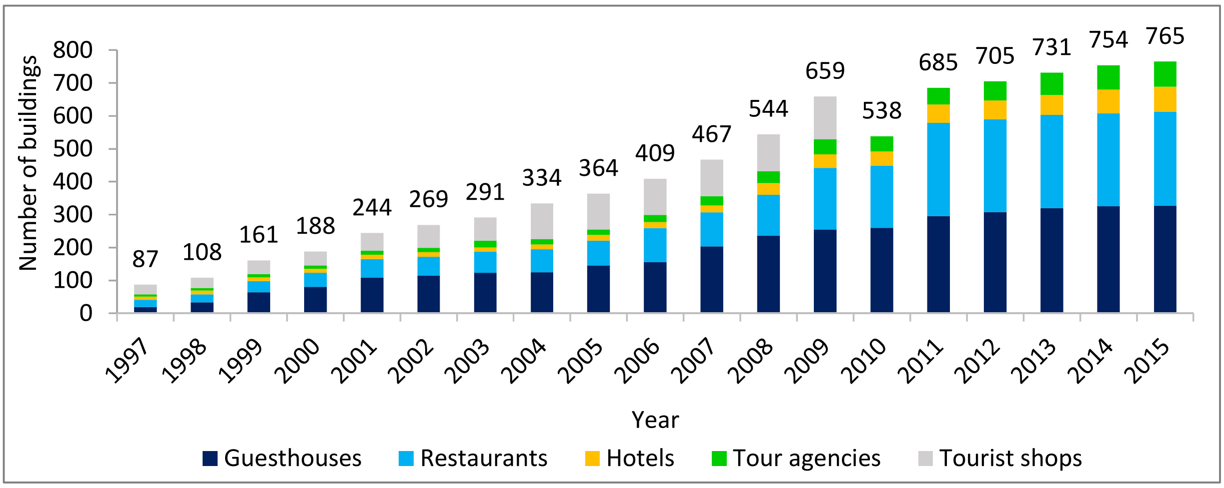

Figure 4. Total number of touristic buildings (1997 - 2015)

Note: Data on tourist shops from 2010 onwards are not available

Source: Summary based on data from DPI, 2016.

Although tourism has become a major contributor to the economy of Luang Prabang, the pressure of development has negatively transformed Luang Prabang's landscape and degraded its heritage values (UNESCO, 2004a; ADUC, 2004; JBIC, 2006; Boccardi & Logan, 2008). The most severe report came from the reactive monitoring commission of the WHC. It warned that the heritage of Luang Prabang is on the verge of being endangered and that development beyond the threshold of the carrying capacity of Luang Prabang has caused irreversible damage (Boccardi & Logan, 2008). The severity of the threats faced by Luang Prabang is reflected by the threats intensity coefficient that has been increasing over the years, as depicted in Figure 5 (UNESCO, 2016). The coefficient value was highest in 2009. The coefficient value is calculated based on number of times WHC has deliberated on issues that threatened Luang Prabang during the annual committee session.

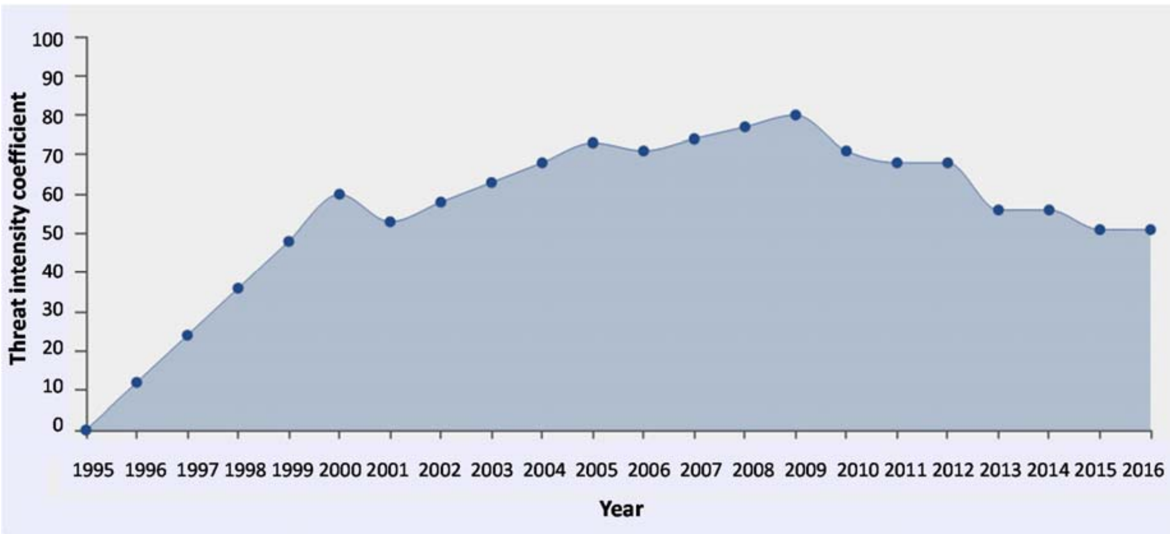

Figure 5. Severity of threats that have affected Luang Prabang since its inscription in 1995

Source: UNESCO, 2016

The reactive monitoring mission report produced by ICOMOS and the World Heritage Centre in 2008 (Boccardi & Logan, 2008). It outlined major issues that were impeding conservation. The site was experiencing development pressure from the construction of larger hotels and the expansion of the airport runway to accommodate bigger aircraft. Unauthorized activities had increased, that include the demolition and reconstruction of inventory buildings and the construction of new buildings using inappropriate styles, techniques, and materials. An increase of residential and touristic land use had resulted in the over-densification of urban areas and the loss of wetland and green space. Lao's traditional wooden houses had been converted to a mix of timber and concrete, or concrete only, which was not compliant with regulations. It was also highly concerned about the decline of Lao characteristics in the landscape. Lao traditional houses had reduced, due to the preference for modern houses and conversions from residential buildings to tourist accommodation. Therefore, the report concluded that Luang Prabang was at a threshold point of development and warned that if the Lao traditional heritage continued to decline, the heritage site would be at risk of being listed as Heritage in Danger.

Conversion of building functions had also led to the gentrification of the local community. As such, 15 specific recommendations were laid out as immediate measures to safeguard Luang Prabang. The 15 recommendations focused on three aspects: 1) increasing local community capacity and involvement; 2) mitigating development pressure with a clearer definition of OUV, the creation of a buffer zone, and urgent revision of the urban plan; and 3) countering unauthorized constructions by a stricter enforcement of regulations. The fifth and sixth recommendations required updated maps to show the extent of changes that reflected the actual condition of the heritage site in order develop counter-measures and serve as a basis to revise urban planning.

A UNESCO tourism impact assessment made similar observations as to Lao traditional houses and building materials (UNESCO, 2004a). A considerable number of religious and secular buildings had been modified with inappropriate practices. The preference to restore and reuse colonial buildings had caused Lao traditional houses and Chinese-Vietnamese shop houses to be neglected. The locals were more inclined to use cheap modern construction methods that imitate Thai houses, leading to the loss of traditional building materials and roof materials. The materials were substituted for a number of reasons, which include lack of awareness about built heritage, media influence on modern lifestyles, high cost, low durability, vulnerability to climate and insects, and lack of skilled craftsmen. However, it mentioned that regulation could revive the use of traditional roof materials if implemented effectively.

Two reports by the Japan Bank of International Cooperation (JBIC) (2006) and French Agency Development (AFD) (ADUC, 2004) evaluated Luang Prabang tourism and town development conditions. It was revealed that there was an excessive concentration of touristic activities in the narrow strip of the World Heritage core area between the two rivers because most of the important cultural and historical heritage was located there. This triggered a high tendency for investors to invest in more tourism-related activities, which explained the increasing number of restaurants, guesthouses, and hotels. Since most of the touristic facilities were built in the core area, it was overcrowded with tourists. Moreover, there was an uncoordinated expansion of the urban area, causing risk to surrounding rice fields, traffic pollution, flood risk, and migration of rural population seeking employment. The landscape would transform, and heritage values had already started to degrade. Both reports proposed a reduction of the strain on the core area.

However, the Asian Development Bank (ADB) reported contradictory findings on the severity of the impact of tourism (Mabbit, 2006). Its report aimed to assess the good practices of urban regional development for sustainable urbanization in Asia. It rated Luang Prabang as having good urban management and infrastructure provision, and being innovative in change. In short, Luang Prabang was credited for its commendable coordination between urban improvement and preservation. The physical intervention in Luang Prabang was considered impressive. At the initial stage when the MdP was formed, there was a lack of clear division between the role of different departments and work tasks. Preservation regulation was perceived as complicated building regulation, and difficult to comprehend by the locals. However, MdP was able to implement building regulations which were far stricter than any ever implemented in Lao PDR. Lastly, it raised the question of sustainability in preservation that was heavily dependent on international support and funds, in particular AFD. The local government had to establish the means to channel the income generated back to preservation.

1.1.3 Heritage Conservation Framework

The inscription of a World Heritage Site involves the development of detailed management mechanisms and a regulatory plan to manage the development and protection of the heritage site. In the case of Luang Prabang, the development started with the approval of a revised master plan by the Prime Minister's Cabinet in 1996, as summarized in Table 1. The existing master plan was revised by the Institute of Technical Studies and Town Planning of the Ministry of Communication, Transport, Post, and Construction (MCTPC). The legally binding master plan covered conservation and non-conservation areas and was used by local authorities to conserve and control development (UNESCO, 2004a). The plan clearly distinguished three major areas: 1) architecture and urban heritage areas; 2) urban areas on the riverbank and their economic activities; and 3) natural areas of agriculture, forest, and river. The non-conservation area served as a potential area for expansion and had more flexibility in land use.

Table 1. Timeline of development of heritage conservation framework

Year	Development of conservation framework
1996	• Revised existing Urban Master Plan of Luang Prabang • Formed national and local heritage committees
1994-2004	Decentralized cooperation Chinon, France - Luang Prabang under the aegis of UNESCO to develop major interventions framework: • Establish local institution, La Maison du Patrimoine (MdP) • Locate funds • Develop Safeguarding and Preservation Plan (PSMV) • Develop alternative urban development plan (Scheme for Coherent Territorial Development, SCOT)
2009	Heritage Office mandate upgraded to Department of World Heritage
2013	Establishment of buffer zone

Source: Summarized from ADUC (2005), Chaiyong et al. (1996), MdP (2001a, 2001b), and Savourey (2015)

In promoting development which was considerate of heritage issues, appropriate government and management are essential. National laws and regulations on cultural heritage preservation, urban development, and environmental protection were reviewed and issued (MdP, 2001a; Sitthivan, 2006; Young, 2012). These decrees and orders were pivotal in developing a conservation framework, such as the decentralization of program cooperation between Chinon and Luang Prabang (Advice of Prime Minister no. 1037/PM), the establishment of the Local Heritage Committee (LHC) (Order Provincial Governor of Province of Luang Prabang No. 157) and the creation of a National Committee for cultural heritage, history, and environment (Prime Minister Decree no. 176/PM).

At the national level, the National Heritage Committee presided over by the Deputy Prime Minister was established to ensure the compliance and cooperation of all ministries. At the Luang Prabang level, the Local Heritage Committee serves to coordinate local departments' development plans and heritage management, such as construction approvals.

Local management, spearheaded by Heritage House (MdP), was created under decentralized cooperation with the sister city, Chinon (France) from 1996 to 2004 (MdP, 2001a). The collaboration, sponsored by UNESCO and AFD, made major interventions to: 1) develop a local institutions framework, MdP; 2) locate funds; 3) conduct training and skill transfer; 4) draw up a Safeguarding and Preservation Plan (*Plan de Sauvegarde et de Mise en Valeur*, PSMV); and 5) promote public awareness activities (ADUC, 2005).

MdP, a local government unit established for the heritage conservation of Luang Prabang, has two main responsibilities. First, it monitors and manages development in heritage sites following the PSMV which includes giving local residents advice on proper construction methods and approving construction plans. The final approval of construction is examined and coordinated by the Urban Development of Authority Agency (UDAA) and Local Heritage Committee. Second, it coordinates and implements conservation projects with international organizations (MdP, 2001a). In 2009, MdP was upgraded to Department of World Heritage[2] (*La Departmente du Patrimoine Luang Prabang*, DPL) and provided with an official mandate similar to other provincial services (Savourey, 2015).

During the formulation of PSMV, extensive work was carried out to determine the most important attributes in buildings and the natural environment to be preserved according to OUV criteria, and articulately define them in the PSMV (ADUC, 2005). A comprehensive PSMV was developed from 1999 to 2001 using detailed field survey analysis. It identified eight pertinent indicators that were likely to be subjected to change over time, and affect heritage values. The indicators needing to be monitored are: 1) building usage; 2) building architecture; 3) building materials; 4) building roof materials; 5) building height; 6) building condition; 7) building area size; and 8) coefficient of soil occupation (C.O.S)[3].

The PSMV was approved by UNESCO and enforced by a Prime Minister Decree in 2001 (MdP, 2001a). The PSMV serves as a detailed guideline to preserve the heritage site and a basis for the DPL to authorize diverse types of construction work without compromising the heritage site. The DPL manages the site with detailed mapping and specific regulations according to four zones, as shown in Figure 6 respectively as: 1) preservation zone - core heritage (Zpp-Ua); 2)

[2] The organizational structure of DPL is comprised of four units, namely: 1) administration, 2) urban planning, 3) environment, and 4) construction and restoration (Savourey, 2015).

[3] Coefficient of soil occupation (C.O.S.) is a term adopted and translated from the French. C.O.S. is equivalent to the commonly-used floor area ratio (FAR). FAR is often used as one of the regulations in city planning, together with the building-to-land ratio (Onishi, 2005, p. 269).

protection zone – peripheral area of core heritage (Zpp-Ub); 3) monasteries zone (Zpp-M); and 4) natural environment zone (Zpp-N) (MdP, 2001b).

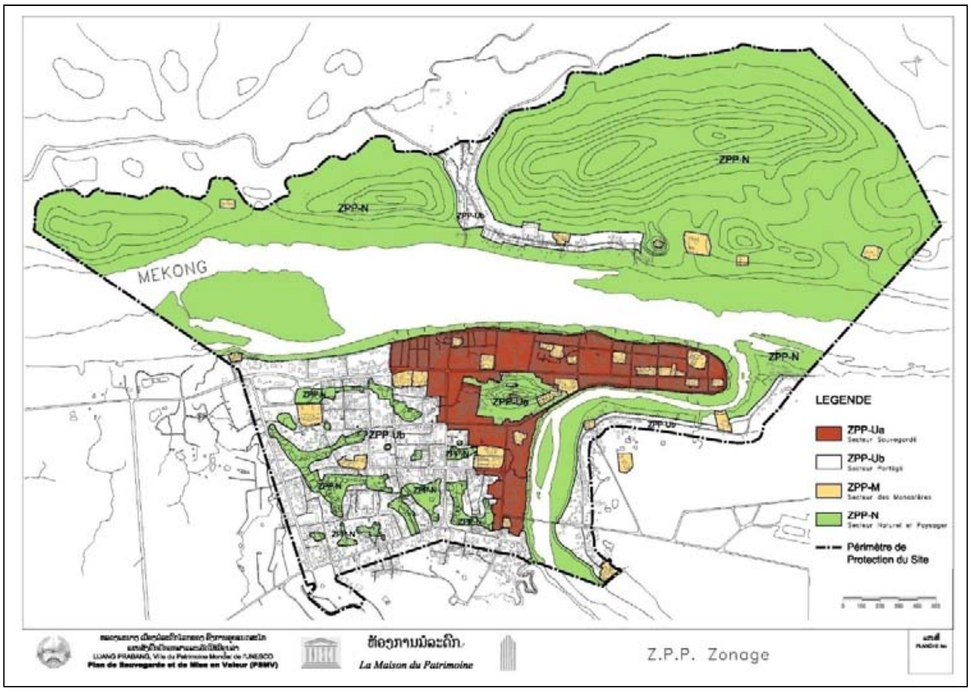

Figure 6. Safeguarding and Preservation Plan of Luang Prabang

Source: MdP, 2001b, p.11

In 2013, a buffer zone based on the Scheme for Coherent Territorial Development (SCOT) was approved by the Lao government and WHC. A more refined definition of OUV for Luang Prabang's heritage was also introduced (Savourey, 2015). The buffer zone covered an area of 12,500ha and was issued by Prime Minister decree in 2012. The creation of a buffer area aimed to preserve the historical landscape which encompasses more of the natural environment and rural traditional elements. There are four distinctive zones, respectively: 1) natural areas; 2) riverbanks; 3) rice paddies, market gardens, and agricultural areas; and 4) traditional villages.

Authenticity was defined at the time of inscription; however, integrity was not defined until 2013. In an Advisory Body Evaluation, ICOMOS evaluated the authenticity of Luang Prabang.

> *The level of authenticity of materials and techniques of many of the domestic buildings in Luang Prabang is low since modern techniques and materials (especially concrete) have been used to replace traditional materials over a long period. The quality of the temples and monasteries is higher. However, the overall landscape and urban fabric of the town are still authentic to a high degree (ICOMOS, 1995, p.4).*

By 2013, authenticity has been expanded to include cultural traditions related to Buddhist monasteries, such as rites and ceremonies (UNESCO, 2013). The integrity of Luang Prabang was defined for the first time as "linked to an architectural and cultural heritage set in a natural landscape that reflects its OUV" (UNESCO, 2013, p. 2). It has been outlined that all significant elements, such as urban fabric and important structures, are preserved, which supports the OUV. However, it also acknowledged that the site is suffering from rapid development and economic growth.

1.1.4 Introduction of ICT for Heritage Conservation

The Tokyo Institute of Technology (Tokyo Tech) had been collaborating with the DPL and UNESCO for more than a decade, since 2003. The joint research aimed to promote the sustainable development and management of the World Heritage Site, as well as to educate the local community on the importance of preserving Luang Prabang (Yamaguchi et al., 2008). The joint research introduced ICT tools, based on the needs assessment of Luang Prabang. A database system was created to share information effectively between local institutions and community. A heritage database and authorization database were created to manage built heritage information and building architecture records. The system was designed taking sustainability and the cost of software into consideration. The collaboration resulted in successfully establishing the first ICT center which offered accessible information on heritage sites and inventories to the locals and tourists.

The collaboration introduced various applications of ICT tools, such as visualization and mobile applications. Visualization technology was introduced to monitor change in the World Heritage Site for long-term preservation. This includes the application of virtual reality panorama and GIS to analyze change in the townscape and wetland (Takada et al., 2008; Yokoi, 2013; Irie, 2016). Mobile technology was applied to promote World Heritage Site preservation awareness among the youth of Luang Prabang (Poong et al., 2016).

1.2 Problem Statement

The inscription of a World Heritage title has been gaining recognition around the world and inscriptions are increasing in number. The inscription itself is not without contradictions, offering opportunities while posing threats. The inscription of a World Heritage Site has brought benefits in terms of social and economic development, and international recognition. The inscription is also accompanied by increased attention, with a mass influx of tourists. Although tourism provides jobs and becomes the main economic revenue, the demands of tourism, without proper planning, can trigger uncontrolled development and degrade the state of the heritage site. In other words, there are positive and negative implications of becoming a World Heritage Site. The World Heritage Site needs to have the capability to manage change while preserving its heritage.

Development needs often conflict with conservation priorities. This is especially acute in HUL in developing countries (Imon, 2013). Tourism growth and development pressure have affected the built environment of historic cities (Li, 2004, 2008; Imon, 2013; King, 2015). Modernization can diminish the traditional characteristics of the HUL. Ill effects include the construction of high-rise modern buildings, the demolition of old, dilapidated, traditional houses, the build-up of mega commercial facilities, encroachment, and more (Gao, 2008; ICOMOS, 2005; Vonvilay, 2015).

Luang Prabang of Lao PDR became a World Heritage Site in 1995 and is experiencing similar consequences of sharp tourism growth. Most of the literature is critical of the impacts of tourism development on Luang Prabang. Most researchers have concluded that the landscape has transformed negatively and its heritage values have been degraded. However, some have revealed conflicting findings on the impact of tourism. An ADB report pointed out that Luang Prabang has good urbanization practices and strict conservation interventions. The analysis and conclusions derived from the only study on the built environment (Dearborn & Stallmeyer, 2009, 2010) were questioned and considered subjective (Staiff & Bushell, 2013). They did not reflect the change from a local perspective. Perception of change affects the principle and methods used to assess change (Bandarin & van Oers, 2012). Negative perception has caused an assessment to be carried out in an impromptu and subjective manner in historic cities. In addition, a small sample size does not reflect the full impact of changes occurring in the World Heritage Site.

The gap identified in the existing literature indicates that there was a lack of in-depth analysis and significant sample size to provide a holistic analysis and clearly discern the changes occurring in Luang Prabang. At the same time, there was an urgent need to prepare updated maps, as recommended by the WHC. The maps provide critical information to draw up strategies to remedy negative changes. However, the change in the built environment remained unclear. Poor understanding of change made it difficult to formulate effective strategies to manage change. To the best of author's knowledge, GIS has been applied to wetland only but no prior study has conducted spatial analysis of the built environment. Therefore, visualization of change through mapping is essential.

The UNESCO guideline for monitoring World Heritage Sites specifies that measurements of change need to use a baseline that reflects the original state of the inscription (Stovel, 2002). Indicators of change should relate to authenticity and integrity, which supports the OUV of the heritage site. Thus, seven indicators of change were adopted from the PSMV in spatial analysis (MdP, 2001a). The indicators were pertinent building attributes subject to change over time and were identified during the formulation of the PSMV (ADUC, 2005). Moreover, landscape documented in the PSMV dated 1999 was the closest to the original state at the time of inscription. The analysis of landscape needs to be supported by interpretation, and the reasons behind change derived from the local point of view. Adequate information from local stakeholders to explain the change is valuable to support the development of strategic heritage management plans to cope with the changes.

1.3 Objectives of Study and Research Questions

This study aims to examine the changes that occur in the HUL by using the case of Luang Prabang, Lao PDR. The investigation utilizes the comparison of landscape between 1999 and 2009 based on seven pertinent indicators adopted from PSMV. The specific objectives of this study are as follows:

1. To explore significant factors for the sustainable application of GIS in Luang Prabang;
2. To identify significant changes in the built environment of Luang Prabang between 1999 and 2009 through visualization;
3. To identify the reasons behind the significant changes from local stakeholders.

Research questions developed corresponding with each of the specific objectives are as follows:

Question 1

What are the significant factors for the sustainable application of GIS in Luang Prabang?

Question 2

What are the significant changes in the built environment of Luang Prabang between 1999 and 2009?

Question 3

a. What are the reasons behind the significant changes in the built environment of Luang Prabang?
b. What is the relationship between the increase of touristic use and significant changes in the built environment of Luang Prabang?
c. What is the relationship between the Safeguarding and Preservation Plan and significant changes in the built environment of Luang Prabang?

1.4 Significance of Study

This study contributes in three aspects. First, the preservation of the landscape of Luang Prabang is important and conveys the OUV of the heritage site. Built environment is an integral part of the landscape and encapsulates the unique characteristics of a World Heritage Site. The degradation of the built environment would have adverse consequences on the heritage site. Hence, it is significant to analyze the state of the built environment. The changes reported in Luang Prabang's landscape were conflicting and remained unclear. To the best of the author's knowledge, no spatial analysis has been carried out of the built environment of Luang Prabang. Therefore, it is essential to visualize and analyze the changes occurring to the built environment. The spatial analysis of the built environment entails the use of GIS mapping tool. However, the introduction of GIS is very challenging in developing countries in terms of data resources, cost, and sustainability. This study looks at how GIS technology can be introduced sustainably in the context of Luang Prabang. Therefore, the deployment of GIS in Luang Prabang considers the sustainability aspect by addressing local constraints and adopting potential solutions in the design.

Secondly, this study employs a more holistic approach by conducting an in-depth analysis on a significant sample size and uses a reliable baseline by adopting pertinent indicators relevant to heritage values. Thirdly, this study seeks to comprehend the reasons for changing the buildings from a local perspective by interviewing relevant stakeholders, such as local experts and residents. The existing literature was criticized for assessing change from a western perspective and lacking local perspective. Therefore, the empirical evidence obtained by this study helps to clarify and grasp what has changed in the built environment, and why the changes occur. Mapping of change using GIS and develop counter-measures to manage changes in the built environment was identified as one of the top priorities by the DPL in response to the WHC. This study, as an action research[4], offers potential solutions to the pressing issues faced in preservation. Managing change means defining the limits of acceptable change in accordance with the threshold or carrying capacity of the World Heritage Site (Bandarin & van Oers, 2012; Labadi, 2013). Information derived from the study could be useful to determine the capacity of the World Heritage Site to accommodate and withstand development without undermining its OUV. This would facilitate local decision-makers in drawing up strategies and policies to manage change.

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[4] Action research is "based upon a philosophy of community development that seeks the involvement of community members" (Kumar, 2014, p.160). Community members are involved in the entire process from problem identification to implementation of solutions. Its philosophy is similar to participatory research and collaborative inquiry.

Overall, this study serves as a reference for other HUL. It is important to relate to other heritage sites and align with the current evolvement in heritage conservation. The three major paradigm shifts in heritage conservation which need to be taken into consideration are: 1) a broader approach, from object-orientated to including the surrounding landscape; 2) an integrated conservation approach with urban planning; and 3) adaptation to local context.

1.5 Thesis Outline

This thesis consists of six chapters. The outline of each chapter is as follows:

1) Chapter 1, the introduction, provides a general description of the study in terms of background, objectives, research questions, problem statement, and significance.
2) Chapter 2, the literature review, examines several overarching concepts important in developing the research framework. It reviews the evolvement of heritage conservation and implications of becoming a World Heritage Site. It is preceded by a review of the application of GIS technology in developing countries and landscape analysis.
3) Chapter 3, methodology, describes the research design developed to address the research questions and hypotheses. The research design includes the application of GIS and investigation from a local perspective.
4) Chapter 4, data analysis, presents the results of the GIS application, analysis of the built environment, examination of relationships, and results of interviews with local stakeholders.

5) Chapter 5, discussion, comprises a discussion of the results and identifies contributions to research knowledge by linking the findings with existing literature.
6) Chapter 6, conclusion, summarizes the major conclusions, presents limitations of this study, and suggests potential future research.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews related research and practices to provide overarching concepts and the framework of this study. The review is divided into two broad themes: heritage conservation and GIS. This provides an overview of what is important in heritage conservation and how heritage sites are evolving due to tourism growth and development. GIS are reviewed in terms of application in developing countries and landscape analysis. It is necessary to find out how GIS are used and implemented in developing countries, as well as to identify appropriate methods of analyzing landscape. It also includes review of statistical methods instrumental to analyze relationships.

2.1 World Heritage Conservation

The modern concept of heritage started in Europe in the 16^{th} century, after the Renaissance. The concept focused on monuments and artistic creations. However, in the middle of the 20^{th} century, mass destruction and demolition brought by war and industrial revolution made people aware of the importance of their environment and cultural identity. Thereafter, many countries in Europe began to enact laws to protect historic towns and cities (Lennon, 2006). Heritage conservation principles have developed, evolved, and refined from 1877 to recent times. In 1877, the manifesto of the Society for the Protection of Ancient Building (SPAB) was the first attempt to establish coherent ideals on building conservation, and advocate the protection of ancient buildings. The Charters of Athens, organized by the International Museums Office in 1933, was instrumental in developing an international code of practice for conservation and focusing on urbanism.

It was in the post-war era that an international movement to preserve heritage was initiated. The "World Heritage" concept emerged when the Abu Simple temple of Egypt, considered one of most important heritage sites, was threatened by flood following the construction of the Aswan High Dam on the Nile River. In 1959, UNESCO launched an international aid campaign to save Abu Simple temple, with donations of USD 80 million from 50 countries. The temple was dismantled stone by stone and relocated to higher ground. The case of Abu Simple temple has shown that preserving OUV is a shared concern and responsibility of the people of the world. This realization led to the adoption of international legislation for a conservation framework, the Convention Concerning the Protection of World Cultural Heritage and Natural Heritage in 1972 (UNESCO and Institute of Tourism Studies (IFT), 2007).

The UNESCO World Heritage is divided into three categories: 1) cultural heritage; 2) natural heritage; and 3) mixed cultural and natural heritage. Cultural heritage consists of monuments, groups of buildings, and sites which include cultural landscape which have OUV. Natural heritage consists of natural features or habitats of species with OUV. Mixed cultural and natural heritage has outstanding qualities of both natural and cultural heritage (UNESCO, 1972). In 1976, UNESCO held an Expert Meeting to discuss OUV, which was interpreted as

> *meaning that a property submitted for inclusion in the world heritage list should represent or symbolize a set of ideas or values which are universally recognized as*

important, or as having influenced the evolution of mankind as a whole at one time or another (ICCROM, 2008, p.11).

In order to be nominated, a World Heritage Site must possess OUV which meets at least one of 10 selection criteria. The selection of a World Heritage Site is based on six cultural criteria (i-vi) and four natural criteria (vii-x) (UNESCO, 2005).

2.1.1 Evolution of Heritage Conservation

Conservation principles and guidelines were disseminated through charters, recommendations, resolutions, and statements by UNESCO and ICOMOS. The initial approach of conservation had a very limited scope and was object-orientated. In the 1960s, it was recognized that safeguarding world heritage sites required the extension of heritage conservation laws beyond monuments and archaeological sites, which led to the development of Article 1 of the International Charter for the Conservation and Restoration of Monuments and Sites (Venice Charter). The charter stipulated the need "to include the urban and rural settings as the contents of conservation, where evidence of civilization was found or historical events had occurred" (ICOMOS, 1964, p. 5).

One of the most significant documents on conservation was adopted in 1972. UNESCO adopted the approach of emphasizing the links between heritage, conservation, and harmonious development in its General Conference of the 17th session of the Convention concerning the Protection of the World Cultural and Natural Heritage (UNESCO, 1972). Later, UNESCO redefined conservation by recommending that "every historic area and their surroundings should be considered as a coherent whole" (UNESCO, 1976, p.12). The 1972 World Heritage Convention was an important one in the domain of heritage conservation for three reasons. Firstly, for the first time in history, principles debated among experts for almost a century were converted into an international legal system. Secondly, the Convention integrated categories relating to nature and cultural properties. Thirdly, a system of international responsibility was created to protect and monitor the evolution of sites that possess OUV (Bandarin & van Oers, 2012).

In 1975, the European Charter of Architectural Heritage emphasized the application of relevant and appropriate restoration techniques (Council of Europe, 1975). Within the same year, in the Declaration of Amsterdam, the Council of Europe redefined the conservation approach as an integral part of urban and regional planning. It suggested reconciling the needs of heritage in economic and social frameworks to assure the long-term survival of heritage. Later, in 1987, the Washington Charter was established to develop principles and guidelines for the protection and conservation of historic towns. The Washington Charter broadened the conservation framework to align it with coherent policies at every level of planning and implementation. This Charter focused on the integration of preservation into policies, preserving the quality of towns, involving locals in preservation efforts, and addressing the social and economic dimensions of historic towns (ICOMOS, 1987). The Budapest declaration in 2002 emphasized the balanced distribution of heritage of all diversities and highlighted the roles of World Heritage Sites in promoting sustainable development. It highlighted that conservation work should serve to contribute to economic and social development and improve the quality of life of communities (UNESCO, 2002).

The evolvement of conservation has signified a paradigm shift in the philosophy and approach of heritage conservation to a broader scope. The definition of conservation has expanded from protecting individual objects to a wider context that includes the landscape. The initial conservation approach centered on restoration techniques has developed into an integrated approach by taking into account the cultural, economic, and social dimensions.

Another pivotal shift in conservation was acknowledging the importance of the local context by respecting, and corresponding to, different cultural and heritage diversities. This changed the perception of authenticity. Authenticity[5] is an essential attribute of heritage. Formerly, authenticity was more Western-centered; however, it has shifted to recognize the different meaning of authenticity for different cultural groups (Jerome, 2008). For example, Japan is practicing a centuries-old tradition of replacing timber in temples and rebuilding using original techniques. The spirit and value of heritage lie in practice itself, rather than in the structure or materials. The Japanese government and UNESCO organized an international conference in Nara in 1994, prompted by the need to seek a better understanding of authenticity. It was a revolutionary move. The Nara Document (ICOMOS, 1994) focused on converting heritage interpretation and conservation into a local context. The value, significance, and authenticity of heritage resources need to be interpreted respecting particular cultures, and the values of the local community. The authenticity of heritage was originally defined by physical tangible aspects comprised of the four parameters of design, material, workmanship, and setting. It has expanded

[5] Authenticity is the "measure of the degree to which the values of a heritage property may be understood to be truthfully, genuinely and credibly, expressed by the attributes carrying the values" (Stovel, 2004a, p.3).

to incorporate intangible heritage, such as traditions, language, techniques, spirits, and feeling (UNESCO, 2005).

Furthermore, ICOMOS (2004) reported that the World Heritage List has unbalanced representations of types of World Heritage Sites and that the list is mostly dominated by Western World Heritage Sites. An action plan was drawn up to fill the gap in World Heritage Sites and have diverse representatives from all regions. Apart from the representation of World Heritage Sites, charters drawn up for local contexts have grown too. The Venice Charter has been used as a guide in conservation works by professionals around the world since the 1960s. However, local conservationists have found it difficult to adopt the Charter because the conceptualization of heritage was heavily influenced by European-orientated heritage. Therefore, the development of conservation for localized contexts can be observed from the emergence of Australia's Burra Charter, China's Principles, and Asia's Hoi An Protocol.

The Burra Charter was drawn up in 1999 and adopted by ICOMOS' national committee in Australia because there was a need for new concepts and techniques to preserve diverse and valuable heritage resources (Australia National Committee ICOMOS, 1999). The local conservationists could not relate to the European concept of "monument", which refers to buildings of great antiquity and history. The European settlement in Australia has only a short history of 200 years, while aboriginal archaeological sites date back 40,000 years. The charter used the Venice Charter as a fundamental philosophy and refined it to develop practical concepts and guidelines for cultural significance, conservation policy, conservation studies, and codes of ethics.

The China Principles emerged in 2000 when there was an urgent need to have coherent guidelines which complied with existing legislation in China for local conservationists at different levels of authority. This was due to the profound impact of rapid economic development since China's open-door policy was introduced in 1978. The rapid growth triggered massive construction and development, which brought great pressure on rich historic sites in China. The China Principles consist of 38 articles developed to address a wide range of conservations issues faced by China's ancient and diverse heritage. The principles present coherent conservation methodologies and guidelines along with a systematic compilation of successful domestic and international experiences (ICOMOS China, 2000).

The Hoi An Protocol (Engelhardt & Rogers, 2009) was developed due to the need to have effective regional conservation guidelines for Asia. The protocol is instrumental in bridging the gap between the Nara Document and the practical application of restoration methods for different heritage categories in Asia. One of the major contributions of the Protocol is defining authenticity in an Asian context and relating it with international guidelines. In addition to authenticity, the Protocol identified common threats in Asia and listed prerequisites for all conservation sites to follow.

World Heritage sites' facing of realities and dynamic changes led to the issuance of more charters for intangible heritage, namely the Convention of Intangible Cultural Heritage and the Quebec Declaration. The Convention for Safeguarding of Intangible Cultural Heritage of 2003 defined the types of intangible cultures and recommended methods to preserve them (UNESCO, 2003). The Quebec Declaration of 2008 focused on the preservation of the spirit of the place where it is important to interpret the heritage values in general but with a specific interest in the setting of urban heritage and 'spirit of place' (genius loci) (ICOMOS, 2008).

More than 250 cities are inscribed as World Heritage Sites and it was challenging for the diverse cities to adopt a traditional conservation framework (Bandarin & van Oers, 2012). As such, recommendations on HUL were introduced in 2011 (UNESCO, 2011). The HUL approach is a heritage management tool to provide guidelines for heritage conservation and urban development. It was unique in that the approach is applicable to all cities with heritage worth preserving and not limited to World Heritage Sites. The HUL approach functions around the idea that when an urban area is properly managed, development can contribute to the quality of life of local communities and conservation of heritage. The HUL approach framework consists of six steps, namely (UNESCO, 2011; Veldpaus et al., 2013); 1) comprehensive mapping of a city's natural, cultural, and human resources; 2) obtaining consensus through participatory planning and consultation of stakeholders on preserving heritage values and attributes; 3) assessing the vulnerability of heritage to development and climate change; 4) integrating the results from steps 1, 2, and 3 into a city development framework; 5) putting priority on action to be taken on conservation and development; and 6) forming a local partnership and management framework.

Bandarin and van Oers (2012) added that the trend of charters, conventions, and recommendations have changed profoundly over the years in five aspects, namely: 1) increased and diversified different categories of World Heritage Sites; 2) conventional and fixed principles and techniques changed to open-ended and emerging themes; 3) heritage conservation no longer being viewed as a final outcome but as a process-oriented effort' 4) Euro-centric conservation principles being changed to regional and local value systems; 5) promotion of cultural diversity.

In summary, a World Heritage Site needs to be protected in accordance with the evolving concept of heritage conservation and its values. Major transitions in heritage conservation which can be surmised from the literature are: 1) a broader scope of conservation, expanding from an object to the entire landscape; 2) an integrated approach to urban development; 3) customization to local culture and situation; and 4) inclusion of intangible heritage. It is important to highlight the most recent recommendation issued by UNESCO on the HUL approach. This suggested the mapping of all heritage attributes as the first step of integrating heritage management into urban development and promoting sustainable development. This study needs to align with the current paradigm shift in conservation, and mapping is the first and foremost important step for heritage management.

2.2 Positive and Negative Impacts of World Heritage Inscription

There is an increasing number of World Heritage Sites in the Asia Pacific region. A great deal of literature indicates that the inscription of a World Heritage Site comes with positive and negative implications. It is recognized that the inscription of a World Heritage Site title inevitably attracts a high number of tourists and increases various human activities on the site (Johnson & Thomas, 1995; Kammeier, 2008). Heritage tourists regard a World Heritage title as a prestigious benchmark, thereby warranting the heritage site as unique and worth visiting (Rakic & Chambers, 2008). Hence, tourism becomes one of the biggest industries in World Heritage Sites and plays an important role in providing jobs, reducing poverty, and preserving customs in developing countries.

The expected benefits of World Heritage inscription are summarized as follows: 1) state parties gain international recognition and are held accountable to preserve the site; 2) improved protection and management with implementation of a site-specific management plan and framework; 3) new partnerships and projects are opportunities to gain funding and gain or exchange international expertise; 4) social and economic improvement of local livelihoods; 5) political and ethnic recognition at local and international level; and 6) increased tourism activities (Hall & Piggin, 2001; Frey & Steiner, 2011).

Cultural Heritage Sites, particularly in the less-developed countries of Asia, have faced intense pressure from tourism for three reasons, respectively: 1) the highest growth rate in the world; 2) tourism still being in its developing stages; and 3) increasing concern as to the sustainability of heritage-based tourism (Imon, 2013). There are consequences if a World Heritage Site is inept in balancing the positive and negative impacts of tourism in the long term. It is recognized that the lack of capability to manage such impacts is particularly acute in developing countries due to lack of resources, experience, and trained human resources (Kammeier, 2008). Frey and Steiner (2011) argued that the major negative consequence of increased popularity among tourists would be the deterioration of the site. They voiced concerns that the local government’s strong interest in continuously promoting the growth of tourism could lead to degradation of the heritage site. In the absence of proper management and policies, rapid investment and infrastructure development will occur. Moreover, the continuous preservation and maintenance of the site requires substantial funds. Nasser (2003) added that urbanization, the global scale of tourism, and the marketing of heritage as a product is acutely observed in World Heritage Sites. In many cases where heritage sites are reinterpreted and redefined to be more lucrative according to consumer demands, their preservation is compromised. Although there are numerous studies on the impacts of tourism from social, cultural, and economic aspects, very few have focused on the impacts in the Asian heritage context (Imon, 2013).

A common challenge often debated in heritage conservation is the conflict between development and conservation. In a review of heritage cities in England, Ford (1978) observed both extreme cases of the devastating effects of unplanned development and overly strict conservation. If a historic city is preserved without embracing any change, it will be a ghost town. And if a historic city changes too quickly and loses its connection to its heritage, it will be in turmoil. He argued that a historic city needs both continuity and change. He stressed an important point taken from a book by the renowned American urban planner, Kevin Lynch, entitled “What time is this place?”, that preservation techniques and regulation alone were insufficient to manage change, and it was more vital to understand the relationship between urban form and capacity for change.

Stovel (2004) argued that for historic cities to continue to thrive and develop socio-economically, change is inevitable. Rather than halting change, the flexibility to cope with and react to change is vital for the sustainability of the city. It has been pointed out that the need for change does not necessarily mean all change is acceptable. Tangible heritage resources are finite and not regenerative (Teutonico & Matero, 2003). Matero explained sustainability in the tangible heritage context means “ensuring the continuing contribution of heritage to the present through the thoughtful management of change responsive to the historic environment and to the social and cultural processes that created it” (Teutonico & Matero, 2003, p.viii). He stressed that the management of change and the continuity of heritage are only made possible by first grasping how heritage is being lost, and what factors have contributed to the process. Therefore, it is essential to grasp the process of change in heritage cities without eroding the OUV (Imon, 2008).

Managing change is finding the limit of tolerable change according to the threshold or carrying capacity of a World Heritage Site (Bandarin & van Oers, 2012; Labadi, 2013). However, changes in heritage cities tend to be seen as modifying heritage values (Bandarin & van Oers, 2012). Negative perceptions of change have made it difficult to interpret change and define the limits of tolerable change. These negative perceptions also affects the principles and methods used in the assessment of change, where it tends to be ad hoc and subjective. It is also problematic as to who is responsible for defining the limits and taking action. Therefore, change needs to be understood and interpreted from the point of view of local cultural values, as advocated by the Nara Document (Staiff & Bushell, 2013).

It is important to monitor how historic cities evolve over time, and how this affects their OUV. The UNESCO document on guidelines to monitor change in World Heritage Sites states that monitoring efforts must be focused on the impact of time and circumstances on heritage values defined during the inscription process (Stovel, 2002). If the baseline used does not refer to the original state at the time of inscription, it would deteriorate and not reflect a desirable state of conservation. Hence, monitoring should be measured according to key indicators related to authenticity and integrity[6] that convey the OUV of the World Heritage Site. Boccardi (2002), learning from his experience in Arabic and African countries, cautioned against introducing impossible monitoring standards in developing countries. Monitoring should be designed with due consideration for local conditions, and restricted to vital observations that could evaluate changes affecting heritage values.

Inevitably, the World Heritage Site and its inhabitants are subject to change or new developments as time passes. The development of a World Heritage Site is especially challenging and complex in developing countries. The author agrees that it is important for the World Heritage Site to have the capability to manage change. Managing change needs to effectively maximize the positive effects and minimize the negative effects of becoming a World Heritage Site. It is crucial that the measurement of change in World Heritage Sites uses specific data based on indicators which reflect heritage values. The significant information derived will serve as a basis for stakeholders to manage change. As Staiff and Busshell pointed out, the changes that occur need to be understood from a local perspective. Collective opinion from relevant local stakeholders helps to interpret the changes that occur in a more holistic manner.

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[6] Integrity is "a measure of the wholeness and intactness of the natural and/or cultural heritage and its attributes. Examining the conditions of integrity, therefore requires assessing the extent to which the property: a) includes all elements necessary to express its outstanding universal value, b) is of adequate size to ensure the complete representation of the features and processes which convey the property's significance, c) suffers from adverse effects of development and/or neglect." (UNESCO, 2005, p. 22)

2.2.1 Impact of Tourism and Development on Historic Urban Landscape

This section examines the impact of tourism and development pressure on HUL in Asian developing countries such as the Old Town of Lijiang of China, Melaka and George Town of Malaysia, Hoi An Ancient Town of Vietnam, and the Historic Center of Macao in China. Sharp tourism growth has often triggered unplanned development, accompanied by modernization. Commercialization has occurred in almost all historic cities, where the need to cater for tourism has outweighed the needs of local residents (Peters, 2013). Developers have often built to cater for the market rather than to preserve traditional characteristics (Gao, 2008). ICOMOS has analyzed 1570 threats that were reported in 614 World Heritage Sites (ICOMOS, 2005). Among the negative effects of urban development pressure are the destruction of traditional or vernacular [7] buildings, construction of larger buildings, high-rise, and modern houses, encroachment, illegal constructions, and waste pollution (Gao, 2008; ICOMOS, 2005). The impact of tourism on the historic built environment in terms of positive and negative aspects is summarized in Table 2.

[7] Vernacular building refers to the traditional and natural way of living of the local community. The architectural style and construction materials used express and reflect local culture and traditions. (ICOMOS, 1999; Stovel, 1987)

Table 2. Impact of tourism and development on a historic built environment

1. Urban environment • Land lost through development which may have been used for agriculture • Change to the hydrological system
2. Visual impact • Expansion of the built area • The effect of new architectural styles • Population growth
3. Infrastructure • Overloading the urban infrastructure with the following utilities and developments: - Roads - Railways - Car parks - Electricity grid - Waste disposal and water supply • Provision of new infrastructure • Additional environmental management measures to accommodate tourists and residential areas
4. Urban form • Changes to the land use as residential areas see hotels/boarding houses develop • Alterations to the urban fabric from pedestrianization and traffic management schemes to accommodate tourists • Changes to the built environment lead to contrasts in the quality of the urban areas used by tourists and residential areas
5. Restoration • Re-use of redundant buildings • Restoration and preservation of historic sites and buildings

Source: Page, 1995, p. 147

Lijiang, located in China's Yunnan Province, was designated in 1997. Lijiang, known as Dayan Ancient Town, was the trading market on the Tea and Horse Trade Route since before the rule of the Tang Dynasty until the 1950s and served as a meeting-place for Chinese and Tibetans. Lijiang derived its dramatic urban landscape and diverse architecture from the unique fusion of

Chinese and Naxi, a Tibetan cultural group. The town has an ancient water-supply system of great complexity that still functions effectively (ICOMOS, 1997). Lijiang experienced a sharp increase in tourists from 1.7 million in 1997 to 4.6 million in 2007 which caused large-scale development pressure on the core of heritage and buffer areas (Feng & Nishimura, 2008; Gao, 2008). The built area expanded rapidly and almost all areas surrounding the Old Town were converted to touristic use (Li, 2004, 2008). Large-scale hotels were built. New modern construction have affected the site (Li, 2004). Much of the historic land was lost and only a few isolated historic buildings remained due to urban sprawl (Li, 2008). The local population steadily declined and was replaced by businessmen from Fujian, Kunming, and Guangdong (Peters, 2013). The World Heritage Committee issued a warning in 2008. The committee stressed the lack of a comprehensive conservation master plan and site management plan to control tourism businesses. The town was managed under an Old Town Conservation Plan following the zoning of national Urban Planning Act, which was deemed not to be suitable for a heritage site (Feng & Nishimura, 2008).

Hoi An Ancient Town in Vietnam was a South East Asian trading port from the 15th to 19th centuries, drawing on influences from indigenous and foreign cultures. The town, inscribed in 1999, has well-preserved traditional human settlements of houses and shops with unique angles of streets and alleys. The unique architecture, made mostly from wood, combines local design and techniques with those from other countries, such as China and Japan (UNESCO, 2008). Hoi An is one example of successfully using tourism to alleviate poverty. It was reported that Hoi An experienced a similar increase in tourists of 872, 663 (544%) and tourist accommodation buildings of 2,478 (467%) between 1999 and 2007. Hoi An suffered mainly from gentrification, with private investors from other parts of Vietnam buying the old houses from lower-income families. The transformation of conventional land use to touristic purposes led to the decline of local residents and affected the cultural lifestyle, which degraded the authenticity of the site. In addition, Hoi An was impacted by uncoordinated building construction, increased traffic, noise and air pollution, and increased garbage. The town also suffered from congestion and overcrowding (Galla, 2012). The old timber houses are vulnerable to fire and termite infestation. Moreover, locals could afford restoration, which was considered too costly before. Construction was occurring at a fast pace and needed to be monitored. Strategies drawn up to tackle these challenges were the capacity-building of local government staff, and projects to mitigate urban development pressure on other areas surrounding the heritage site.

Melaka and George Town in Malaysia were inscribed in 2008. Both Melaka and George Town have 500 years of history as rich trading ports linking the East and West in the Straits of Malacca. Melaka town was shaped by the influence of the Malay Archipelago in the 15th century and the Portuguese and Dutch from the early 16th century. Meanwhile, George Town was influenced by the British in the late 18th Century. Both towns demonstrate the multicultural exchange between Malay, Chinese, Indians, and three European colonial powers, which formed the development stages of the townscape and architecture. There was major tension between the economic development promoted by the Federal Government and heritage conservation. In George Town, proposed development projects were approved before nomination that contradicted protective measures. The development projects were allowed to be located within the buffer zone, and the proposed buildings of 12 to 28 stories would exceed the permitted height limit. A 2009 report examining the state of conservation judged that this occurred due to lack of any legal framework for the Federal Government to practice control of properties that might threaten the heritage site (UNESC0, 2009; King, 2015). As for Melaka, large-scale infrastructure projects were conducted to reclaim land surrounding the trading port. New, big tourist facilities continued to grow along the coast of the Old Town of Melaka. Although both cities have well-developed heritage management and managed to retain important monuments, pressure from modernization and the drive to provide for the tourism industry continue to pose risks to preservation because economic development has been prioritized over preservation (King, 2015).

The Historic Center of Macao was inscribed in 2005. Originally, the historic city was a small fishing village that grew over 450 years to become a prosperous trading port and business center (Imon, 2008). Macao is recognized for its living settlement, formed as a result of a rich cultural exchange between the Chinese and Portuguese over several centuries. The heritage city is comprised of twenty-two monuments and eight piazzas, connected by a network of streets. Macao is well known as a casino city. Large-scale investment from casino, entertainment, and hotel industries has impacted Macao socially, economically, and environmentally. Rapid development since 2002 has led to a great deal of construction in the core heritage area. Large casinos are being built, with high-rise luxury apartments. The transformation of the built environment has affected the visual integrity of the historic city (Imon, 2008, 2013). In 2011, the World Heritage Committee urged local government to take urgent action (Imon, 2013). This negative impact occurred because of a failure to anticipate and manage change caused by development. A framework to control the demand for new construction is needed.

The impacts of the sharp growth in tourism and development on the several World Heritage Sites reviewed above are summarized in Table 3. It can be surmised that the impact of tourism on HUL are mainly conversion to touristic use which leads to the migration of locals, the expansion of built land, large-scale development projects, and the construction of larger buildings, modern buildings and high-rise buildings. It can be deduced that the transformation of building function to touristic use has prompted hasty construction and alterations to buildings. This has inevitably changed the built environment. This information would serve as a premise to develop hypotheses on two aspects: 1) significant changes in the built environment, and 2) relation between the significant changes and increase of touristic use.

Table 3. Summary of the impact of the growth and development of tourism on the HUL of World Heritage Sites in Asia

Major impacts identified	World Heritage Site in Asia
Rapid construction of touristic facilities	• Lijiang, China (Li, 2008) • Macao SAR, China (Imon, 2013) • George Town and Melaka, Malaysia (UNESCO, 2009; King, 2015)
Large-scale development, construction of larger buildings, modern buildings, and high-rise buildings, for example, hotels, casinos, shops, and luxury apartments	• Lijiang, China (Li, 2004, 2008; Feng and Nishimura, 2008; Gao, 2008) • Hoi An, Vietnam (Galla, 2012) • Macao SAR, China (Imon, 2013) • George Town and Melaka (UNESCO, 2009; King, 2015)
Rapid conversion from residential to touristic use resulting in decline of original population and its replacement by local investors from other parts of the country	• Lijiang, China (Peters, 2013) • Hoi An, Vietnam (Galla, 2012)
Much historic land lost; only a few isolated historic buildings remaining due to urban sprawl	• Lijiang, China (Li, 2008)
Fast-paced and uncoordinated construction	• Lijiang, China (Li, 2004, 2008; Feng and Nishimura, 2008; Gao, 2008) • Hoi An, Vietnam (Galla, 2012)
Large casino and high-rise luxury apartments affected the visual integrity of the heritage site	• Macao SAR, China (Imon, 2013)

Source: Summarized from Feng and Nishimura, 2008; Galla, 2012; Gao, 2008; King, 2015; Li, 2004, 2008; Imon, 2013; Peters, 2013; UNESCO, 2009.

2.2.2 Changing Landscape of Luang Prabang

Much literature from the disciplines of architecture, built environment, heritage, and tourism have attempted to analyze the change caused by the impacts of rapidly growing tourism. Most of the literature was critical of the implications of tourism development on Luang Prabang's landscape and its intangible heritage.

Sitthivan (2005a, 2005b) and Dearborn and Stallmeyer (2009, 2010) used different methodologies to assess the change in the built heritage of Luang Prabang. Sitthivan's is one of the earliest studies to try to assess the actual situation of Luang Prabang, and identify problems in conservation (Sitthivan, 2005a, 2005b). He carried out a quantitative analysis of the authorized and unauthorized constructions (392 cases) which occurred in the entire World Heritage Site for the years 2002 and 2003, and supported this with a qualitative analysis of the level of locals' awareness of preservation. Locals increased building size and constructed inappropriate roof shapes because they were unaware of preservation regulations, did not understand the contents of regulations, undertook building works themselves without prior plans or the help of experts, and were satisfied with the end results. He deduced that the source problems in conservation were that the heritage management system was not fully operational; the government had formulated a one-sided PSMV without consulting locals; locals did not have the know-how and knowledge to alter buildings following the preservation guidelines; and the administration itself lacked ability. He concluded the analysis with additional questionnaires to evaluate local awareness of preservation using 197 participants including citizens, local government officials, academicians, and undergraduates from Vientiane and Luang Prabang (Sitthivan, 2005b). The key findings show that the locals felt Luang Prabang was becoming more beautiful and developed, and that traditional Luang Prabang houses should be preserved. However, they preferred to live in different types of houses and preservation regulations were becoming a problem in constructing their houses.

A recent study by Vonvilay (2015) presented different findings to Sitthivan's that Lao houses have transformed in accordance with regulations. He analyzed the transformation of Lao traditional architecture houses by comparing five cases. He observed the change in the floor plans of original and transformed Lao houses in terms of spatial formation, components, and elements. The transformation was influenced by four factors, namely, globalization, economic and social aspects, and preservation regulations. He found that Lao houses have maintained their exterior and aesthetics because of regulations. The use of houses' interior space has changed from residential to touristic use, and modern techniques and materials are now used. Preservation regulations play a major role in controlling the transformation of the houses, especially in the core heritage area. It was noted that in the case of developing countries, the oldest houses are normally located in the poorest area, and could easily be changed or destroyed without much consideration of their heritage values. However, in the case of Luang Prabang, no inventory buildings were destroyed and the transformation was strictly controlled. Transformation to touristic use was the most effective way to generate income, alleviate poverty, and sustain the houses. It concluded that regulation had prevented globalization and economic factors from strongly influencing the transformation.

Dearborn and Stallmeyer (2009, 2010) attempted to compare changes in buildings using the PSMV. They utilized photographic documentation and hand-drawn maps. They made a walking route in the core heritage area and singled out the small number of 18 inventory and non-inventory buildings. They found that the buildings did not follow the recommended regulations, and later interviewed the owners to find out the reasons. Their findings supported the claims made in the WHC mission monitoring report on inappropriate building practices in regard to architectural form, use of materials, and size (Boccardi & Logan, 2008). The dominance of guesthouses and hotels has resulted in the loss of local craft production, and gentrification. The authors further claimed that the PSMV intended to preserve the heritage site has valorized particular aspects of it, and transformed it into a touristic landscape. The local authorities have erased and removed heritage that is inconvenient to the political agenda and heritage title. However, Staiff and Busshell (2013) questioned the study's strong critique. The study was too strict and disapproved the demolition of non-inventory buildings that were, in fact, replaceable according to regulations. The demolished buildings were mainly temporary and poorly-constructed residential dwellings.

Staiff and Bushell (2013) were skeptical of the type of analysis and conclusions derived by Boccardi and Logan (2008) and Dearborn and Stallmeyer (2009, 2010). Heritage, tourism, and community were treated independently, and the complexity of what was happening in Luang Prabang was oversimplified. Moreover, the critique of previous studies seemed to be influenced by their Western perceptions of Luang Prabang, and its heritage and modernity. They observed that one of the authors of the mission report, William Logan, had contradicted himself, given what he has written on imposing a uniform global heritage system on non-Western heritage sites and accepting conservation practices that reflect local cultural values. Hence, they tried to link heritage, tourism, and community by using a mobility theory that treats modernity as a fluid rather than a static state. Their study analyzed the mobility of community at global, regional, and local levels. Their findings had a wide scope and captured elements in an evolving society including social interactions, movement, interconnectedness through telecommunications, local understandings of heritage, and more. They concluded that the change in Luang Prabang should not be viewed as fearful, but should be treated as an arresting process that could be negotiated.

Another study attempted in-depth analysis and tried to comprehend the dynamics of tourism, heritage, and development, and the role of local politics and economy (Reeves & Long, 2011). The pressure faced in Luang Prabang and problems in heritage conservation were mainly because of changing political and economy processes at the regional level, rather than at local level, for example, investment pouring in from China and Korea, and the development of Asian mass tour packages. They believed that the indefinite development of tourism would disrupt the traditional use of buildings, and cultural and religious practices, drive up land prices, and force residents with a low economic capacity to move out. Therefore, they concluded the traditional approach to heritage management would not be able to address these complex issues, and that they were beyond the jurisdiction of local heritage managers. Luang Prabang's current designation only covers the preservation of the built and natural environment. It was deemed as not sufficient to protect its living heritage. Reeves and Long (2011) proposed that the heritage managers and policy-makers of Luang Prabang should adopt the cultural landscape approach, which encompasses broader strategies to protect both tangible and intangible heritage. Rellensmann (2010) analyzed whether the World Heritage framework contributes to the sustainability of Luang Prabang in the long run, and found similar constraints. She identified an inappropriate heritage categorization was inscribed for Luang Prabang. She concluded that the town should be conferred cultural landscape status to preserve both its intangible and tangible heritage. In short, she felt that the inappropriate heritage categorization awarded Luang Prabang has made the existing heritage management unsustainable.

Pierre (2008) supported the claims of Boccardi and Logan (2008) on the loss of wetland with an in-depth study using GIS technology. The study on wetland was a project funded under European Union and City of Chinon, France. Pierre reported that originally there were 183 protected wetlands, covering 9.6ha. However, 75 ponds have disappeared, of which 56 were filled intentionally, and 19 suffered the natural process of filling through the accumulation of fine deposits. Luang Prabang has lost 41% of its protected ponds, and the remaining ponds cover 7.5ha. This alarming loss is traced to the sharp rise in new activities related to tourism. The loss of function and use of pools, and the increasing land costs in the core heritage area, have pushed many owners to consider filling the ponds or selling land parcels (Pierre, 2008). A recent study on wetland combined GIS with qualitative methods to analyze change in wetlands, and people's attitude towards wetland (Irie, 2016). Three datasets were compared between 2001 and 2015. Forest cover and wetlands have reduced, and the buildings zone has increased. The study revealed that wetlands were intentionally reclaimed because of an increased population and the accumulation of mud at the bottom of ponds. Six factors that affect people's attitudes were identified from a factor analysis as cost, feeling, knowledge, usefulness, importance, and accessibility of wetlands.

Most literature was critical of the perceived impacts of tourism impacts on Luang Prabang. However, Staiff and Bushell (2013) and Vonvilay (2015) have revealed rather mixed findings from other studies. The inconsistent observations reported in the existing literature indicate the lack of empirical evidence to support the perceived impacts. There is a lack of in-depth analysis and significant sample size. Although Sitthivan's study is the only one that offers ample empirical data, it focused only on certain houses that have changed negatively. The overall impacts of tourism development on Luang Prabang's landscape, and factors leading to the changes, still remained unclear. To the best of author's knowledge, GIS visualization has only been applied on wetland (Pierre, 2008; Irie, 2016). No spatial analysis has been conducted to visualize the change on the built environment of Luang Prabang. Therefore, this study will examine and identify significant changes that are transforming the built environment by using GIS mapping tool. As pointed out, when managing change in a heritage site, it needs to be understood from the local stakeholders' perspective. It is necessary to comprehend the relation between the significant changes with the increase of touristic use and the PMSV. The empirical evidence obtained by this study will help to clarify and gain a clearer understanding of what has changed in Luang Prabang, and how.

2.3 Geographical Information Systems

GIS is described as integrated computer-based technologies capable of performing operations of geographic information from acquisition and compilation through visualization, query, and analysis, to modeling, sharing, and archiving (Longley et al., 1999 and 2010). In short, GIS simplify real-world data into a spatial database that stores information on various phenomena and their locations. The basic functions of GIS are summarized in Table 4.

Table 4. Basic functions of GIS

Function	Type of questions asked	Description
Location	Where is it?	To identify what exists at a particular location
Measurement	How far/big is it?	To examine distance, area, perimeter
Condition	Where is it? What state is it in?	To identify what is present at a given location and what could be present
Trend	What has changed?	To describe differences in an area over time
Patterns	What spatial patterns exist?	To identify concentrations of certain activities and their location
Modelling	What if?	To determine what happens if a certain action is taken

Source: Fadahunsi, 2010, p. 301; Maguire & Dangermond, 1991

The development of GIS technology has taken place over 40 years (Clarke, 1999; Foresman 1998; Goodchild; 2012). In the early 1960s, GIS began to emerge as the first automated mapping and military satellite imagery appeared at the same time. The earliest development GIS was started in Canada by the Canada Geographic Information System. The Canadian government intended to recommend a policy for the effective use of Canada's huge land resources in collaboration with provincial governments. However, Roger Tomlinson, an experienced geographer in aerial surveys, recognized the massive scale of the project meant it was too time-consuming to measure from thousands of individual map sheets. He developed a scanner to input map data, created vectorization of scanned images, and programmed various GIS operations, for example, overlay and area measurement.

Since then, GIS technology has been increasingly common in government and the private sector because of significant developments in its analytical functions on land use, and the production and mass distribution of geographical data with the emergence of new satellite sensors, the Global Positioning System (GPS), and the Internet (Longley, 2010). GIS is used in a wide range of applications, from global climate change to patterns of disease and crime, or even the distribution of plants and animals. In other words, GIS is considered a useful tool because of its advanced analytical functions on land use with geographical data. In developed countries, GIS serve as a powerful tool to integrate development plans in order to address complex problems and pursue sustainable development (Campagna, 2006; Mantaay et al., 2006; Salvador & Juliao, 1999).

GIS technology has also become important in archaeology, cultural heritage management, and heritage studies over the past twenty years (Wheatley & Gillings, 2002; Fitzjohn, 2009). On cultural and natural heritage sites, the challenge lay in monitoring and comprehending the evolution of the sites (Hernandez, 2004; Stovel, 2004). A large amount of data needs to be collected and interpreted to assess whether the heritage site is under threat and take the necessary counteractive actions. The use of satellite imagery and georeferencing through GIS has played a significant role in the monitoring process.

2.3.1 GIS Application in Developing Countries

Developed countries have focused mostly on the complex and advanced use of GIS; however, developing countries are still dealing with the implementation of GIS (Ramasubramanian, 1999; Campagna, 2006). The success or failure of GIS is influenced by many factors which are irrelevant to its technicality. In search of a better approach to implement GIS in developing countries, Ramasubramanian (1999) reviewed three existing frameworks in developed countries: 1) ease of adopting technology; 2) a typical GIS implementation approach in organizations; and 3) a paradigm shift within GIS in technology, applications, and data management. In his paper, he refined the framework for successful GIS implementation. In the past, implementation was considered adequate as long as the technology was accepted and the technology transfer had been completed. His paper suggested that GIS success meant that organizations had the ability to overcome problems by using GIS and benefited from the advantages of GIS technology. He stressed that GIS implementation needed to be understood in the context of policies that facilitate its implementation. The four essential characteristics of successful implementation were summarized, based on three case studies from Ecuador, South Africa, and Mauritius, as the following: 1) clear identification of a problem; 2) establishment of strategic partnerships; 3) an incremental rather than an ambitious scale of implementation; and 4) the development of local and context-specific knowledge.

Mennecke and West (2001) also examined one of the existing frameworks reviewed by Ramasubramanian (1999). They opted to highlight the importance of the availability of spatial data for developing countries. As a result, they simplified the ease of adopting a technology framework into two variables for developing countries: 1) the technological characteristics of innovation; and 2) the managerial and organizational characteristics of the innovation environment. They knew that the nature of spatial data collection made it difficult, even for certain developed countries, to acquire spatial data. The situation would be more severe for developing countries. In developing countries, the physical data of mountains and lands were developed using conventional method of digitizing paper maps. However, in many cases, there were inconsistent scales, inaccuracies, and outdated data. Moreover, socioeconomic data such as populations, economics, and social patterns were not revealed in the maps and needed to be surveyed. For example, the spatial map of a building could indicate if it was a factory but could not detect the type of products produced there. Apart from spatial data, data integration and management was a major issue because measurement and collection methodologies varied across different regions and departments. In terms of implementing organizations, they learned that many were unable to wait for tangible benefits after a long period of implementation. As the initial investment does not yield tangible benefits immediately, it normally took 3 to 5 years to design and implement GIS. Other issues encountered by the organizations were a lack of trained personnel and organizational politics. It was often the case that organizational politics in public sectors were very significant in influencing GIS implementation. Being in possession of information gives rise to power and a position above other members in the organizations. Organizational politics also resulted from conflicting interests, different ownership of data, and competition between different departments.

Mennecke and West (2001) suggested that a number of steps are taken to counter the problems of spatial data, such as developing a national base map to eliminate the expenses of each database producer; imposing national standards to standardize mapping and facilitate information sharing; ensuring low-cost data acquisition by using a GPS and purchasing remote sensing data; and initiating public and private collaboration policies. As for organizational issues, it was best to view these as tools rather than obstacles. Therefore, it was necessary for the organizations to develop policies to encourage shared responsibilities, shared commitment, shared benefits, and shared control between participating parties in the project.

Mennecke and West and Ramasubramanian learned from the case of developed countries and provided an overview of frameworks for implementing a successful GIS in developing countries. Although similar problems can be identified for developing countries, they emphasized that there was no one generalized solution for all and that it was important to consider the local context in implementation. It is often the case that the failure of GIS is due to inability to overcome local constraints and adapt its use to the local environment.

Bishop (2000), learning from the case of Bangkok Metropolitan Administration's ambitious use of GIS, argued that there are stark differences between the characteristics of developed countries and those of developing countries. The differences hamper the adoption of successful GIS land-use models from developed countries. Bishop has distinguished various barriers, such as 1) uncoordinated development due to quick financial-gain-induced development; 2) the urgent demand to address rapid growth and a growing population; 3) diverse and incoherent laws for planning and management; 4) an acute absence of spatial data; 5) lack of funding; and 6) lack of political will. Bishop argued that developing countries faced diverse circumstances and complex problems. He stressed that there were only a few successful GIS applications which could be guidelines for developing countries.

In heritage conservation, UNESCO first tested the usefulness of GIS in Angkor Wat in 1992 and pioneered their implementation since the local government was newly formed after 20 years of civil war (Box, 1999). It consciously chose the site knowing the severe limitations faced, such as scarcity of electricity, non-existence of data, and lack of local staff who had heard of GIS. GIS application was designed to overcome the constraints through the data integration of different maps and local GIS training. GIS was successfully implemented, and instrumental in developing a local heritage preservation framework known as the Angkor Zoning and Environment Management Plan (ZEMP). As such, UNESCO was confident that it could be replicated in any World Heritage Site and demonstrated a keen interest in GIS technology by developing an introduction manual for cultural heritage management. The manual was developed with the purpose of integrating heritage preservation into regional development using cutting-edge technology.

Although GIS can be considered a useful tool in developed countries, as seen in the previous examples, not all successful cases can be easily replicated in developing countries. The gaps between developed and developing countries have exacerbated the problems faced in implementing GIS in developing countries. The common problems impeding a successful GIS implementation are mainly technical (accessible spatial data and skilled personnel); and institutional (organizational politics). However, it is precarious to generalize. It is important to consider the local context in implementation. Since successful and sustainable applications of GIS in developing countries are few, as Bishop reported, it is imperative to identify clearly the factors which lead to success and failure in their implementation in the context of World Heritage Sites and cities in Asia. As Box (1999) has shown in the success of GIS implementation in Angkor Wat, it is crucial to consider potential constraints and incorporate possible solutions in the design of GIS prototype. For the purpose of designing an appropriate system and sustainable implementation of GIS, the author intends to conduct comparative case studies from Asia to identify the common factors of sustainable use of GIS and assess the local situation in using GIS.

2.3.1.1 Common Factors of Sustainable GIS in Developing Countries

The introduction of GIS can be beneficial to local use if the constraints are identified in advance and incorporated into the development of the GIS application (Box, 1999). Five case studies were compared to identify important factors that lead to practical GIS implementation in World Heritage Sites and urban cities in Asia (Leong et al., 2008; Takada et al., 2008). Although each country has a different background in economic, social, institutional, legal, and technical aspects, important lessons can be drawn from the success and failure of the cases. The five cases analyzed comprised three World Heritage Sites and two urban cities, namely, Hue in Vietnam; Plain of Jars and Vat Phou in Lao PDR; Cebu in the Philippines; and Bangkok in Thailand. A range of GIS implementation strategies was adopted in these cases. In each case, the major factors which determined the success and failure of GIS introduction are summarized in Table 5.

Through comparison of five case studies, it is recognized that the potential sustainable deployment of GIS must not only address technical aspects in terms of software, hardware, and data. It should have a holistic approach to consider financial, human resources, and institutional issues. Six significant factors contributing to successful GIS introduction were identified, as illustrated in Figure 7.

Table 5. Factors that determine the success or failure of GIS introduction in case studies

Background of case	Purpose of GIS	Successful factors	Barrier factors
1. Hue, Vietnam (Box, 1999) • The World Heritage Site located in Thua Thien Hue Province in the central of Vietnam. • The Imperial city of Hue with its own Forbidden Purple City built in 1802 possesses a unique architecture. • The structure is deteriorating because of climate, a prolonged period of war, and lack of funding for restoration. • The project aims at protection, conservation, and enhancement of the site's cultural resources.	• Assist in micro-management of the Hue Monuments Complex o Produce an inventory of cultural heritage resources and their constituent parts. o Analyze, manage, and visualize structure condition. o Assess needs of prioritizing resources for maintenance, conservation, and restoration. • Assist in macro-management of cultural resources within the context of Hue's cultural landscape o Management of urban area of Hue through analyzing land-use, demographic data, and development plans. o Management of the cultural landscape of Hue through analyzing land-use, heritage protection zones, and regional development plan zones.	• Selected the appropriate GIS software according to the users' needs, and which was suitable for beginners. • Fully utilized local experts to conduct gradual and locally-based GIS training. • Did not rely on vendor support by using locally-developed GIS software called DBMap, by the Institute of Information Technology (IOIT) in Vietnam. • Cost-effective.	• Limited finance to generate spatial data and maps. • Lack of data availability and map sources at different scales for regional, urban, and site-planning purposes.

Factors that determine the success or failure of GIS introduction in case studies (continued)

2. Plain of Jars, Lao PDR. (Box, 2003) • The site nominated as a World Heritage Site is located in Xieng Khouang, south of Lao. • The Jars are believed to be mortuary vessels, dating back to 500 B.C – 500 A.D. • The area suffered heavy aerial bombardment during the Vietnam War. • The project aims at creating a heritage inventory.	• Define map boundaries for most frequently visited jar field sites to request clearance of unexploded ordnance.	• Successfully integrated cartographic map data with different scales through the cooperation of four agencies. • Data collection and field survey achieved through participatory approach by training and mobilizing local district officers and village chiefs.	• Lack of suitable and available topographic maps. • Generating spatial data at different scales is costly.
3. Vat Phou, Lao PDR. (Box, 1999) • The World Heritage Site is located in the southeast of Lao. • It is a Hindu-Buddhist sanctuary of the Khmer Empire period, spanning from the 9th to 13th centuries. • The project aims at developing a heritage protection zone strategy of the site.	• Collect and archive archeological, geological, demographic, land use and hydrological data. • Analyze data collected to develop a heritage protection zone strategy for the site.	• Selected appropriate GIS software according to the users' needs, ability, and good vendor support. • Utilized standardized data format which is compatible with other local departments to encourage sharing and integration of spatial data.	• Lack of full-time and dedicated local GIS personnel to continuously update the data.

Factors that determine the success or failure of GIS introduction in case studies (continued)

4. Bangkok, Thailand (Bishop, 2000) • Bangkok Metropolitan Administration (BMA) initiated the Bangkok Land Information System (BLIS) project from 1989 till 1991. • The project aimed for a long-term strategy development of the BLIS.	• Produce a base map common for BLIS project and analyze data collected for a long-term planning strategy of Bangkok, such as garbage disposal management, demand for primary education in districts, and different districts' population density for policy making.	• The presence of high-level awareness and management support in integrating information from different local departments. • Encouraged interagency collaboration. • Emphasized GIS training program to educate, train, and provide experience to local officials.	• Requires high cost, takes a long time, and is administratively complicated to develop a large-scale digital map.
5. Cebu, Philippines (Vegt, 2001) • Cebu Province established GIS center which provides services and GIS products to local clients with support from the German Agency for Technical Cooperation (GTZ).	• Produce and update digital data and maps.	• The presence of high level of awareness and management support for the continuous development of GIS. • Promoted information flow from different sources.	• Limited funds to generate and maintain spatial data. • Lack of qualified GIS local staff and high turnover due to low salaries.

Source: Leong et al., 2008

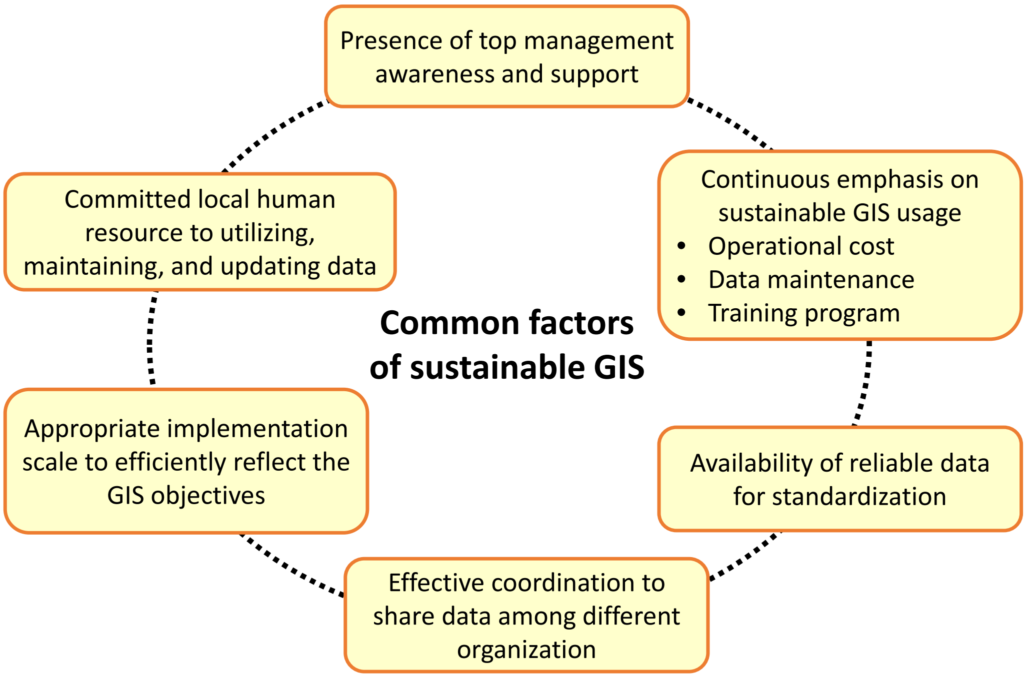

Figure 7. Six common factors of sustainable GIS use identified from comparative case studies

Source: Leong et al., 2008

The six factors are summarized as follows (Leong et al., 2008):

1. Presence of top management awareness and support towards efficient GIS usage

A high level of awareness and management support is identified as one of the most important factors. In the context of developing countries, the successful implementation and use of spatial information infrastructures are strongly dependent on political and institutional support. Management support is necessary to build a solid infrastructure by understanding the limitations, and providing the necessary flow of information to the system. In the case of Bangkok, the project only received the necessary political support after the expert in charge was seconded as the deputy governor to the Bangkok Metropolitan Administration (Bishop, 2000). In the first few years of the GIS project in Cebu, the project suffered from a lack of financial buffers and a high turnover of staff, due to low salaries and poor work conditions compared with the private sector (Vegt, 2001). However, with strong management support, the project finally overcame the difficulties and succeeded in establishing the Geoplan Cebu Foundation. The Foundation was able to gain more decision-making responsibility, run independently from the administration of province government, and be flexible in offering services and products on the GIS market.

2. Local human resources committed to fully utilizing, maintaining the system and updating data

Local human resources are the key to fully utilizing the appropriate technology, maintaining the system, and updating data. Therefore, the availability of local human resources is a crucial factor. A strong team of full-time and dedicated local professionals needs to be established. In the case of Vat Phou, Lao PDR, a small team consisting of a Lao archaeologist, a museum specialist, and a conservator was formed and trained (Box, 1999). However, they were not assigned as full-time GIS operators and had other duties and responsibilities. This situation led to a lack of continuity in data processing and management. In both Vat Phou, Lao PDR, and Hue, Vietnam, appropriate software packages were selected according to the users' ability and needs. Beginner-level software was used and satisfied the users' needs although it lacked spatial analysis functions. In Hue, Vietnam, local experts from the Institute of Information Technology in Vietnam fully contributed to conducting gradual local GIS training (Box, 1999). There is a need for a very substantial training development program aimed at raising and maintaining skills.

3. Availability of reliable and compatible data

In developing countries, appropriate maps are scarce (Mennecke & West, 2001). Appropriate data are difficult to obtain in digital form and base maps were often outdated or non-existent. Even when spatial data were available in digital form, few results were derived. It is important to start with basic data collection in order to make GIS fully functional and effective. This requires time and cost, which few people are willing to commit to as the benefits may not be immediate. In the case of the Plain of Jars, Lao PDR, producing a base map even for a limited area was problematic because of the lack of a suitable topographic map (Box, 2003). Spatial data generation is very costly. Thus, the project is only feasible if a base map or data generated by a third party can be procured for little or no cost. The project had to incorporate data from four different local departments at different scales. Appropriate data standards are crucial to ensure compatibility of data, encourage sharing of data, and reduce data redundancies. However, it is difficult to obtain consensus due to different institutional needs. An organization which leads in establishing data standards, deciding on the scales, and constantly updating data is often lacking in developing countries.

4. Effective internal and external coordination to facilitate data-sharing among different organizations

Another commonly observed factor is the importance of institutional coordination with GIS implementation. The decision to implement a large-scale GIS has greater consequences in terms of organizational change. Implementation of GIS to support the objectives of a specific department may cause a lower impact on the other departments, restrict the availability of data, and limit inter-departmental coordination. Regardless of the scale of implementation, the GIS system must be able to integrate with existing information management procedures. The Plain of Jars, Lao PDR, was able to adapt GIS intervention into its current system and integrated maps from four different departments (Box, 2003). This enhanced interagency collaboration thus achieved mutually beneficial development objectives.

The Plain of Jars project was conceived as a collaborative effort to safeguard the cultural resources of the site, together with the lives of local inhabitants and tourists. However, not all the cases were successful in adapting GIS into the organizational structure. One such example is Bangkok, Thailand. Although there was a common interest in producing a base map, urban planners and utility agencies had different scale needs and different point of views as to map requirements (Bishop, 2000). At the same time, there was a lack of understanding of the technology concepts of the GIS system. The conflict of interest, lack of understanding, and misconception gave rise to unnecessary competition among the government agencies who were participating in the Bangkok Land Information System (BLIS) project. The agencies were considering their own interests as they were competing for budgets to develop their own computerized systems which were independent of the BLIS project.

5. Continuous emphasis on balancing operational cost, updating data, and implementing training program to assist users

Sustainable use of GIS requires three aspects to be fulfilled: a) balance operational cost and cost incurred for future development of the system; b) implement a training program to assist and guide GIS users who are facing changing technologies to continuously utilize GIS; and c) maintain system with constant updating of the data. In the cases mentioned above, these aspects were discussed extensively. The three aspects are dependent on each other, and it was observed that sustainable usage of GIS system will be difficult if one of the three is missing.

The GIS introduction and training in all case studies except that of Bangkok were initiated and funded by foreign aid organizations. Once the project completed, it was difficult to sustain the necessary operational cost without foreign aid organizations since the GIS software maintenance and licensing fees are often costly. All cases relied on vendor support, except for Hue, Vietnam. The sustainable use of GIS requires financial support from the government and could incur high costs if the system totally depends on the vendor's support. In Hue, Vietnam, the case enjoyed considerable success due to the fact that all three requirements were met. Low cost was incurred due to GIS software being developed by the Institute of Information Technology (IOIT), and locally-based training. The local experts from IOIT, being sensitive to the users' lack of experience and educational level, designed a gradual training program to ensure a smooth learning process for them. Though the software did not include spatial analysis functions, the users' needs were satisfied and it encouraged a continuous data updating. Data maintenance requires solid financial resources and the commitment of human resources.

6. An appropriate implementation scale to efficiently reflect the objectives of GIS

The scale of GIS implementation in developing countries makes a difference to its degree of success. The GIS system utilizes a base map, which is costly and requires considerable effort to generate spatial data. Many government agencies in developing countries do not possess a quality base map and it is often the case that appropriate data are not available. In the case of Bangkok, the Bangkok Metropolitan Administration (BMA) aimed to develop a large-scale digital map (Bishop, 2000). It was mentioned in the case study that, after nearly a decade of struggle, although the BMA realized that GIS is an effective tool for planning and managing urban infrastructure, the development and maintenance of a large common digital base map has not been realized. It is now recognized as costly and administratively complicated. Therefore, it is likely that starting with a smaller-scale implementation with specific usage and a simple analysis is more convincing. Operational cost and initial investment are also likely to be recovered through short-term benefits, and a concrete good example of this can encourage the expanded use of GIS. These small- or medium-scale projects are good options to introduce the GIS concept in developing countries, to convince decision-makers and to gather a wide range of supporters for the introduction of such technologies.

2.3.1.2 Spatial Data in Lao PDR

In review of GIS application in developing countries, one of the main barriers to successful GIS applications is the lack of availability and sharing of spatial data and a base map. Hence, it is important to comprehend the use of GIS, the availability of spatial data in Lao PDR, and potential solutions offered in the literature, as these will be useful in designing a localized GIS application for Luang Prabang.

The use of mapping and GIS is relatively new in Lao PDR. The Lao government has developed a database of maps and enacted several policies to guide the use of mapping within the country. The use of GIS and spatial data is mainly promoted by National Geographic Development (NGD) and collaborations between international donors and local government offices. NGD, under the supervision of the Office of the Prime Minister of Lao PDR, is the authority in charge of land surveying, aerial photography, mapping, and geodetic control networks (Mishra, 2007). The mandate of NGD was enacted by Prime Minister Decree No.73/PM in 1995. NGD has the power to promulgate regulations and supervise surveying, aerial photography, and topographic mapping. NGD has created GIS database to store fundamental geographical information to generate geographical maps. NGD also supplies GIS datasets to the public for a fee and provides free data to government organizations or projects upon request (Wada, 2006).

There were five standard topographic maps available in Lao PDR as a result of NGD collaboration with different countries (Mishra, 2007; Souminen et al., 2011). Each mapping was surveyed by different counterparts importing different technological measurement systems at different periods of time; as a result, different geographic coordinate systems known as datum were developed. Datum enables all locations on earth to be specified by a set of numbers, longitude, latitude, and elevation. Among the five maps, one of them were made by the US Army (1963-1967). The four remaining maps were developed by Lao government with the assistance from the Soviet Union (1975-1981), the Japanese International Cooperation Agency (JICA) (1993-1996), Vietnam (1996), and Finland (1998-2003 and 2011-2015). The work with Finland is the most recent effort to produce higher-quality digital mapping at the smaller scale of 1:5000 for developing cities and towns such as Vientiane, Luang Prabang, Thakhek, Savannakhet, and Pakxe. Among all the maps developed, the two maps made by the US Army and the Soviet Union are the most widely used among the local governments. However, the maps were produced at different scales and used different datum. The US Army maps were developed at scale 1: 50,000 with 20m contour interval, using Indian Datum 1960. While the Soviet Union maps were made at scale 1:100,000 with 40m contour interval, using Vientiane Datum 1982.

In 1997, NGD developed the Lao National Datum 1997, a new geodetic datum system from the Land Titling Project in a bid to unify with the world standard, WGS84. According to Mishra (2007), NGD has recommended all land surveyors in the country to use this datum. However, poor understanding of different datum and the relationship between them could cause confusion and obstruct data integration from different sources. This has led to difficulty in sharing maps, which has finally resulted in low map accuracy and overall inefficiency. Thus, the National Land Management Authority (NLMA) collaborated with the Lund University GIS Centre to resolve the datum problem by producing a manual to guide the transformation of all datum to Lao National Datum 1997 and the world standard, WGS84 (Nilsson & Svensson, 2004, 2005).

Multiple Lao government agencies have separately developed their own GIS databases and generated maps in diverse fields using ArcInfo, ESRI, such as Mekong River Commission (MRC), the Ministry of Agriculture and Forestry (MAF), the Department of Electricity under the Ministry of Electricity and Mining (MEM), and Unexploded Ordnance Lao (UXO Lao) (Wada, 2006). It was difficult to share the data since there was no clear scheme for sharing fundamental datasets and to standardize GIS data. Various decrees related to surveying, aerial photography, and mapping activities were enacted. Among them, an important decree, no. 255/PM, stipulated that it was necessary to "ensure unity in administration management of data, quality, technique, equipment, and funds in accordance with technical instructions outlined by government" (NGD, 2005, p. 12). The use of results and activities was to be within a single unified system throughout the country. Although efforts were made by NGD and the decrees were employed, Mishra (2007) observed that there were no technical instructions on practical implementation and too few organizations adhered to the decrees. This resulted in it being difficult to get an overview of the geographical datasets available in the country.

The literature revealed the availability of five different topographic base maps in Lao PDR but with different scales, projection, and datum. It is difficult to find an existing reliable and compatible base map. Hence, it is necessary to develop a reliable base map suitable for an analysis of the built environment of Luang Prabang. The knowledge of various datum in Lao PDR, and the transformation to national and world datum developed by Lund University, could serve as a guide to integrate the available maps. Learning from observations by Wada (2006) and Mishra (2007) on the importance of data standards being promulgated, the author finds it necessary to align with the national standards of a single unified system. The geographical information, method, and tools need to adhere to the national standard in order for standardized data to be shared with other institutions. It is an important aspect that contributes to the sustainability of GIS use in local sites.

2.3.2 GIS Application for Landscape Analysis

Various methodologies are introduced to analyze landscape change. In this section, three methodologies using GIS to analyze landscape are identified: 1) the Steinitz model; 2) land use/land cover change analysis (LULC); and 3) the Stewart methodology. Steinitz (1990), a renowned expert in landscape architect from Harvard University, has developed a model to visualize and analyze landscape change. The model is considered to be one of the greatest contributions to GIS landscape analysis (Dave, 2010). The Steinitz model is versatile and provides a general framework to outline analysis of landscape. The model aims to evaluate landscape change to identify potential problems and analyze future impacts, in order to propose alternative solutions to continue to preserve or rectify a degraded landscape.

The Steinitz model has been demonstrated in various cultural and natural World Heritage Sites, such as Coiba National Park in Panama (Steinitz et al., 2005a), Upper San Pedro River Basin in Arizona, and Sonora, Mexico (Steinitz et al., 2005b). The case studies used the Steinitz model to explore the core issues in landscape planning in heritage sites where development is considered to conflict with conservation work. The Steinitz model is used to identify and evaluate the advantages and risks posed to landscape by land use development. It consists of 6 stages, as illustrated in Figure 8: 1) visualization and characterization of the current landscape; 2) identification of current landscape function; 3) evaluation of how well the landscape is working (positive and negative aspects); 4) identification of how landscape can be altered for improvement through possible scenarios studies; 5) assessment and estimation of the possible impacts of the proposed alteration; and 6) decision as to the best alteration solution for the landscape. Specific analysis methods for each stage need to be identified by researchers themselves from other relevant studies.

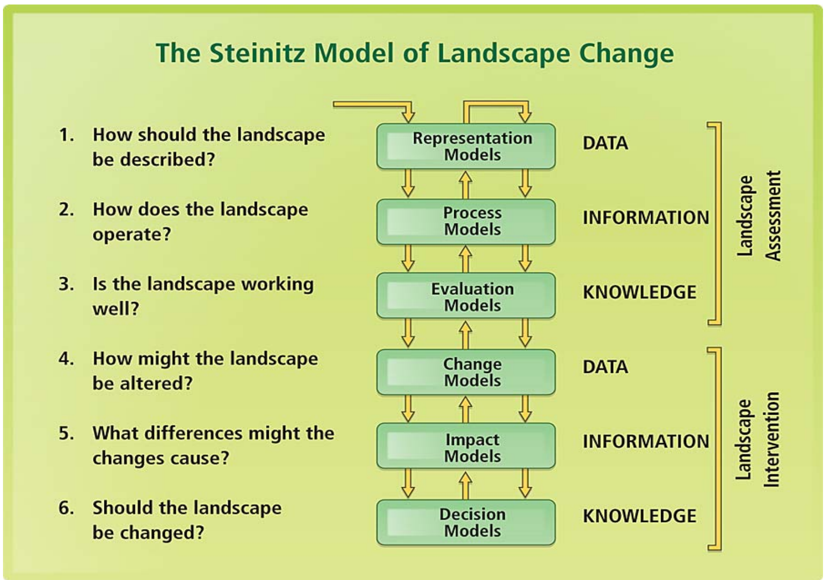

Figure 8. Carl Steinitz's six-stage model of landscape change

Source: Dave, 2010, p. 3

In the case of the Coiba National Park in Panama, there were serious conflicts between controversial development plans for hotel expansion and the exploitation of natural resources in the park. The plans were initiated by the national government but cooperating national conservation agencies, and local individuals, were against them (Steinitz et al., 2005a). The Steinitz model was used to analyze the impact of potential conservation and development strategies on the economy and ecological environment. The study relied heavily on the expertise and experience available locally, and the existing available data. Fifteen alternative scenarios, based on a broad range of policies, were generated with the input of many local stakeholders. It was found that the national park, located on an island, would sustain high ecological damage and show poor economic performance due to its geographical self-containment, and to policies restricting the growth of service towns. Tourism development in the coastal areas of the mainland would generate higher income instead.

Other demonstrations of the Steinitz model being applied to study alternative futures were in the Upper San Pedro River Basin, Arizona, and Sonora (Steinitz, 2005b). The basin is a significant global biodiversity region, known for the presence of endangered species. Development and land use are changing patterns of groundwater recharge, stream flow, and vegetation, thereby affecting the habitat of critical specifies. The model is used to understand the dynamic relationship between land use, hydrology, and vegetation. The study utilized three scenarios to project a development model in 2020: 1) planned, based on existing strategies and land use practices; 2) constrained, based on controlled development; and 3) open, based on less controlled development and high population growth. The study did not any propose any solutions, but only projected the alternatives of different consequences to the policy-makers. The study served as a resource for policy-makers to develop land management. The Steinitz model is an advantageous and critical tool for urban planners to analyze current land use to provide potential scenarios for local stakeholders to develop future plans. It has proved to be useful when the interests of preservation and development conflict. However, the limitations faced by this model are the availability of reliable data, assumptions drawn, and accessibility to local experts and policy-makers in the government. Without strong evaluation of government policies, it would be difficult to draw reliable alternative scenarios in stages 4, 5, and 6. Moreover, in stage 5, certain assumptions have to be made which do not consider the complex situation of the local site, or future complications. To summarize, model stages 1 to 3 are to analyze changes to the landscape, and stages 4 -6 are useful to decide the best alterations and interventions to change the landscape.

Land use/land cover (LULC) change analysis is commonly used to study landscape changes and examine the dynamics of the landscapes (Wu et al., 2008). LULC change analysis is one of the categories under change detection. Change detection techniques are used to analyze the changes on the surface of the earth, primarily environmental change (Singh, 1989). Change detection is an important process to manage urban development and environmental change, for it provides quantitative analysis of the spatial distribution of the area of interest.

This review focuses on the analysis of change in the area of interest, LULC, using GIS integrated with the following data: 1) remote sensing data, such as satellite images and aerial photographs; and 2) parcel data. In general, the mapping of changes of vector and raster data can help to track the transition of change (Mitchell, 2006). The analysis of LULC visualizes and models land use change over time by summarizing the total amount, type, and locations of the change (Logsdon, 1996). The majority of changes are detected through pre-classification and post-classification (Singh, 1989). Pre-classification yields "change" and "no change" maps. Post-classification tracks the change from the original category to another category which provides more information on the nature of the detected change compared to pre-classification (Jensen, 2004).

Iqbal and Khan (2014) demonstrated an analysis of LULC change in terms of urban growth in Kashmir, Pakistan, over the last 15 years. LULC has changed for several reasons, such as urban growth, poor infrastructure development, and natural disaster. LULC change detection and temporal analysis of Landsat satellite data were performed. Post-classification was carried out to see LULC changes. Vegetation and forest cover had decreased whereas built-up areas and bare soil have increased. They mapped the location of changed and unchanged areas in order to avoid overcrowding a diverse range of changes and produced an easily-understood map for visualization. It is helpful to look at a similar study on land use change in Islamabad, Pakistan (Butt et al., 2015). That study tracked the transition between each different land use category and showed that the transformation in land use posed danger to the watershed. It concluded by recommending proper watershed management for the area.

Gaughan et al. (2009) analyzed the Angkor Basin of Cambodia using two different remote sensing methods such as post-classification trajectory analysis, and analysis of changes of a continuous-field vegetation index. Post-classification is utilized to identify forest and non-forest change trajectory, while analysis of continuous-field vegetation index detects the presence of healthy green vegetation. The number of tourists at the World Heritage Site has grown tremendously by 40-fold since 1993. The area is pressured by the demand for wood, biomass fuel, and extensive land use change. Gaughan et al. used Landsat images of 30m by 30m, dated 1989 to 2005, to analyze three image dates to determine patterns of spatial and temporal changes. The study revealed that although at least 50% of landscape areas still kept their original land use of rice production, 23.4% of the forest area between Angkor Wat temple and Phnom Kulen National Park had been lost. The deforestation was mainly due to demand for charcoal production to support tourism growth.

Fletcher (2007) monitored heritage landscape changes and environmental impact to evaluate the effectiveness of heritage management policies at Angkor Wat. Since the 1980s, Angkor Wat has suffered deforestation and severe environmental impacts. He used multiple statistical methods and an image-differencing approach to analyzing change in data; and data from aerial photographs and high-resolution satellite images, 30m by 30m from 1990 and 2002, combined with field-surveyed data. The analysis found that vegetation land had been cleared in half of the area north of Siem Reap, due to the rapid growth of local settlements. The development impacts incorporate local inhabitants' understanding of the landscape by including it into the change detection technique. The changes in land use serve as information to the local community so they can readjust heritage management practices to align with the popular land usage.

On the other hand, LULC analysis can also be done by using parcel-level data, which is considered at a micro-level scale and could provide more spatial details (Allen et al., 2002). This is particularly significant for detailed investigation of land use development where building records of abundant information were generated from parcel attributes. Allen et al. (2002) used building permits and parcel data to detect change that affected the coastal area of South Carolina. The coastal area of South Carolina at that time changed enormously because of the development of tourism and the growth of residential area. The study found that the area had grown rapidly and undergone a transition from a commercial to a residential area. Commercial parcels, linearly distributed on primary roads, were spatially different from residential parcels. A logistic regression model was used to predict future land use change. The prediction required identifying factors that influenced land use change in order to determine predictor independent and dependent variables. A total of 20 variables were analyzed and the model was successful, with rates of over 90% in predicting future land use change.

The LULC change analysis quantifies land use change through remote sensing (Butt et al., 2015; Fletcher, 2007; Gaughan et al., 2009; Iqbal & Khan, 2014) and parcel level data (Allen et al., 2002). Analysis and simulation of LULC is an advantageous tool to study land use change and ecological change, and assess environmental impact. LULC can incorporate analysis of a wide range of land use classifications, which includes crops, forest, settlements, factories, infrastructures, water bodies, and more. In other words, a LULC analysis is used to study landscape undergoing a broad change in diverse land use. However, the limitation of LULC analysis is that it is dependent on the availability of high-resolution remote sensing data. Without sufficient funds, remote sensing data of good quality is considered inaccessible and costly for developing countries.

GIS has been criticized as too broad and limited to macro-scale analysis (He et al., 2015; Khirfan, 2010; Stewart, 2001). In the heritage context, more in-depth information on the physical appearance of buildings, such as architecture, materials, courtyards, natural settings, and so on, is essential. Most GIS systems in the heritage context document location and basic information, but do not proceed to integrate detailed information through georeferencing method. Rich information on heritage is left out and not analyzed through spatial analysis (He et al., 2015). The micro-level approach, in other words, a parcel-based analysis, could benefit the application of GIS in heritage conservation (He et al., 2015; Khirfan, 2010; Oh, 2001; Stewart, 2001). It provides more descriptive information to comprehend the urban fabric of cities (Khirfan, 2010).

Stewart (2001) analyzed HUL change in Cairo, Egypt. She found that studies of urban growth in developing countries focused mostly on economic and environmental impacts at the macro level, such as at national and city level. Stewart argued that HUL composed of rich heritage is fragile and vulnerable to all modifications and demolitions. Therefore, it required detailed studies of specific locations at a smaller scale, such as at sub-city level, to reflect all changing trends resulting from rapid growth phenomena. She illustrated micro-level landscape analysis methodology through a detailed visual comparison at the micro level of Zamalek, a pilot site within the city of Cairo. The approach compared the landscapes of 1920 and 2000 and analyzed building-by-building attributes. The detailed tracking of each building aimed at monitoring preservation, and to serve as a baseline for the long-term planning of preservation and development. Stewart's methodology combined with knowledge of Cairo's history and politics to yield, overall, a more holistic analysis and interpretation and an in-depth understanding of change experienced at street and neighborhood level. Stewart managed to identify four major trends, namely: 1) transformation of historical land uses; 2) increased densification; 3) destruction and alteration of 1920s villas; and 4) breach of height limitation on the Nile skyline.

Important aspects to investigate in the heritage context are authenticity and the integrity of the heritage site. Damen et al. (2013) investigated the factors that affect authenticity and integrity, which convey the OUV of a World Heritage Site in the case of the island of Mozambique. This World Heritage Site is affected by threats such as management deficiencies, aggressive developments, and general degradation. However, there is no evidence to link the loss of OUV with these threats. Similarly to Stewart, Damen et al. (2013) investigated the change in HUL over time and explicitly analyzed it building by building. The evidence of change in the built environment is compiled through a comparative analysis of photographs of buildings, floor plan drawings, and interviews with owners. Authenticity attributes are identified from collective UNESCO and ICOMOS documents, such as nomination files, advisory evaluation body files, and monitoring reports. All information is integrated using GIS to produce comparable table and graphical representations. It can be verified that the tangible attributes of architecture, materials, and decoration can still be found and have contributed to the formation of a homogenous HUL. However, the state of three attributes has degraded, which indicates the deterioration of authenticity.

The Steinitz model, LULC change analysis, and Stewart's methodology have their advantages and disadvantages. The relevance of each method will be integrated and applied to achieve the objective of this study. The Steinitz model has been demonstrated in various cultural and natural heritage sites. It provides a general framework to analyze landscape, and specific analysis methods need to be identified from other relevant studies. The Steinitz model is composed of two parts: landscape assessment (stages 1-3); and landscape intervention (stages 4-6). Stages 1 to 3 are sufficient for the purpose of this study, which is to analyze landscape change in Luang Prabang. The three stages are as follows: 1) visualization and characterization of the current landscape; 2) identification of the current landscape; and 3) evaluation of the impact of landscape change.

Stewart's method of overcoming the constraints in spatial data in developing countries, and interest in the heritage context, are useful for this study. The landscape of World Heritage Sites is vulnerable to all forms of changes from the construction, modification, and demolition of buildings. Therefore, the analysis of landscape change needs to closely examine the detailed change in the attributes of each building. Hence, Stewart's methodology of micro-level landscape analysis, combined with tracking change at parcel-level (Allen et al., 2002; Mitchell, 2006) to determine the nature of change in HUL through visual comparison, and tracking of change from original to different categories of building attributes.

2.4 Statistical Methods for Categorical Variables

There are various methods to analyze the relationship between categorical variables. The Chi-square test of independence is frequently used to analyze pairs of categorical variables (Urdan, 2010). It is used to determine whether two categorical variables associated with a sample are dependent or not. Chi-square is nonparametric; it requires no assumption as to the distribution of samples or population. In the case of multiple categorical variables, there are only a few methods. Principal component analysis (PCA) and factor analysis (FA) are common multivariate methods used for continuous variables and to measure the relation based on the Pearson correlation coefficient (Sourial et al., 2010). Although FA has been extended for binary and ordinal variables, it is based on certain assumptions and does not explore the individual response categories of variables.

Logistic regression is a predictive regression analysis used to explain the relationship between one or more dependent categorical variables, and one or more continuous or categorical independent variables (Yang, 2010). Logistic regression determines the probability or odds ratio of an event, based on exponential distribution. Allen et al. (2002) combined GIS with a logistic regression model to analyze and predict future land use change in the Murrells Inlet of South Carolina. The model to predict land use change was important to reduce risk in land use decision-making. The prediction required the identification of factors that influenced land use change in order to determine predictor independent and dependent variables. Hence, 20 variables were selected for prediction based on three criteria, where the variables must represent the coastal tourism destination areas, spatial relationship, and characteristics of parcels. A total of 4107 parcels were analyzed. Residential and commercial use were binary coded. It was predicted that commercial development would likely occur along the highway, especially north of Murrells Inlet. Li et al. (2015) claimed that Allen et al. (2002) only analyzed land use change, without examining the relationship with tourism. As such, they went a step further to analyze the relationship between spatial patterns of tourism in Hong Kong, using logistic regression models. The characteristics of hotels were chosen within a buffer of 500m, 1000m, and 2000m using GIS. The logistic regression models used hotel ratings as a predictor. Other dependent variables were multiple factors such as land use, transportation, type of attractions, and others. It was revealed that the commercial type of land use was positively influencing the spatial distribution of upper-grade hotels, while the number of attractions negatively influenced the likeliness of establishing upper-grade hotels.

Another approach developed for large, multiple-categorical data is a combination of MCA and HCA. MCA combined with HCA is useful to analyze datasets without distinguishing independent and dependent variables, and with no assumptions (Giannopoulou et al., 2014a, 2014b; Jobson, 1992; Lebart, 1994). MCA is a dimension reduction technique similar to principal component analysis but extended in two aspects where it is applicable for categorical data and to create perceptual map-based extracted components (Greenacre, 2007; Jobson, 1992). MCA converts frequencies of co-occurring features into distances and uses an optimal two-dimension plot to depict association among variables. HCA is used to identify homogeneous groups.

MCA and HCA are combined because they are able to show the significant association between multiple variables and interrelation between categories of variables, and, at the same time, provide better explanations for the diversity and nature of the categorical data (Charreire et al., 2012; Giannopoulou et al., 2014a, 2014b; Riviere and Malair, 2010). MCA is a pre-processing step, before clustering, because it can remove non-relevant dimensions that might be mixed with 'statistical noise' (Charreire et al., 2012; Husson et al., 2010). The most significant dimension obtained from MCA is used for cluster analysis to generate groups of specific characteristics. As a result, these methods could overcome the limitations of factor or cluster analysis.

The usefulness of this combined method was demonstrated in several cases of large datasets. Giannopoulou et al. (2014a, 2014b) integrated GIS with a multivariate analysis to visualize and evaluate the evolution of urban heritage areas in the Old Town of Xanthi of Greece. The heritage buildings data are mostly categorical. MCA combined with HCA were used to determine the correlation and patterns that exist in the datasets. The multivariate analysis was able to reduce dimensions and groups, based on similarities and dissimilarities. The buildings were classified into blocks and analyzed. They analyzed 17 variables and were able to identify four distinct groups of building characteristics clustered in different parts of Xanthi, as shown in Figure 9. The four groups of building characteristics identified helped to interpret and closely describe the actual situation of the built environment in Xanthi as follows:

1. Group A were remarkable two-floor buildings located in the core area of the historic city with interesting morphology, used mostly as residential dwellings, and in bad condition. These buildings displayed the traditional architecture of northern Greece and the Balkans during the Ottoman period.
2. Group B consisted of buildings in the north and southwest of the city. The buildings were single-floor, of small size, and used cheap materials, but do not have a unique morphology. These buildings were illegally built or altered and considered not to be compatible with the characteristics of the city.
3. Group C was positioned in the central and southeast area, where buildings displayed a remarkable neoclassical typology using industrialized materials such as bricks and metals. These buildings were mostly public buildings.

4. Group D was the most recent addition of three- to four-floor buildings in the south of the city, built with concrete.

The analysis by Giannopoulou et al. was able to reveal the patterns of the built environment of Xanthi and determine that the main characteristics of the city were still preserved. Only the negative intervention of a few undesirable buildings was observed. The built environment patterns obtained were expected to be used to draw up urban planning policies for Xanthi.

Figure 9. Four distinct characteristics of buildings in Xanthi, Greece

Source: Giannopoulou et al., 2014b, p. 495

Riviere and Malair (2010) analyzed the incidents of risk in biofuel production by examining 100 incidents in a database. The incidents were classified with multiple variables and diverse categories within each variable. The combined method of MCA and HCA was able to identify five main typologies of incidents, which contributed to gaining much-needed information on safety issues. Eight variables were analyzed in MCA. MCA optimally summarizes or denoises the data, and principal coordinates of reduced dimension were used for clustering. The 100 incidents were illustrated in a factor map. The incidents revealed the relationship between the different biofuels involved, the different location of incidents, and the different activities that caused incidents. The clustering of three types of information helped to identify five types of scenario, and provided a greater understanding of how incidents occurred. The grouping helped to comprehend specific characteristics of related information. Each of the five typologies was illustrated by actual cases of accidents. For example, one of the scenarios described the risk of using ethanol (biofuel) in the storage of hazardous materials (location) during maintenance works (activity). The analysis results were consistent with the response provided by the administration which deals with biofuel. The study was successful in disclosing relevant association of multiple variables, which was useful in determining accident patterns (Silva & Jacinto, 2012).

Charriere et al. (2012) also investigated built environment patterns in relation to the health lifestyle of French adults. The study identified seven built environment patterns using GIS, such as accessibility to green spaces, proximity to facilities, and availability of cycling paths. Later, the spatial distribution of the seven patterns was explored in relation to different types of exercise and body mass index using MCA and HCA. The multivariate methods were able to categorize different neighborhoods into homogenous patterns corresponding with built environment characteristics. They revealed distinct characteristics according to different geographical areas. Poor access to green spaces, little proximity to facilities, and absence of cycling paths were found in suburban areas, whereas in the city center, these problems were not present. The information derived was useful to determine urban and health policies to promote a healthy lifestyle.

In this study, built environment data are mostly categorical, and there are seven multiple variables. The author will adopt different statistical methods for one or multiple categorical variables to examine the relations between building attributes, such as the Chi-square test of independence, logistic regression, and the combined methods of MCA and HCA. The Chi-square test of independence could be used to find out the relation between touristic buildings and changes in other building attributes. Logistic regression could be useful to validate spatial patterns. The three cases above have illustrated that MCA and HCA were able to identify the relevant association between multiple categorical variables, and helped to determine patterns in their dataset. The author will adopt MCA and HCA to explore the relationship between PMSV and the significant changes. It will identify the specific characteristics of buildings created since the heritage site evolved, which was exemplified by Gauphilaou et al. (2014a and 2014b) in Xanthi, Greece.

2.5 Summary

The literature review has suggested three main research questions and helped develop the research framework. Firstly, it is necessary to explore significant factors for sustainable GIS application in the context of Luang Prabang. Few successful guidelines are available, due to the diverse and complex problems faced in developing countries. The failure of GIS commonly stems from the inability to adapt to the local environment and overcome local constraints. The application of GIS needs to address potential local constraints with possible solutions. Therefore, common factors of sustainable GIS need to be identified from other similar cases, and local constraints need to be identified.

Secondly, the significant changes in the built environment of Luang Prabang need to be clarified. Mixed findings were presented on the impact of tourism and development on the built environment of Luang Prabang. A visualization and spatial analysis of the built environment is necessary, using a significant sample size. The baseline used to measure change needs to be relevant to heritage values. The tourism and development impact in other HUL provides a reference to develop hypotheses.

Thirdly, the changes in the built environment need to be interpreted and understood from a local perspective. The analysis of significant changes needs to be supported by an investigation of the reasons behind the changes from local stakeholders. It is crucial to examine whether the significant changes are related with two important aspects that the literature claimed to have impacted the built environment of Luang Prabang such as increase of touristic use and the implementation of PSMV.

CHAPTER 3: METHODOLOGY

This chapter describes the research design of this study and the methods employed. Sections 3.1 and 3.2 summarize the hypotheses derived and the research design devised to answer the research questions. Sections 3.3 until 3.5 detail the preparation and development of a localized GIS application suited for the Luang Prabang context. Sections 3.6 until 3.9 describe the analysis carried out to identify significant changes, identify reasons given by local stakeholders for these significant changes, and examine relations.

3.1 Review of Study Objectives and Research Questions

As discussed in Chapter 1, Introduction, it is necessary to visualize and examine changes in a HUL by using the case of Luang Prabang, Lao PDR. The specific objectives and corresponding research questions are reviewed as follows:

Specific objectives:

1. To explore significant factors for the sustainable application of GIS in Luang Prabang;
2. To identify significant changes in the built environment of Luang Prabang between 1999 and 2009 through visualization;
3. To identify the reasons behind the significant changes from local stakeholders.

Research questions were developed corresponding with each specific objective:

Question 1

What are the factors significant for the sustainable application of GIS in Luang Prabang?

Question 2

What are the significant changes in the built environment of Luang Prabang between 1999 and 2009?

Question 3

a. What are the reasons behind the significant changes in the built environment of Luang Prabang?
b. What is the relationship between the increase in touristic use and significant changes in the built environment of Luang Prabang?
c. What is the relationship between the Safeguarding and Preservation Plan and significant changes in the built environment of Luang Prabang?

3.1.1 Hypotheses

The second research question attempts to investigate the significant changes in the built environment. Eight hypotheses were constructed to provide answers to the second research questions, based on the literature review of the impact of tourism and development on HUL (Feng & Nishimura, 2008; Galla, 2012; Gao, 2008; Imon, 2008, 2013; King, 2015; Li, 2004, 2008; ICOMOS, 2005; Peters, 2013; UNESCO, 2009) (refer to Chapter 2 Section 2.2.1) and a review of the changing landscape of Luang Prabang (Dearborn & Stallmeyer, 2009, 2010) (refer to Chapter 2 Section 2.2.2). The hypotheses derived are listed below:

Question 2

a. What are the significant changes in the built environment of Luang Prabang between 1999 and 2009?

   H1: Touristic use has replaced residential use.

H2: Modern architecture has replaced Lao traditional architecture.

H3: Modern building materials have replaced traditional building materials.

H4: Modern roof materials have replaced traditional roof materials.

H5: Average building height has increased.

H6: Building density has increased.

H7: Number of improved-condition buildings has increased.

H8: Changes of built environment have occurred throughout the core heritage area.

The research question 3b examines the relation between touristic use and the significant changes. The hypothesis was derived based on review of the impact of tourism and development on HUL (Feng & Nishimura, 2008; Galla, 2012; Gao, 2008; Imon, 2008, 2013; King, 2015; Li, 2004, 2008; ICOMOS, 2005; Peters, 2013; UNESCO, 2009).

Question 3

b. What is the relationship between the increase of touristic use and significant changes in the built environment of Luang Prabang?

H9: Increase of touristic use and the significant changes in built environment are related.

As for research question 3c that probes on relation between PSMV and the significant changes, there was no hypothesis and the relation was explored through data analysis.

3.2 Research Design

The research design of this study consists of four major steps, as illustrated in Figure 10: 1) preparation prior to the application of GIS; 2) identification of a significant pilot site; 3) GIS application; and 4) data analysis and interpretation.

Comparative case studies of GIS application in Asia (Chapter 2 Section 2.3.1.1) and on-site assessment (Chapter 3 Section 3.3) served as guidelines to apply GIS and select a significant pilot site (Leong et al., 2008, 2010; Takada et al., 2008). A comparison of five case studies from World Heritage Sites and urban cities in Asia was carried out in the literature review. The case studies were helpful in understanding the barriers and successful factors of GIS application in the context of developing countries. A total of six common factors were identified as vital for a sustainable GIS application. The common factors were incorporated into the selection of a pilot site and the development of a localized GIS application.

On-site assessment was necessary to determine the level of GIS application, if any. It was also to evaluate the advantages and disadvantages of GIS application unique to the local site. Thirdly, once the site assessment had been carried out, a significant pilot site for introducing GIS which reflected the objectives and appropriate scale needed to be identified.

Thirdly, GIS introduction needed to take into consideration the limitations faced in developing countries and, therefore, a localized GIS application for Luang Prabang needed to be designed. Methods employed to apply GIS are described in Chapter 3 and the result of the GIS application is presented in Chapter 4. The three components developed are: 1) data collection; 2) development of an appropriate database; and 3) development of a reliable digital base map (Leong et al., 2010, 2016; Sitthirath et al., 2010). The GIS application also included a review of its sustainability.

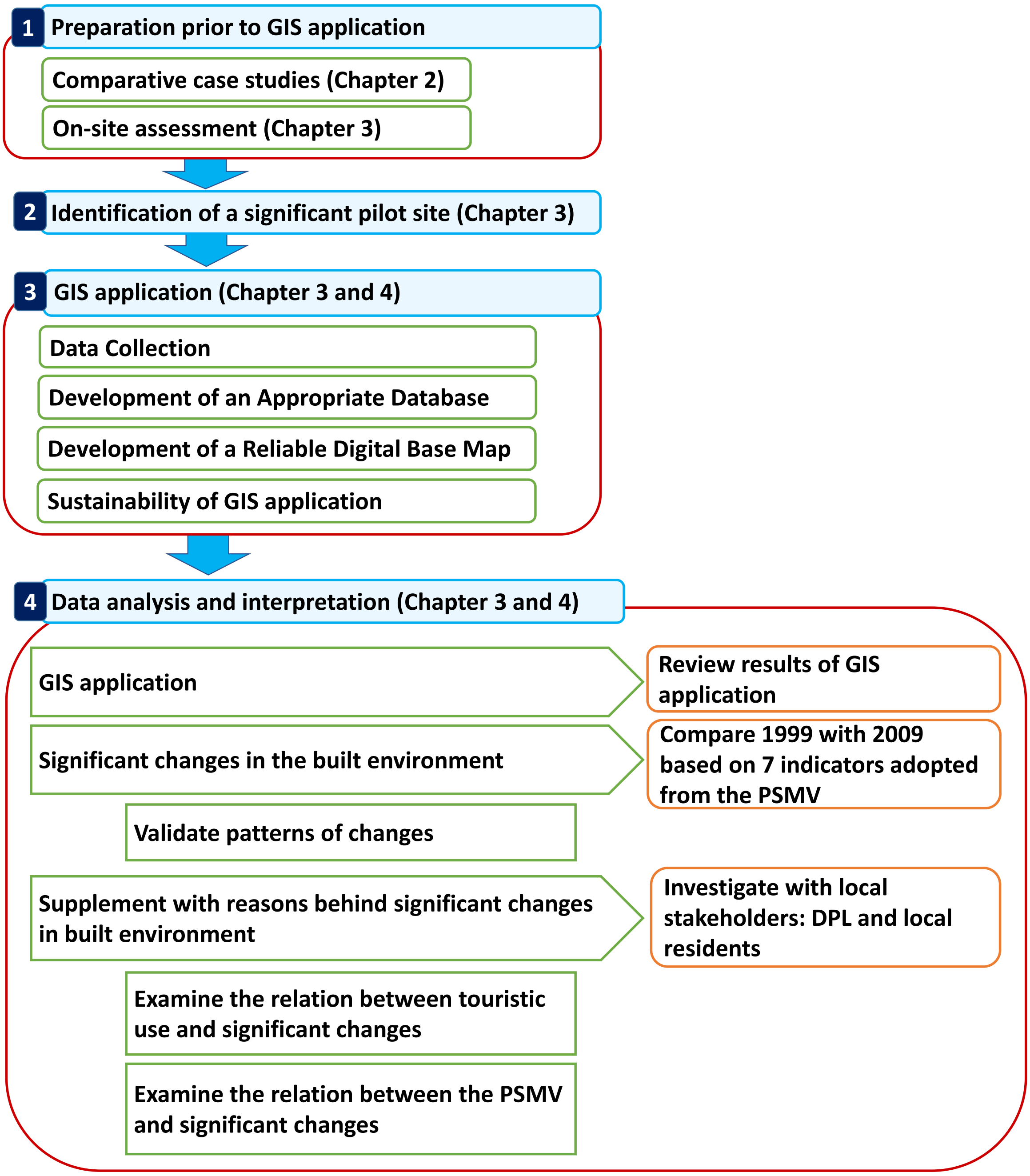

Figure 10. Four major steps in research design

Source: Developed by author, 2016

The built environment was analyzed with the aim of identifying significant changes. The Steinitz model (1990) offered an overall framework to analyze Luang Prabang's built environment between 1999 and 2009, based on seven indicators adopted from the PSMV.

Under the Steinitz model, specific methods were chosen to perform analysis, such as visual comparison of spatial distribution (Stewart, 2001), tracking transition in each indicator (Mitchell, 2006), and statistical methods. The spatial patterns of changes obtained from spatial analysis were validated using logistic regression (Yang, 2010; Li et al., 2015). The data analysis was supported by DPL's interpretation of results, and evaluation of the potential impact of the changes. It was also supplemented by an investigation with local stakeholders, such as DPL and local residents, to identify the reasons behind significant changes (Leong et al., 2016). The reasons for significant changes to occur could be comprehend by investigating its relation with other aspects such as 1) touristic use by using the Chi-square test of independence (Yang, 2010), and 2) PSMV by using multivariate analysis, a combination of MCA and HCA (Giannopoulou et al., 2014a, 2014b).

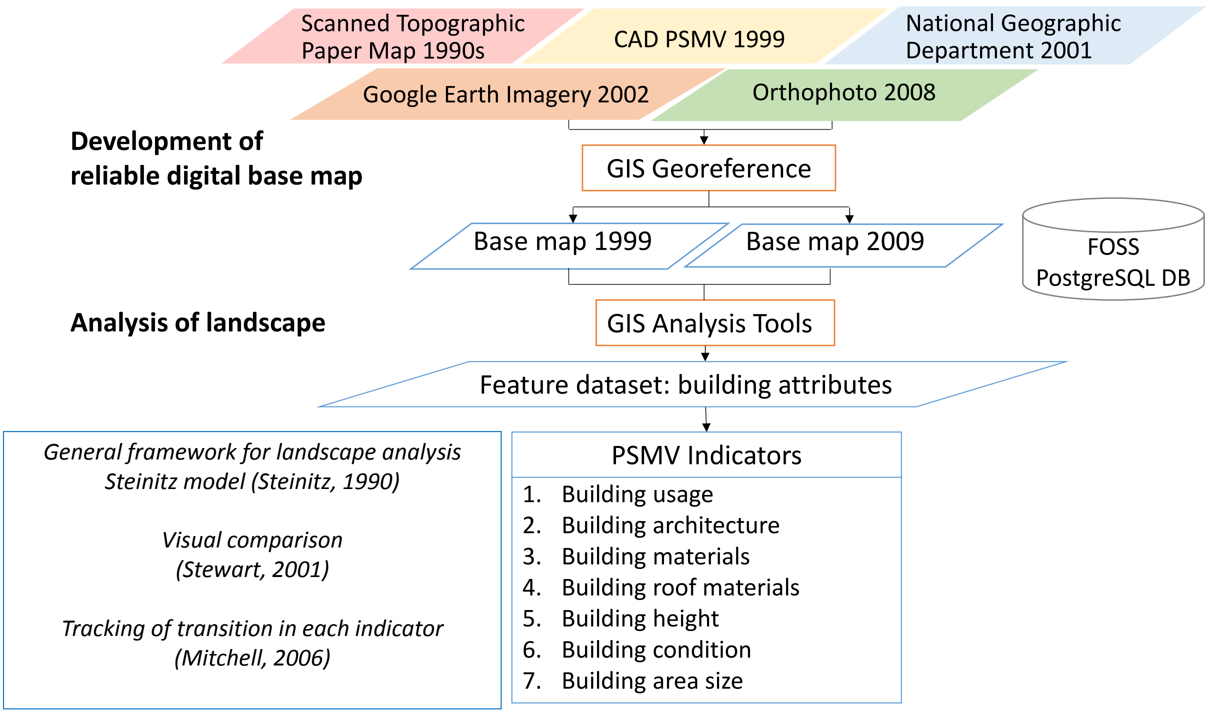

Figure 11. Methods employed to develop a reliable digital base map and analyze landscape

Source: Developed by author, 2016

3.3 On-site Assessment

An on-site assessment was conducted in March 2008, with the aim of assessing the conditions of how GIS were being used locally (Leong et al., 2008, 2010; Takada et al., 2008). The on-site assessment identified missing elements which were critical to the sustainable deployment of GIS in Luang Prabang. Major issues that impede the sustainable use of GIS are as follows:

1. Lack of data availability

GIS can only function effectively and conduct analysis with accurate data. It is crucial to identify the necessary and reliable data. It was found that geographical coordinates were missing, and the system was unable to identify accurate building positions. Moreover, heritage data, such as the location of inventory buildings, temples, and others, had not been updated since the first PSMV map was created in 1999. There was a severe lack of digitized data of the protected area. Moreover, the local departments and users misunderstood the cost related to GIS introduction. The majority deliberated the high cost of GIS software but often underestimated the costs related to data collection and maintenance. The cost and method of acquiring essential spatial data needs to be considered at the planning stage.

2. Inefficient data management

Extensive data was collected on building information between 1999 and 2001 to develop the PMSV (MdP, 2001a; ADUC, 2005). However, they were paper-based. The specific use of such data was not fully understood. It was discovered that PSMV documented maps were only available in PDF format and detailed information of every building in the World Heritage Site was lost. Thus, abundant building information was found to be missing.

3. Lack of a reliable digital base map

Since no GIS had ever been implemented at full scale within the DPL, a specific base map of buildings was not previously considered necessary. Although different local departments introduced GIS in the past, the building maps were not accurate because they focused on data relevant to their expertise, such as irrigation, watershed, agriculture, and road networks. Moreover, the mapping standard was not set, which made it difficult to share the data. The users found discrepancies between two widely-used base maps, which originated from a 1964 American map scaled 1: 50,000 and a 1981 Russian map scaled 1: 100,000. The two maps produced at different scale and datum have a discrepancy of a few hundred meters. The lack of compatibility posed a major problem. The National Geographic Department enforced Decree No.255 in 2005 of the Prime Minister's Office, which unifies mapping systems and data compatibility with the national standard (NGD, 2005). However, the policy was not effectively implemented at the local site.

4. Complex scale of implementation

It was essential to study the entire World Heritage Site in order to understand the full impact of landscape change; however, it was highly complex to implement a large-scale mapping. A large-scale GIS implementation required considerable resources. The World Heritage Site has more than 4000 buildings and 611 inventory buildings in 29 villages. It was not feasible to collect data for the entire site. Hence, it was necessary to select an appropriate scale and significant pilot site.

3.4 Identification of a Significant Pilot Site

It was identified in the comparative case studies that an appropriate implementation scale to efficiently reflect the objectives of GIS is one of the common factors which influence a sustainable GIS system. A significant pilot needed to be selected. A pilot site was identified jointly with the Construction and Restoration Unit, DPL (Leong et al., 2010, 2016). The pilot site is located in Zpp-Ua, the core of the heritage site, as displayed in Figure 12. There are six villages in the pilot site, namely Xieng Thong, Phone Hueang, Khili, Vatnong, Vatsene, and Xieng Mouane. In the PSMV, ten villages were identified as priority preservation zones requiring an action plan to control land use (ADUC, 2005). Five of the villages in the pilot site are located in the priority preservation zones. There are 205 inventory buildings in the pilot site, constituting 30.4% of the total inventory buildings in the heritage site, providing a high concentration of inventory buildings. Therefore, the pilot site selected is considered significant qualitatively and quantitatively.

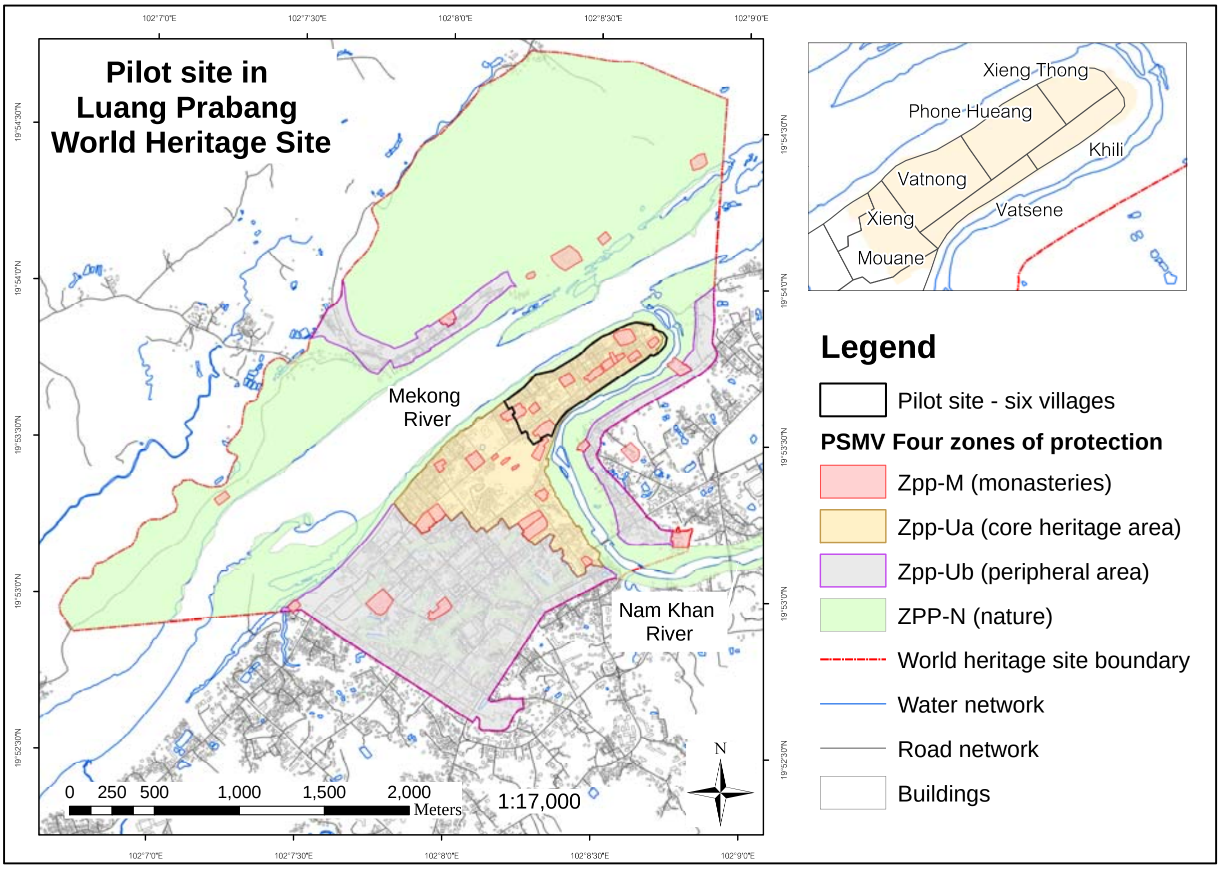

Figure 12. Pilot site selected in core heritage area, Zpp-Ua

Source: Leong et al., 2016, p. 3; Department of World Heritage, 2009

3.5 GIS Application

GIS application is designed to cater to local needs, tackle the constraints observed in case studies, and promote the use of GIS sustainably. Three factors important for introducing GIS sustainably are applied in developing three components of GIS, namely: 1) the availability of reliable and compatible data; 2) an appropriate implementation scale to efficiently reflect the GIS's objectives; and 3) continuous emphasis on balancing operational cost, updating data, and implementing training program for local users. After the GIS was implemented, its sustainability in Luang Prabang was reviewed.

3.5.1 Data Collection

The availability of reliable and compatible data is very important to achieve precise spatial analysis. As pointed out in an on-site assessment, the severe lack of data in Luang Prabang posed a big challenge. Therefore, it was essential to identify crucial and necessary data needed for spatial analysis. Extensive data collection was conducted to update building information for seven indicators (Leong et al., 2010, 2016; Takada et al., 2009). The eighth indicator, the coefficient of soil occupation, was excluded because there was a lack of resources to collect the required measurement of each floor and land plot size. Data were collected through field survey, and compiled from archives in DPL. It took five months, from January to May 2009, and was carried out with two architects and an engineer from the Construction and Restoration Unit, DPL. A total of 745 buildings were surveyed, of which 206 were inventory buildings and 539 were non-inventory buildings. The method and survey form utilized were adopted following the PSMV, as shown in Appendix 1 (MdP, 2001a). The validity of building attributes data was verified with the local architects, led by the Chief of the Construction and Restoration Unit, DPL during the field survey. Information collected includes GPS data, building usage, architecture, construction materials, roof materials, level of preservation, year of construction, the number of floors, and building condition. GPS data were collected using DNR Garmin eTrex Vista. Other information required was integrated from multiple sources, such as authorization database, heritage database, photo database, and PSMV inventory sheets.

3.5.2 Development of Appropriate Database

In the past, unsystematic data management led to the loss of all building information in the PSMV except for PDF files. It was challenging to manage a large number of buildings. Learning from the comparative case studies, a sustainable GIS system requires a balance of operational cost and system maintenance by updating data. As such, it was crucial to strategize data management through a relational database management system. A new database, known as general building database, was developed with the purpose of managing building information collected from the field survey (Leong et al., 2016; Sitthirath et al., 2010; Takada et al., 2009).

The new database was designed according to the architecture of existing database systems to avoid redundancy. The heritage database and authorization database were developed prior to the introduction of GIS through a joint collaboration of the Tokyo Institute of Technology, MdP, and UNESCO (Yamaguchi et al., 2006). At that time, the paper-based information in the MdP needed to be organized into a database system which could be shared effectively among government institutions and the local community. The architecture of the database reflected the local conditions in five aspects: 1) use of free and open source software (FOSS); 2) the establishment of client-server architecture; 3) the development of web-based user interfaces; 4) the identification of easy-to-learn software; and 5) multi-language support by UNICODE. The software utilized in the system were: 1) Debian GNU/Linux for server OS; 2) Zope for web server application; and 3) PostgreSQL for DBMS (Yamaguchi et al., 2006; Sitthirath et al., 2007 and 2010).

Moreover, existing databases have abundant information useful to supplement base map and data analysis. The heritage database has comprehensive information, thousands of photos, and 2,870 drawings on inventory buildings as well as protected wetlands. The authorization database was designed to facilitate authorization procedures and archive construction activities. It compiled building permits, architectural drawings, and owner and land information. A total of 320 cases from 2001 to 2008 were inputted (Sitthirath et al., 2010).

3.5.3 Development of a Reliable Digital Base Map

Reliable and compatible data in spatial analysis not only include accurate building attributes but also a digital base map. A base map provides a spatial reference for users to locate and identify objects in the surrounding terrain. The base map layers in GIS act as a reference to critical features which support advanced cartography and spatial analysis (Mennecke & West, 2001; Nilsson & Svensson, 2005). Therefore, a reliable and specific digital base map suitable for built environment is important. It was necessary to identify good quality mapping resources to provide accurate building records, shape, size, and location. The inconsistency and errors in existing sources required a systematic analysis and cleaning of the data (Nilsson & Svensson, 2005). Five mapping resources were identified from the DPL archive, other projects, and online sources, namely: 1) scanned topographic maps; 2) computer-aided design (CAD) drawn map; 3) Lao PDR national base map; 4) orthophoto imagery; and 5) Google Earth imagery (Leong et al., 2010, 2016; Takada et al., 2009). The five maps' metadata, strengths, and weaknesses are summarized as follows:

1. Scanned topographic map

Scanned topographic maps from the 1990s were developed by the Institute of Paris of Research Architectural and Urbanism Society (IPRAUS) at the scale of 1:2,000. The coverage of the entire town was completed in 13 pieces of maps. Although the legend did not specify map projection coordinates, it was identified as India 1975 UTM 47N. Even though the maps were outdated, they had good building polygon shapes and location. The map also provided accurate contour lines showing the elevation of the town and surrounding terrain.

2. CAD-drawn maps for the PSMV

The CAD-drawn maps were produced between 1999 and 2001 with ADUC support during the development of the PSMV. The CAD maps were made from small aerial photos, an incomplete cadastral map from 1972, and a digital base map from the Mekong committee (ADUC, 2005). The CAD map is most commonly used by architects in DPL for their daily tasks. Among the mapping sources, the CAD map captured the most detailed information and annotations, and an accurate number of built structures and polygon shapes. The disadvantage of the CAD map was the absence of geo-location, an inaccurate scale, and outdated information.

The CAD map was rotated horizontally to provide an easier view for local architects. As a result, it has a distortion of 50m to 100m. The map also excluded temporary wooden structures. Since the CAD map does not have a scale, the architects have altered building polygons, causing inaccurate building size. Building polygons were drawn in detailed segments that included kitchen, shed, and staircase. During the field survey, the overlapping roofs made it difficult to distinguish the different parts of the buildings. Therefore, local architects decided to focus on the main building and merged the surrounding segments with the main building.

3. Lao PDR national base map

Prime Minister decree No. 255 was enforced in 2005 to use the NGD map as a base map (NGD, 2005). The NGD map was produced at 1:5,000 scale in 2001 using 1982 Russian topographic maps. Even though the NGD base map had a wide classification of land use attributes and accurate location, there was low accuracy on the shape of the building polygons. Although the map was considered impractical as a base map for buildings, it was referred to for building location.

4. Orthophoto imagery

A wetland project of bilateral cooperation between the DPL and Chinon, France, as mentioned in Chapter 2, purchased an orthophoto image of high resolution (0.5m x 0.5m) and feature datasets such as buildings, elevation, road network, water network, forest cover, and others. Orthophoto is an orthorectified image that has been corrected to remove distortion and have a uniform scale (Taylor, 1994). The orthophoto and datasets were shared within the DPL and other departments. The image, dated 2008, was collected by SPOT satellite (Satellite Pour l'Observation de la Terresatellite). However, the orthophoto was misaligned 20m from the correct projection due to the inefficiency of the private mapping provider.

5. Google Earth imagery

The orthophoto was only shared after the field survey was conducted. Prior to having the orthophoto, Google Earth imagery dated 2002 was taken from an online source. Although the imagery has low resolution and accuracy, it was utilized as a basic reference for GPS data obtained during the field survey.

3.5.4 Sustainability of the GIS Application

The sustainability of the GIS application is examined by reviewing the use of the GIS over the years since it was applied in 2009. Several aspects were examined, such as the maintenance of system through updating data, the level of GIS utilization, and the involvement of local institutions. The examination was based on information gathered from various sources and responses obtained from the DPL during a workshop. A workshop was conducted on March 22nd, 2016 with the upper management and local DPL experts in which they evaluated the GIS application. Information was collected from observations during fieldworks, publications, and discussions with relevant experts. Observations were made on DPL's utilization of GIS during three fieldwork trips on December 2010, September 2011, and March 2016. They evaluated the use of the GIS application. A book was published on the 20th anniversary of Luang Prabang's becoming a World Heritage Site by ADUC and DPL (Savourey, 2015).

3.6 Significant Changes in the Built Environment

The method used to analyze HUL is adopted from the Steinitz model. The Steinitz model is a general framework design to analyze an overall landscape and is applied in diverse fields (Steinitz, 1990). It is divided into two segments such as landscape assessment and landscape intervention. However, landscape assessment alone was sufficient and adopted for this study. It examined the existing state of the landscape and determined whether the existing landscape was functioning well or not. The landscape assessment comprised three stages. In each stage, specific research methods were identified and utilized. The three stages and inquiries are described respectively as:

1. Representation model: How should the landscape be described?

The representation model focused on obtaining raw data and facts. It concentrated on developing GIS database and linking with relevant sources to produce cartographic maps. Spatial elements and attributes that constitute a landscape needed to be identified. Seven PSMV indicators were selected to visualize and characterize the current landscape of Luang Prabang. Classification and the use of color to represent the building attributes in each indicator in cartography were chosen, based on the standardization applied in the PSMV. It was important to distinguish buildings according to different levels of preservation, such as inventory and non-inventory buildings.

2. Process model: How does the landscape operate?

This model focused on deriving information to support decision-making. Analysis tools were used to examine landscape change and the relationship between attributes. Spatial analysis techniques and statistical methods were utilized to examine significant changes between 1999 and 2009. Various GIS operations and map overlay for vector-based data were used to analyze the thematic layers as depicted in Table 6.

Visual comparison by Stewart (2001) was adopted to study change in spatial distribution (Leong et al., 2016). For parcel level data, the transition between different categories was tracked and summarized into a matrix tabulation (Allen et al., 2002; Mitchell, 2006); for instance, changes from original to different types of architecture were tracked. When there were diverse changes, it was visually difficult to trace on the map. Changed and unchanged areas were mapped in order to avoid overcrowding by a diverse range of changes and to produce an easily understood map for visualization (Butt et al., 2005; Iqbal & Khan, 2014).

Table 6. GIS operations used for spatial analysis

Information needed	Thematic layers	GIS operations
Analyze indicators • Building usage • Building architecture • Building materials • Roof materials • Building height • Building condition	1999 buildings 2009 buildings Road network Commercial road River Orthophoto	Analysis tools in ArcMap • Extract operation through clip, select and split function • Cartographic tools to mask layers Building attribute query • Select by three categories: 1) attribute; 2) location; and 3) graphics • Relational query by joining field of different table attributes Calculate statistics of attributes • Use deterministic formulas in ArcMap Field Calculator • Use summary statistics under Analysis tools
Analyze building density • Building area size Supplemented by analysis of constructions that helps to explain type of alterations made in 10 years	1999 buildings 2009 buildings Authorized constructions	Analysis tools in ArcMap • Extract operation with clip, select and split function • Containment operation with overlap and intersect Attribute table function • Calculate geometry area size • Summarize statistics by fields ArcScene • Extrude number of constructions Display distribution and accumulation of construction cases for each building
Analyze the building height • Building height	1999 buildings 2009 buildings Road network Commercial road River	ArcScene • Extrude overall building height

GIS operations used for spatial analysis (continued)

Information needed	Thematic layers	GIS operations
Track the transition between different categories in each indicator	1999 Buildings 2009 Buildings Road network Commercial road River Orthophoto	Analysis tools in ArcMap • Adjacency relationship using merge function • Containment relationship using overlap and intersect function Building attribute query • Select by attribute and locations Calculate statistics of attributes • Use deterministic formulas in ArcMap Field Calculator • Using summary statistics under Analysis tools
Analyze change of seven indicators according to categorization of inventory and non-inventory buildings	1999 buildings 2009 buildings Road network Commercial road	Building attribute query in ArcMap • Select by three categories: attribute, location, and graphics • Relational query by joining field of different table attributes Calculate statistics of attributes • Use deterministic formulas in ArcMap Field Calculator

Source: Summarized from Mitchell (2006) and Ormsby et al. (2009)

GIS combined with statistical methods for categorical data was useful in this study since the majority of building attributes were categorical data. A logistic regression model was employed to validate the spatial patterns of changes (Yang, 2010). There were two spatial patterns to be examined: first, whether changes were more inclined to occur along riverbanks or in the middle of the peninsula; and second, whether inventory or non-inventory buildings were more inclined to maintain the same building attributes. Inventory buildings have a unique spatial distribution because they are significant monuments located in specific areas of the HUL as a result of different historical and cross-cultural influences (MdP, 2001a, 2001b).

The association between seven indicators with inventory buildings and their location on riverbanks was validated using logistic regression. Inventory buildings and location of change were chosen as primary predictors. The logistic regression model can be expressed as

$$\text{Logit (P)} = \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n \qquad (1)$$

where $\ln\left(\frac{P}{1-P}\right)$ is log odds ratio, P, probability, β, coefficient, and x_i, independent variable (Li et. al, 2015).

The analysis was conducted using R software. The values of unknown buildings, roofless structures, and non-habitable structures were considered as missing values. The missing values were imputed with mode which refers to the highest number of occurrences in data (Gelman & Hill, 2006).

The logistic regression of inventory buildings only analyzed existing buildings and excluded new buildings. Inventory buildings were coded as 1, and non-inventory buildings as 0. Similarly, all seven indicators were coded as well. The buildings that maintained original attributes were represented by 1, and the buildings that did not maintain the same attributes by 0. As for the riverbank location, both existing and new buildings were analyzed. The logistic regression model for the riverbank intended to verify whether buildings were changing significantly along riverbank areas. As such, riverbank areas were coded as 1, and the middle of the peninsula as 0. The buildings that changed the seven indicators significantly, as illustrated in the spatial analysis, were coded as 1; the buildings that did not change significantly as 0.

3. Evaluation model: How does one judge whether the current state of the landscape is working well?

The evaluation model aimed to derive knowledge by evaluating patterns and relationships. The impact of the change was evaluated by metrics of judgment, community values, and objectives. This phase also involved the participation of relevant experts who defined issues, metrics, and a proper method of analysis, such as the DPL. The significant changes were compared against the PSMV. The impact of the change was assessed by local DPL experts as to whether it contributed positively to the preservation, or negatively affected, the World Heritage Site. The method employed is described in section 3.8.1.

3.7 Reasons behind Significant Changes in the Built Environment

In this section, exploratory approach is chosen to explore as to why the built environment has changed from the local stakeholders' perspective. It was because there was lack of studies that applied GIS to analyze built environment and interpret the changes. Moreover, the existing literature (Boccardi & Logan, 2008; Dearborn & Stallmeyer, 2009, 2010) has been criticized for interpreting changes and preservation in Luang Prabang from the western point of view (Staiff & Busshell, 2013). Exploratory approach is a method used to explore what is little known about a certain problem and gain better understanding of it (Kumar, 2011; Awang, 2014). Qualitative method is combined with quantitative method to assess different local stakeholders' opinion such as local experts and residents. It was selected based on the level of knowledge (Jimura, 2011). As Jimura (2001) pointed out on investigating people's perspective on World Heritage Site, not all local people are knowledgeable about the issues that needed to be discussed and method should be appropriate according to level of knowledge. Therefore, workshop and semi-structured questionnaire were suitable to collect detailed information from local experts, and questionnaire survey was conducted to collect the views of local residents.

3.7.1 Department of World Heritage

Qualitative analysis was conducted through a workshop with local DPL experts (Leong et al., 2016). The workshop were held with several purposes, namely: 1) to confirm the validity of results obtained from data analysis; 2) to interpret the significant changes; 3) to evaluate the impact of the significant changes; and 4) to investigate the reasons behind the changes from the local experts' point of view. A total of seven experienced technical personnel from the Construction and Restoration Unit, Urban Planning Unit, and Environmental Unit participated in the survey. They were well-versed with the PSMV and had many years of working experience in authorizing constructions with local residents.

During the workshop, the results of the spatial analysis were presented and discussed. The visualization of the landscape using GIS provided the participants with a better understanding of the situation of the built environment, and enhanced communication between the participants. After the workshop, a questionnaire was administered to collect more detailed responses from the local experts. The questionnaire contained fifteen questions as shown in Appendix 2. It was supplemented with maps and graphs of data analysis. Questionnaire was translated into the Lao language. A one-week period was given to participants to answer the questionnaire. The entire procedure including workshop and the questionnaire took two weeks, from January 19th till February 3rd, 2011.

There were limitations to the questionnaire. The written responses at times did not correctly reflect the respondents' opinion. Certain respondents had difficulty expressing their opinion in writing. Although the questions were translated into the Lao language, not all the respondents were able to correctly interpret the meaning of the questions. To overcome these limitations, a one-to-one discussion was conducted with each respondent to clarify their answers. During the discussion, respondents were able to express their opinions and add to their written answers.

3.7.2 Local Residents

Face-to-face interviews were carried out with the aim of investigating the potential factors that led to significant changes from the local residents' point of view (Leong et al., 2016). The interviews with the DPL highlighted three significant changes that were worthy of investigation, as summarized in Table 7.

Table 7. Three significant changes and the corresponding sample size

No.	Indicator	Significant changes	Sample size
1	Building usage Building architecture	Maintenance of Lao traditional architecture despite changing from residential to touristic use	40
2	Building materials	Modern building materials replaced traditional building materials	112
3	Roof materials	Traditional roof materials replaced modern roof materials	92

Source: Field survey in Luang Prabang, 2011

Structured interviews were conducted using close-ended questions. The plausible reasons listed were derived from the literature (Gao, 2008; Larsen & Marstein, 2000; Li, 2004; UNESCO, 2004) and interviews with the DPL. Direct sampling was employed. Residents dwelling in the buildings that experienced the three significant changes were interviewed from February 24th till March 16th, 2011. The interview was translated into the Lao language and conducted with the assistance of six staff from the Construction and Restoration Unit, DPL. A letter of permission to carry out the interview was obtained beforehand from the Governor of Luang Prabang.

Pre-testing of the interview was done in the first three days. The Chief of the Construction and Restoration Unit tested the questionnaire with local residents to ensure the contents were understandable for the local community and relevant to the purpose of the interview. The questions were refined, and proper explanations were included to facilitate the interview. In the interview with residents about changes to touristic use and maintaining Lao traditional architecture, a multiple-choice questionnaire was applied. As for the building materials and roof materials, the Likert scale was used to rate potential factors in three aspects, namely: 1) level of importance; 2) materials' inherent characteristics; and 3) effect of external factors on use of materials. An attitudinal scale such as the Likert scale is useful to measure the attitude of respondents towards an issue (Kumar, 2014). The Likert scale assumes an equal attitudinal value for each item. Initially, a five-point Likert scale was used. However, it was observed that the interviews were considered sensitive. Most of the local residents were reserved in their answers to the questionnaire and chose neutral answers. For this reason, the five-point Likert scale was changed to a four-point one. The levels of importance used by the four-point scale were "very important", "important", "fairly important", and "not important". As for inherent characteristics and external factors, the scales were worded differently but carried the same value. For example, the affordability factor on the four-point scale could be rated "not expensive", "fairly expensive", "expensive", and "very expensive", whereas the cooling effect of materials could be scaled as "very cool", "cool", "fairly cool", and "not cool". The questionnaire is shown in Appendix 3.

3.8 Relation between Touristic Use and Significant Changes

This part of the study intends to determine whether the increase of touristic buildings is related to the significant changes observed in other indicators. The relationship was analyzed using the Chi-square test of independence. The analysis was divided into existing buildings and new buildings. The data were coded with binary values. For example, in the case of existing buildings, change to touristic use was coded as 1, and for not changing to touristic as 0. For building materials, change to using modern building materials was coded as 1, and not changing to modern building materials as 0. The data were summarized in a 2 x 2 contingency table. The Chi-square test of independence was performed using XLSTAT version 2015. The Chi-square test calculates the distance between the expected number of frequencies, E, and the observed number of frequencies, O (Yang, 2010). The number of rows, r, and columns, c, is represented by i and j respectively. The Chi-square assumes the null hypothesis that two variables are independent, i.e., change to touristic use and change to modern materials are independent. The Chi-square test statistic, χ^2 is calculated as

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(E_{ij} - O_{ij})^2}{E_{ij}} \tag{2}$$

The computed (χ^2) is compared with the critical value to make a statistical decision in regard to the null hypothesis. A similar method was employed for other indicators of existing buildings and new buildings.

3.9 Relation between the PSMV and Significant Changes

It was important to validate the relation between the PSMV and significant changes in built environment. The combined methods were used to explore the relation between the seven indicators. The two methods are well-known data analysis methods under multivariable analysis. The methods were chosen for several reasons. The majority of building attributes were categorical data. In the case of this study, it was useful to analyze a dataset without distinguishing independent and dependent variables, and no assumptions (Giannopoulou et al., 2014a, 2014b; Jobson, 1992; Lebart, 1994). This approach was used in previous studies to identify the different building characteristics formed in an evolving historic city (Giannopoulou et al., 2014a, 2014b).

Correspondence analysis (CA) is a dimension-reduction technique similar to factor analysis but extended in two aspects where it is applicable for categorical data and creates perceptual map-based extracted components. This method was invented in the 1960s by Jean-Paul Benzecri in France. MCA is the simple application of CA coded in the form of an indicator matrix or a Burt matrix when more than two variables are involved. This method is useful to show non-linear relationships that cannot be detected from successive comparisons of pair variables (Greenacre, 2007; Jobson, 1992). MCA converts frequencies of co-occurring features into distances and uses an optimal two-dimension plot to depict association among variables. However, the interpretation of a possible correlation between variables is not obvious and needs further summarizing. HCA is used to complement the MCA method to identify homogeneous groups. HCA congregates records that are close to each other to groups and is an iterative process. The algorithm starts with many clusters and builds up a tree by successively merging the two nearest clusters. The HCA procedure is represented by a diagram known as a dendrogram. The dendrogram is cut off at a chosen level of clustering data to obtain classification. However, the HCA method requires quantitative values. MCA is a prior step that provides the coordinate values of principal components for HCA (Riviere & Marlair, 2010). HCA provides the final results to be interpreted.

All analyses were performed using XLSTAT version 2015, a statistical add-in of Microsoft Excel. MCA was employed, followed by HCA. The computing algorithm is shown in Appendix 4. Prior to analysis, data needed to be prepared and converted to binary values. Each variable was dichotomized into the presence of significant change (coded as 1), and the absence of significant change (coded as 0). For example, in building usage, change to touristic was assigned as 1, and not changing to touristic as 0. The sample excluded unknown buildings that could not be identified in 1999. HCA was applied only for significant dimensions retained from the MCA procedure, and the corresponding principal coordinates were used as quantitative values.

CHAPTER 4: RESULTS

This chapter presents results obtained according to the five research questions and sub-questions outlined in Chapter 1, Introduction. The results of GIS application and its sustainability are summarized. Luang Prabang's built environment is analyzed to identify significant changes. The reasons behind significant changes are further investigated from the perspective of local stakeholders such as local government, Department of World Heritage and local residents living in the buildings. It also presents statistical methods to validate findings and examine relationships.

4.1 GIS Application

GIS application was designed to overcome local constraints, such as a severe lack of data, inefficient data management, lack of a reliable digital base map, and the complex scale of implementation. Three factors identified from comparative case studies were incorporated into the design of the GIS, as mentioned in Chapter 3, Methodology, namely: 1) availability of reliable and compatible data; 2) an appropriate implementation scale to efficiently reflect the GIS objectives; and 3) continuous emphasis on balancing operational cost, updating data, and implementing training program for local users. The outcomes of the GIS application described in this section are: 1) data collection; 2) development of an appropriate database; 3) development of a reliable digital base map; and 4) sustainability of the GIS application.

4.1.1 Data Collection

Reliable and compatible data are important for a spatial analysis of the built environment. Moreover, analysis of the built environment is challenging and normally involves extensive data collection on each building. Detailed building attributes important for heritage conservation cannot be obtained from satellite images, except for geometric information such as building size and shape. Only limited descriptive information was available. Hence, it was important to identify essential data required for analysis. The GIS linked spatial and non-spatial data for analysis. It was useful to integrate various information needed, such as heritage building information, construction records, photo archives, and PSMV reports. Most of the information, except for PMSV reports, were available in existing databases created by a collaboration between the DPL and Tokyo Tech.

The PSMV has a wide range of building classifications. A total of 745 buildings were surveyed according to the classification (Leong et al., 2010, 2016; Takada et al., 2009). Information on seven indicators was collected and verified by DPL architects during a field survey, as shown in Figure 13. The eighth indicator, the coefficient of occupation soil, was excluded due to lack of resources. Each indicator has sub-categories. The description of each indicator and its sub-categories is summarized in Table 8. The level of preservation is essential information to distinguish inventory buildings that need to be preserved, as described in Table 9.

There were various challenges in data collection. The PSMV maps created in 1999 were available in PDF format but detailed documentation in spreadsheets was lost. Moreover, the geo-location of each building was not documented in 1999. It was difficult to identify each building since many years have elapsed. The DPL's architects used their local knowledge of the town's history and building owners to identify each building. A total of 701 buildings in the 1999 PSMV map were successfully traced and tabulated into spreadsheets. However, there was a small number of buildings left blank in the PSMV map of 1999 due to human error. These buildings were labeled as buildings with unknown attributes.

Discrepancies were found between the PSMV inventory sheets and maps. A total of 67 inventory buildings were incorrectly documented in terms of location on the map, architecture, and materials. The errors were rectified and properly recorded for future reference. In addition, authorized constructions which took place from 2001 to 2008 were compiled from the DPL's archive to supplement the analysis of building density. This provides detailed information on approved construction activities carried out on buildings and land plots in heritage sites. It was important to know which buildings had undergone alteration, restoration, and reconstruction over the years.

Figure 13. Building survey conducted with the DPL's architects

Source: Taken by local staff from ICT of DPL, 2009

Table 8. Seven indicators of change

Indicator	Description	Categories
1. Building usage	Building function: whether utilized for public or private purposes	
	Utilized for private use	• Residential • Commercial (e.g. pharmacy, grocery, salon) • Mixed residential and small business • Touristic o Hotel o Guesthouse o Restaurant o Touristic commerce (Other touristic businesses, e.g., spa, boutique, tour agencies)
	Utilized for public use	• Government offices • School • Religious
2. Building architecture	Building typology derived from different influences	
	Traditional: Lao vernacular architectures	• Single gable • Single gable with kitchen • Single gable with veranda • Double gable
	Colonial: French-influenced colonial buildings	• Colonial
	Commercial: Chinese-Vietnamese-influenced shop houses located along main streets, also known as urban front of town	• Shop houses • Shop houses in range
	Modern architecture: Contemporary architecture, influenced by neighboring countries (e.g., Thailand), and low-cost self-built houses	• Apartments • Imported architecture • Other public buildings

Table 8. Seven indicators of change (continued)

2. Building architecture	Religious architecture: all structures and buildings built for religious purposes and located within monastery boundaries	• Main temple • Vihan Luang Prabang style I, II, III, Thai style • Monks' dormitory o Kouti single gable, kouti single gable with veranda, kouti double gable, kouti with attached kitchen, kouti triple gable, kouti colonial • Meditation cell • Drum house • Library • Chapel • Dining hall • Ou Mong (small worship structure) • Stupa • Others (toilet, kitchen, well)
3. Building materials	Materials used to construct buildings	
	Traditional materials: Materials produced from a mix of local resources, using traditional craftsmanship	• Timber • Timber, bamboo • Brick in mortar • Timber, brick in mortar • Timber, plaster • Timber, brick in mortar, plaster
	Modern materials: Materials produced from foreign materials, using modern techniques	• Cement, timber • Cement
4. Building roof materials	Materials used to construct roof	
	Traditional materials produced from a mix of local resources and used traditional craftsmanship	• Bamboo • Timber • Clay tiles • Cement tiles
	Modern materials produced from foreign materials, using modern techniques	• Zinc (corrugated iron sheets) • Fiber cement • Terrace • Tarpaulin (canvas)
5. Building height	Estimation of height based on the number of floors of inhabitable buildings. Building height excludes non-inhabitable structures (e.g., stupa and Ou Mong)	• 1 floor • 2 floors • 3 floors

Table 8. Seven indicators of change (continued)

6. Building condition	State of building evaluated by structural condition based on defined criteria (Chaiyong et al., 1995)	• Criteria for good condition: o No structural damage with the finishing materials still in a good state of repair o Details and ornaments are still intact or in original condition • Criteria for moderate condition: o Certain areas of the building finishing material need to be repaired or replaced o Certain details or ornaments already missing or damaged • Criteria for bad condition: o Large area damaged and in grave need of repair o Majority of ornaments no longer in place o Parts of building suffered structural damage
7. Building area size	Floor area	• Built-up area o Land used to construct buildings • Green spaces and unoccupied land o Open space, green space, and unoccupied land

Source: Summarized from PSMV (MdP, 2001a, 2001b) and Chaiyong et al. (1995)

Table 9. Buildings classified according to level of preservation

Classification		Description
Buildings inventory in the PSMV (inventory buildings)	UNESCO Inventory	Buildings listed in the inventory of the dossier of Luang Prabang City and presented to UNESCO • Restoration to keep building identical to original design and possible evolution determined by the DPL depending on cases • Demolition prohibited
	PSMV Inventory	Buildings needing to be preserved and restored • Restoration to keep building identical to original design and possible evolution determined by the DPL depending on cases • Demolition prohibited

Table 9. Buildings classified according to level of preservation (continued)

Buildings not included in inventory of the PSMV (non-inventory buildings)	3 types	1. Buildings worth being preserved and restored • Restoration or reconstruction should respect original type of architecture • Extension should respect density, coverage, and height
		2. Buildings which can be replaced • Restoration should respect instructions and correspond to the architecture typology • Permission to demolish and reconstruct
		3. Buildings that disrupt urban landscape • Need to be demolished and reconstructed as the architecture has a negative impact on the landscape

Source: Summarized from PSMV (MdP, 2001a, 2001b)

4.1.2 Development of an Appropriate Database

In the long term, sustainable use of GIS also relies on data maintenance and balance of costs incurred (Leong et al., 2008). The abundant data collected requires systematic data management to prevent loss of information. A new database, the general building database, was created based on the existing architecture system of other databases, as shown in Figure 14 (Leong et al., 2010, 2016; Sitthirath, 2010; Takada et al., 2009). The ER diagram is displayed in Appendix 5. The existing architecture system was designed around sustainability and applicability. Building attributes were stored and managed in the FOSS database management system PostgreSQL on Linux. PostgreSQL was chosen to avoid redundancy since PostgreSQL was used to create past databases. More importantly, it was cost-free. The user interface was redesigned and the database was expanded to include the updated building attributes. As mentioned in Section 4.1.1, the integration of various data sources was necessary. Information was retrieved from heritage database, photo database, and authorization database. The heritage database was particularly useful for its rich documentation of all types of architecture illustrated with graphics.

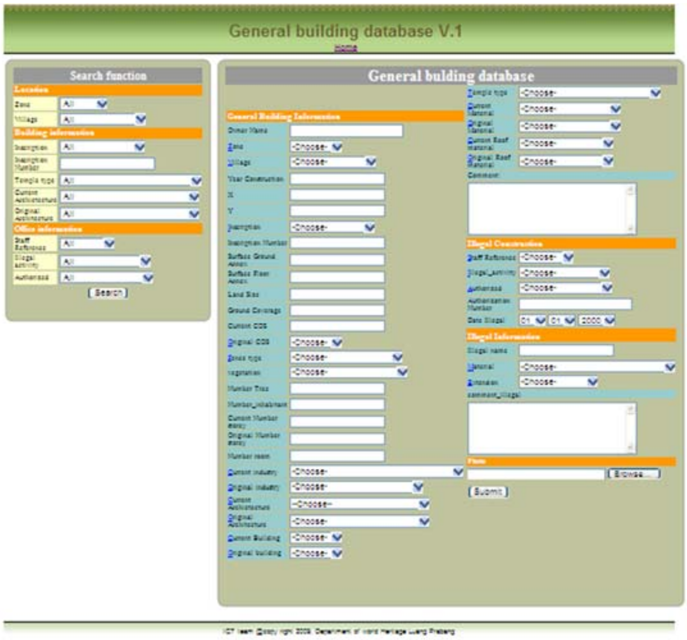

Figure 14. User interface of General Building database

Source: Sitthirath et al., 2010, p.510

ESRI ArcGIS version 9.3.1, proprietary commercial GIS software, was chosen mainly because of its popularity and availability in the DPL through other projects. However, ArcGIS and existing databases existed in different platforms. The databases were developed using PostgreSQL in Linux. Meanwhile, ArcGIS applications run in Windows. The connection between PostgreSQL and ArcGIS was established through the plug-in Object Linking and Embedding Database (OLE DB) and configured client authentication. OLE DB is an application interface program (API) developed for accessing data from different sources in a uniform way (ESRI, 2010).

A unique ID for each building is required. The geographical coordinates were used as a unique ID instead of an address code because not every building address was registered and updated. In addition, general building ID was generated to link and update data in PostgreSQL. In order to make the data compatible with ArcGIS, the data was converted into shapefile format using FOSS PostGIS. The building data can be updated back to the database by converting shapefile to database format (DBF extension) in PostGIS, as illustrated in Figure 15 (Leong et al., 2010). PostGIS provides support for geographic objects to the PostgreSQL database. Three columns were added to the database file to specify the type of geometry (i.e.., point, line, and polygon), dimension (i.e., 2 or 3 dimensions), and geographic projection (e.g., Lao National Datum 1997).

The older version of PostGIS installed in the existing server has limitations and truncated the number of decimals of x and y coordinates. This affected the accuracy of building location. The latest version of PostGIS in PostgreSQL 8.4 at that time allowed a higher number of decimals. However, PostgreSQL 8.4 was not compatible with the existing versions of Linux and Zope. Moreover, the server did not have sufficient memory to store graphic data. The data were converted to shapefiles and stored in a client computer for the time being until the server is upgraded.

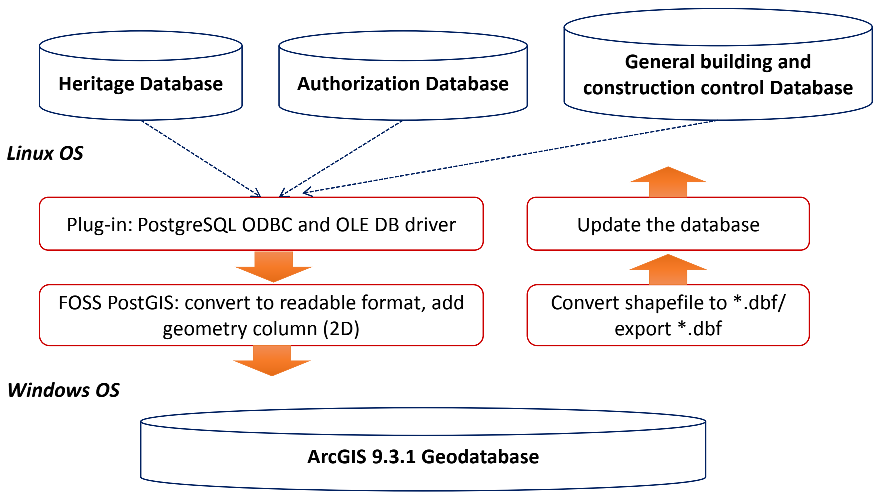

Figure 15. Connection between PostgreSQL databases and ArcGIS

Source: Leong et al., 2010, p. 506

4.1.3 Development of a Reliable Digital Base Map

A digital base map is the basic thematic layer that supports the spatial analysis. There was no reliable and accurate digital base map available on site. Each mapping source available was created for the specific purpose of local or international projects. An accurate analysis of each building is crucial for heritage preservation. As pointed out in comparative case studies, the availability of reliable and compatible data is important. Therefore, five good quality mapping sources were identified as references to develop a reliable and specific base map for this study (Leong et al., 2010, 2016; Takada et al., 2009). The five mapping sources have different projects and scales. The strengths and weaknesses of the five sources were compared to obtain accurate building shape, size, and location. Different methods were used to align the map projections since the sources were in different formats, such as scanned paper, CAD-drawn maps, and others. The five maps' metadata, strengths, weaknesses, and methods for aligning maps projection are summarized in Table 10.

Two base maps dated 1999 and 2009 were developed through georeferencing and selecting quality information in the five mapping sources. The base map of 1999 has 701 buildings and the base map of 2009 has 745. Both base maps documented all structures, including stupas, Ou Mong (small worship structures), and small and temporary wooden sheds. The base map used universal datum WGS 1984 UTM 48N. Ancillary structures surrounding main buildings, such as kitchens, garages, sheds, and others, have been merged with main buildings.

Table 10. Different mapping sources integrated to develop a reliable base map

Map	Year	Source	Projection	Scale	Strength	Weakness	GIS operation to rectify projection
Scanned Topographic map	1990s	IPRAUS (Institute of Paris of Research Architectural and Urbanism Society)	Indian 1975 UTM 47N	1: 2,000	Good shape Accurate position	Outdated	Georeferencing using input x, y
CAD drawn PSMV map	1999	MdP	No projection	1: 5,000	Good shape	Outdated No geographic coordinates	Georeferencing using Transformation coordinate
Lao national base map	2001	NGD	Lao Datum 1997	1: 5,000	Accurate position	Outdated Bad shape	Spatial reference in ArcCatalogue and transformation
Google Earth imagery	2002	Google	World WGS 1984 UTM 48N	Low resolution	Accurate position	Poor resolution	Georeferencing using input x, y
Orthophoto	2008	ADUC wetland project	World WGS 1984	High resolution 0.5m x 0.5m	Updated	Bad alignment Bad shape	Spatial adjustment using link

Source: Developed by author, 2011

4.1.4 Sustainability of the GIS Application

The sustainability of GIS in Luang Prabang was assessed by reviewing the use of the GIS after it was applied in 2009. This was surmised from several sources, namely: 1) responses obtained from the workshop with the DPL on March 22nd, 2016; 2) observations made during three periods of fieldwork (December 2010, September 2011, and March 2016); 3) discussion with relevant experts; and 4) a publication marking the 20th anniversary of cooperation between ADUC and the Lao PDR government (Savourey, 2015).

Since 2009, it has been observed that the DPL has continuously used GIS for heritage management. It was noted that the demonstration of the pilot study was able to show the benefits of GIS technology, and served as a baseline. Michel Brodovitch, a renowned conservation architect and planner from the Ministry of Environment and Culture of France who assisted in the development of the PSMV, has commented that the pilot study using GIS has demonstrated how change could be measured since inscription as a World Heritage Site in 1995 (personal communication, October 27, 2015)[8]. Analysis by GIS was the closest result available to evaluate the state of conservation and authenticity of the landscape of Luang Prabang.

Local staff of the DPL actively participated throughout the development of GIS application and acquired skills in utilizing GIS. As mentioned in Chapter 3, Methodology, the pilot selection, data collection, and development of a database and base map were jointly conducted with the Construction and Restoration Unit, DPL. In 2010, local staff expanded the

[8] Author has communicated and discussed with Michel Brodovitch through email regarding the impact of GIS application on preservation of Luang Prabang.

pilot study's base map to cover the core heritage area (Zpp-Ua) and peripheral heritage area (Zpp-Ub). The WHC has recommended the preparation of maps to show the full extent of changes (Boccardi & Logan, 2008). The DPL was able to respond to the request and assess the state of conservation of Luang Prabang based on mapping of similar indicators from the PSMV. The results were submitted to the WHC in 2011. At the same time, the DPL has utilized the maps to converge different decision-makers, such as the Local and National Heritage Committee. The DPL was also able to determine specific problems and manage change based on empirical evidence of visualization. The conversion from touristic use to residential use has caused a migration of the original population to outside the World Heritage Site (Savourey, 2015). The original population has decreased by 42%[9] in the core heritage area. This loss prompted the DPL to collaborate with the AFD in 2010. They implemented countermeasures to maintain the local population. Among these were investment in services for the local community and incentives for restoration, provided the locals maintained their houses as residential. During the workshop on March 22nd, 2016, Saveuy Silavanh, Director of the DPL, remarked that the effective use of GIS technology has provided solutions and contributed to the heritage management of Luang Prabang.

Later, in November 2016, local staff updated data on the entire World Heritage Site. The DPL took the initiative to purchase a satellite image of the heritage site in order to facilitate the updating of data. The recent efforts in mapping were needed to support the revision of the PMSV and urban planning policies. The expansion of the pilot base map, updating of data, and capability of local staff in utilizing GIS have contributed to sustaining the use of GIS.

[9] The core heritage area population has decreased from 8,263 in 1999 to 4,818 in 2005 (Savourey, 2015).

4.2 Significant Changes in the Built Environment

The analysis was conducted with the purpose of examining and identifying evidence of change in building attributes by comparing the landscape between 1999 and 2009. Seven pertinent building attributes were identified as significant indicators of change in the PSMV, namely: 1) building usage; 2) building architecture; 3) building materials; 4) building roof materials; 5) building height; 6) building area size; and 7) building condition. The building attributes were analyzed through visual comparison of spatial distribution (Stewart, 2001), mapping of changed and unchanged areas (Butt et al., 2005; Iqbal & Khan, 2014), and tracking the transition of different categories to determine what contributed the most to the change in each indicator (Allen et al., 2002; Mitchell, 2006).

A total of 789 buildings were analyzed. The buildings were divided into three types: 1) existing buildings; 2) new buildings; and 3) demolished buildings. Building attributes with missing data in 1999 were labeled as unknown. Unknown buildings were later identified in 2009. The buildings on the pilot site had different levels of preservation and were inventory and non-inventory buildings. Further analysis was also conducted to detect changes derived from non-inventory and inventory buildings, as listed in Table 11 and Figure 16. It was necessary to note that the total of inventory buildings, originally 206, has reduced to 205 with the loss of one residential building, namely, PSMV inventory no. 281. Overall, the inventory buildings on the pilot site have a unique spatial distribution which reflects the urban fabric of the core heritage area. The mapping of the age of buildings on the pilot site captures the changes which have occurred over centuries and the layering of monuments from different eras, as illustrated in Figure 17.

Table 11. Summary of buildings analyzed on the pilot site (N=789)

Level of preservation	Existing buildings	Demolished buildings	New buildings	Total
Inventory buildings (N=206)				
UNESCO	59	0	0	59
PSMV	146	1	0	147
Non-inventory buildings (N=583)	452	43	88	583
Total	657	44	88	789

Source: Department of World Heritage, 2009

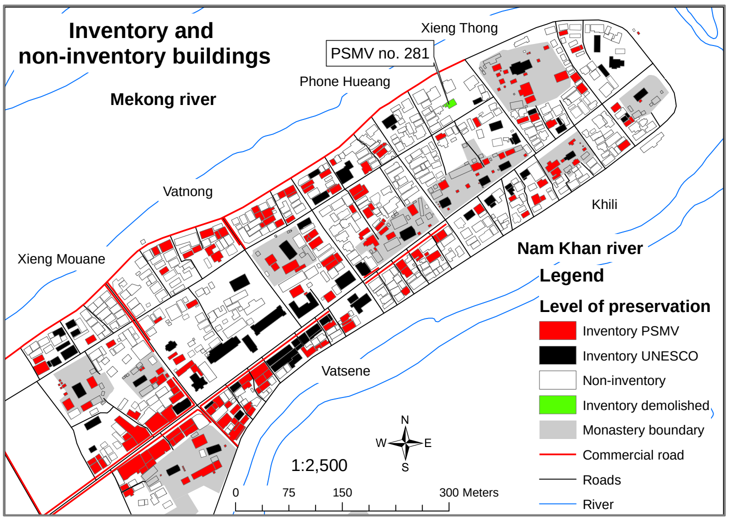

Figure 16. Inventory and non-inventory buildings located on the pilot site

Source: Department of World Heritage, 2009

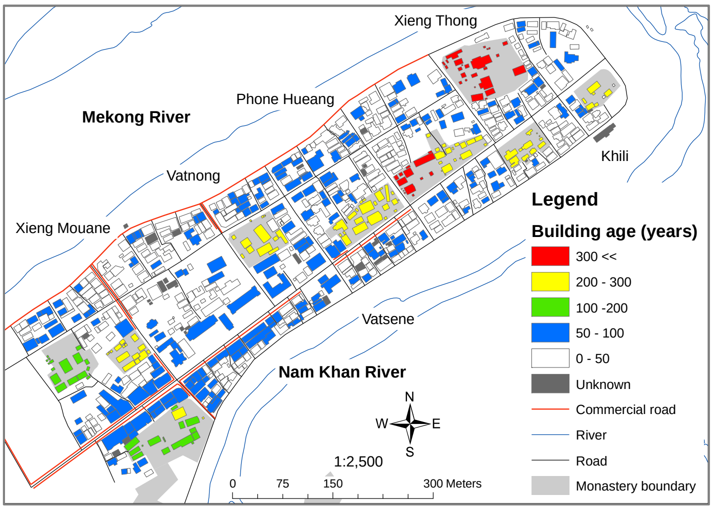

Figure 17. Age of buildings that formed the urban fabric of the World Heritage Site

Source: Department of World Heritage, 2009

4.2.1 Building Usage Indicator

Building usage refers to the function of buildings utilized for public and private use. On the heritage site, there were six groups of building usages, as shown earlier in Table 8. Other private usages, such as commerce and mixed residential and small business, were grouped under miscellaneous usage. In the 10-year interval, the most significant change in the landscape was a substantial increase of touristic buildings (blue), as display in Figures 18 and 19. Figure 18 (a) depicts the visual comparison of the spatial distribution of building usage in ten years. Figure 18 (b) shows the transition in each usage in existing buildings and Figure 18 (c) shows the usage of new buildings and demolished buildings. Figure 19 shows the mapping of changed and unchanged areas to clearly distinguish the spatial distribution of significant change in building usage.

In 1990, the pilot site was dominated by residential buildings (gray) and the middle of the peninsula was occupied by public buildings such as religious (red) and government (orange) buildings. A small number of touristic buildings was concentrated along a commercial road (red line) in the villages of Xieng Mouane and Vatsene. After a decade, the touristic buildings grew and replaced the residential buildings along main roads (black arrows) and the stretch of Mekong and Nam Khan riverbank areas. The increase of touristic buildings appeared to be denser along commercial roads in the villages of Xieng Mouane, Vatsene, and Vatnong. Elsewhere, religious and government buildings continued to be sparsely distributed and open space remained in the middle of the peninsula. The residential buildings remained concentrated in the villages situated at the tip of the peninsula such as Xieng Thong, Phone Hueang, and Khili.

The growth of touristic buildings is reflected in the significant number of conversions from residential buildings, and the construction of new touristic buildings. Table 12 shows the transition in building usage between 1999 and 2009. Initially, there were 428 residential buildings. One third of residential buildings, 141 were converted to touristic usage, and only 231 residential buildings maintained their original usage. Apart from conversion to touristic usage, the loss of residential buildings was contributed to by demolition in 33 cases, and conversion to other usages in 23 cases. The total number of residential buildings, therefore, decreased significantly, from 428 to 268. Meanwhile, the majority of existing touristic buildings retained their original usage (53 of 66). As such, the touristic buildings increased notably, by 2.8 times, from 66 to 252.

Religious and government buildings did not experience much change. Of 160 religious buildings, the majority maintained their usage (150), and marginal was demolished (10). Almost all government buildings continued the same usage except for one which changed to touristic use, and one which was demolished. Other private usages grouped under miscellaneous usages are mixed residential and small business (light green), and commercial (green). More buildings with miscellaneous usages were converted to other usages (16 of 26) than maintained their original usage (10).

A total of 88 new buildings was built as shown in Figure 18. Among them, the highest number were for touristic use (45 of 88). One quarter of the new buildings, 22 were for residential use. Twenty new buildings were used for public usage where 15 for religious, and 5 for the government. Only one new building with miscellaneous usage was built.

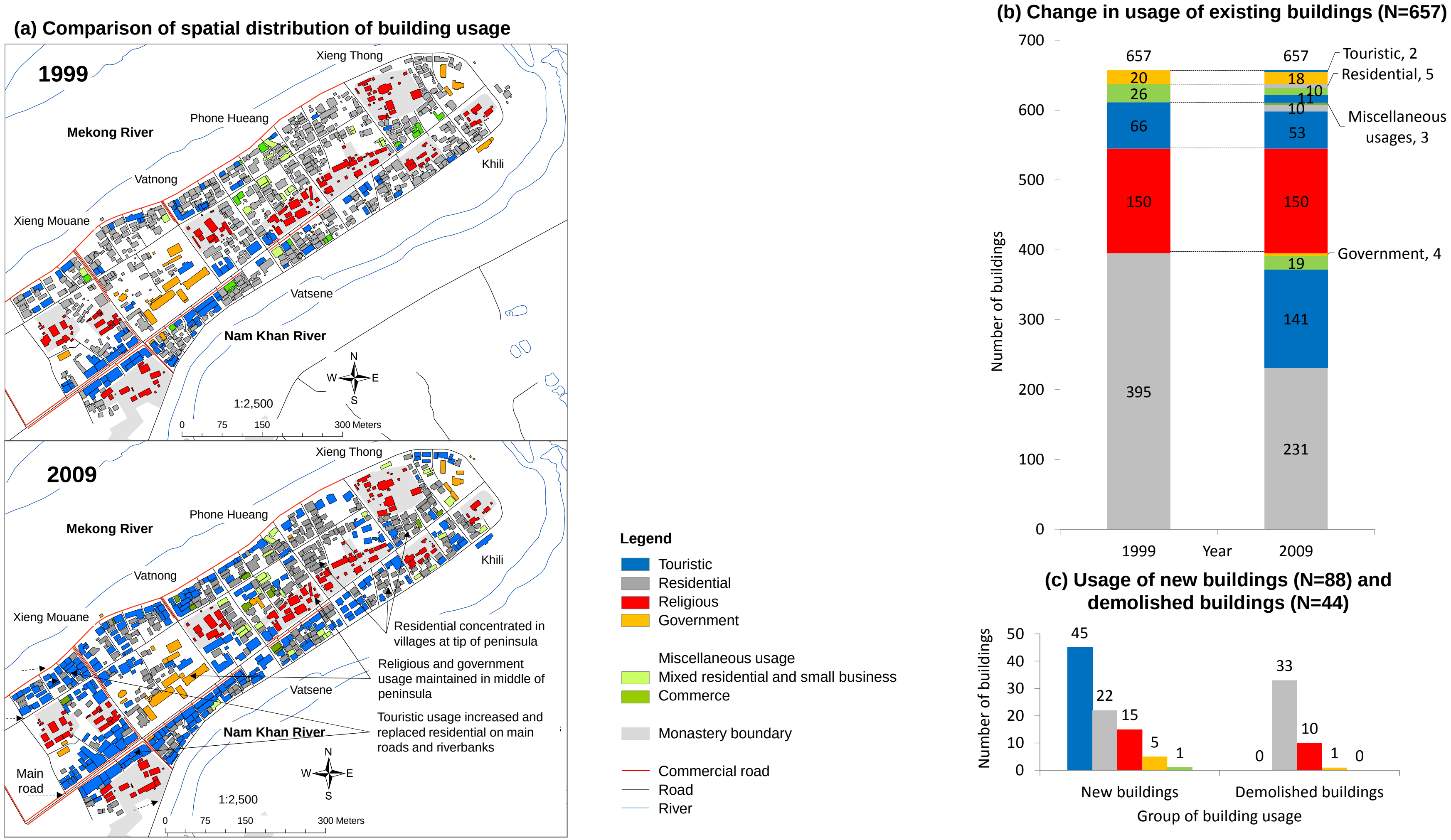

Figure 18. Change in building usage

Source: (a) Leong et al., 2016, p. 8; (b) and (c) Department of World Heritage, 2009

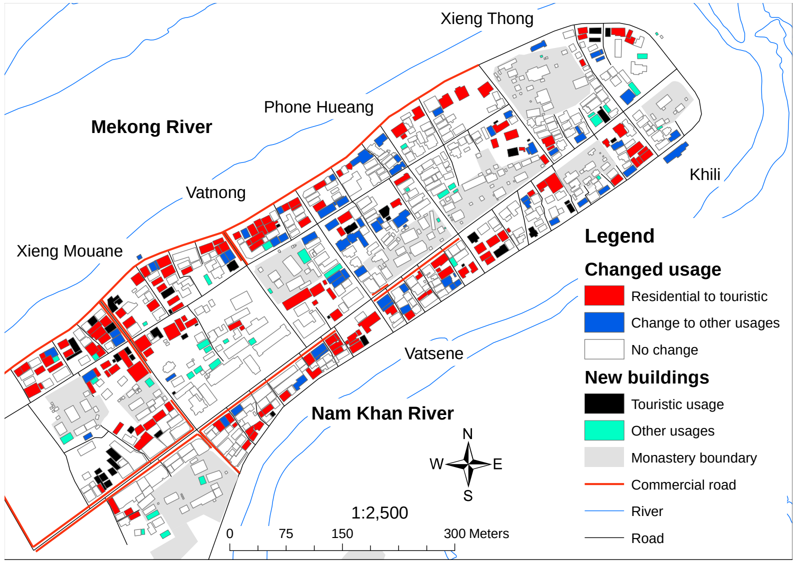

Figure 19. Spatial distribution of changed usage and new buildings usage

Source: Leong et al., 2016, p. 8

Table 12. Transition in building usage between 1999 and 2009

		2009						
		Residential	Touristic	Religious	Government	Miscellaneous usage	None	Total
1999	Residential	231	141	0	4	19	33	428
	Touristic	10	53	0	0	3	0	66
	Religious	0	0	150	0	0	10	160
	Government	0	2	0	18	0	1	21
	Miscellaneous usages	5	11	0	0	10	0	26
	None[1]	22	45	15	5	1	0	88
	Total	268	252	165	27	33	44	789

Note: [1]None in 1999 refers to new buildings and in 2009, to demolished buildings. Source: Leong et al., 2016, p. 9

4.2.1.1 Breakdown of Group of Touristic Usage

Since touristic buildings experienced the biggest increase, a breakdown of tourist usage is helpful to identify which type contributed most to change. The analysis of building usage earlier shows that the increase of touristic use was mainly due to the conversion of residential buildings, and new touristic buildings. Hence, it was also essential to find out which residential buildings have been converted to which type of touristic usage.

In 1999, touristic buildings were mostly used for touristic commerce (aqua blue), such as spas, internet cafés, and boutiques, as shown in Figure 20. The touristic commerce buildings were mostly located along the commercial roads in the villages of Xieng Mouane and Vatsene on the Nam Khan riverside. There was only a small number of guesthouses (dark blue), hotels (blue), and restaurants (light blue). By 2009, all types of touristic usage had experienced expansion. Guesthouses increased the most and spread along riverbanks as well as the main roads.

Tracing the change in residential use shows that a remarkable number of residential buildings were converted into guesthouses, compared to other types of touristic usages (78 of 141), as shown in Table 13. Moreover, guesthouses account for more than half the total of new touristic buildings (24 of 45) (Appendix 6). Although there were fewer hotels than guesthouses, hotels also grew along the riverbanks and main roads. Hotels increased following the conversion of 14 residential buildings and construction of 7 new hotels. The touristic commerce buildings remained concentrated and grew along commercial roads. The increase of touristic commerce was contributed to by the conversion of 27 residential buildings and the construction of 6 new ones. As for restaurants, the increase was attributed to the conversion of 22 residential buildings and construction of 8 new restaurants.

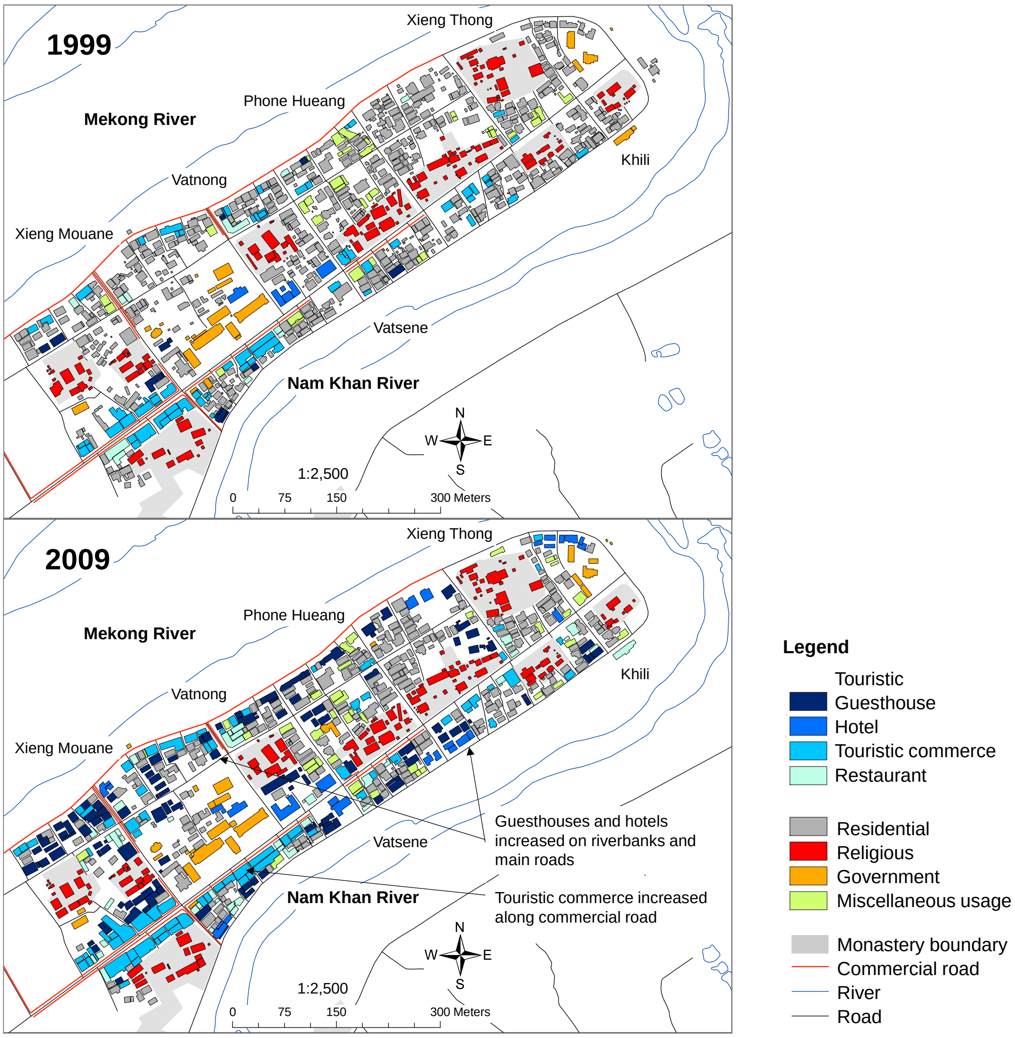

Figure 20. Spatial distribution of different types of touristic usage

Source: Department of World Heritage, 2009

Table 13. Residential that converted to touristic use and new touristic buildings

Type of touristic usage	Converted from residential	New touristic buildings
Guesthouse	78	24
Touristic commerce	27	6
Restaurant	22	8
Hotel	14	7
Total	141	45

Source: Leong et al., 2016, p. 9

4.2.1.2 Inventory and Non-inventory Buildings

It was important to identify which significant changes in building usage were derived from which buildings at different levels of preservation. The analysis excludes one demolished inventory building, PSMV no.281. More than one-quarter of inventory buildings (54 of 205, 26.3% of the total number inventory) have changed their usage, and the remaining three-quarters of inventory buildings have retained their original usages (151, 73.7%), as illustrated in Figure 21 (a). Figure 21 (b), (c), (e), and (f) show the spatial distribution of significant change in usage, and maintenance of the same usages, in both inventory and non-inventory buildings. Meanwhile, one-third of non-inventory buildings (144 of 452, 31.9%) have changed their usage, and the remaining two-thirds of non-inventory buildings have maintained the same usages (307, 67.9%), as summarized in Figure 21 (d).

Earlier usage analysis of existing buildings shows that touristic buildings increased due to mainly residential buildings being converted to touristic usage. This was observed in both inventory and non-inventory buildings. In inventory and non-inventory buildings, conversion from residential (red) to touristic occurred more prominently along riverbank areas. Inventory and non-inventory buildings which changed between other usages (yellow) were scattered throughout the peninsula.

In Figure 21 (b), inventory usage changed mainly from residential to touristic usage (36 of 54), compared to changes to other usages (18). Similarly, non-inventory residential converting to touristic accounted for the highest number of changes in usages (105 of 144), as depicted in Figure 21 (c). Non-inventory with other usages changed to touristic in the case of 10 buildings, and between other usages in 30. This illustrates that both inventory and non-inventory residential buildings changed to touristic use along the riverbank areas.

In Figure 21 (e), almost half of inventory buildings that retained the same usages were public usages, such as religious (58) and government (11) buildings. On the pilot site, the monasteries are built on a longitudinal line in the middle of the peninsula, parallel with the rivers, and local houses occupied the areas surrounding the temples. The unique spatial distribution of the inventory religious buildings was maintained in the middle of the peninsula. It is also observed that the religious and government properties retained a large open space, which left the buildings sparsely positioned in the middle of the peninsula. Touristic buildings remained concentrated along commercial roads which represent the area of commerce established with the arrival of Chinese-Vietnamese merchants in the past.

Figure 21 (f) shows that the non-inventory public buildings also remained in the middle of the peninsula, of which 92 are religious buildings and 8 are government offices. The non-inventory buildings that maintained their original touristic usage (24) were located more towards the inner peninsula and along the riverbank areas. Non-inventory buildings, on the other hand, retained their residential usage (179), mostly in three villages located towards the tip of the peninsula, Phone Hueang, Xieng Thong, and Khili.

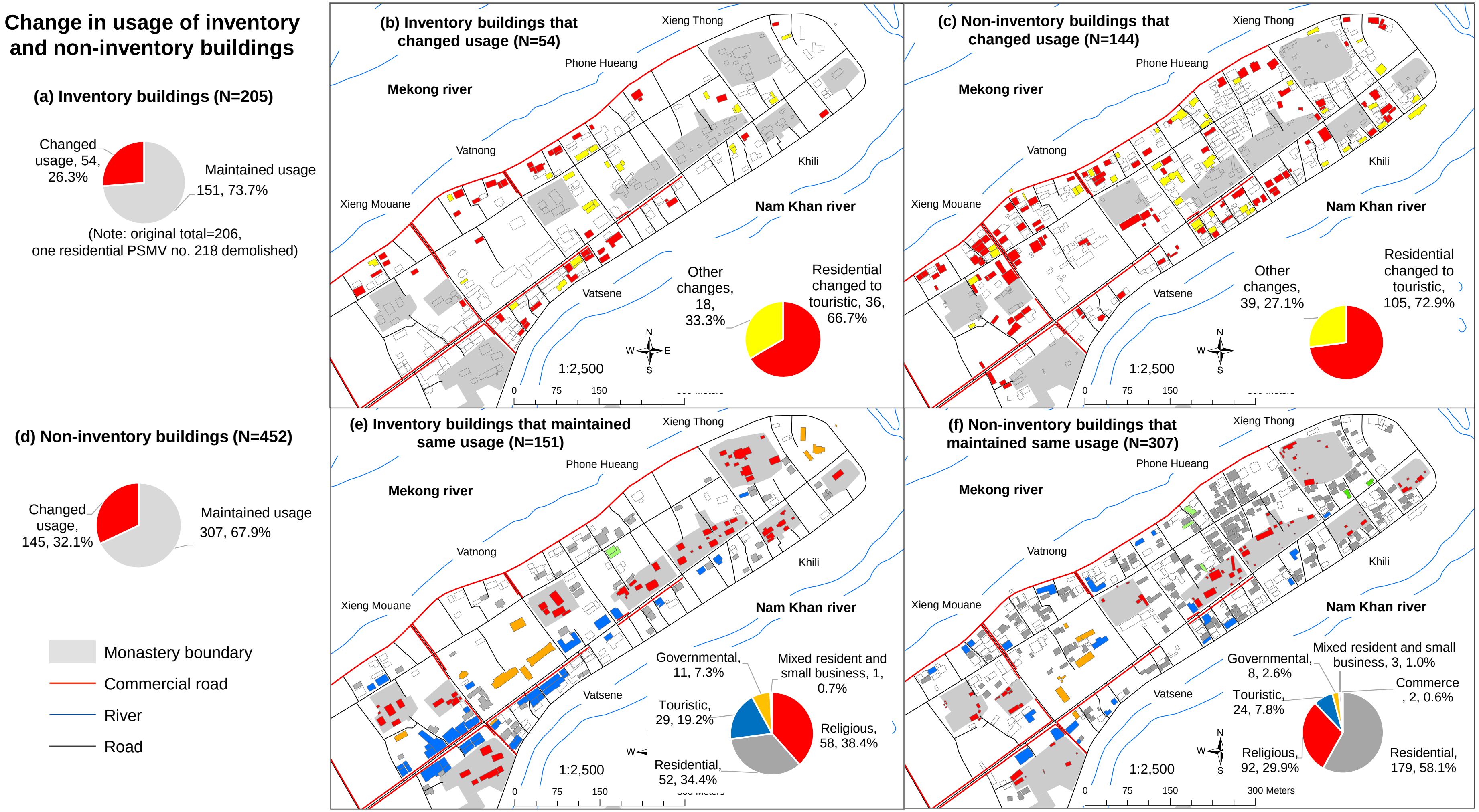

Figure 21.Change in building usage of inventory and non-inventory buildings

Source: Department of World Heritage, 2009

4.2.2 Building Architecture Indicator

Five groups of architectures were categorized according to different historical influences and recent modernization influences as follows (see Table 14): 1) Lao traditional architecture; 2) commercial architecture; 3) colonial architecture; 4) religious architecture; and 5) modern architecture. The vernacular influence was represented by Lao traditional architecture, and foreign-influenced architecture by French colonial administrative buildings and Chinese-Vietnamese commerce shop houses. The sample of buildings analyzed consisted of 642 existing buildings, 88 new buildings, and 44 demolished buildings. The analysis excluded fifteen buildings of unknown architecture.

Table 14. Types of building architecture

No	Typologies	Description	Example
1	Lao traditional	Vernacular houses on stilts predominantly built from timber and bamboo. All Lao traditional typologies have only one floor. This model later evolved to enclose the lower floor with bricks, making Lao traditional architecture a 2-floor building.	
a	Single gable	Simplest Lao traditional architecture with two slopes of roof covering the building. Balconies, staircase outside, and appendices can be built-in.	
b	Single gable with veranda	House is attached with enclosed veranda.	
c	Single gable with kitchen	House is attached with a perpendicular roof. The perpendicular area was originally used as a kitchen and now houses additional rooms. It is the most common typology assimilated.	
d	Double gable	House is covered by joint twin roofs. This typology is rare as it occupies a larger volume than other typologies.	

Table 14. Type of building architecture (continued)

No	Typologies	Description	Example
2	Colonial	French-influenced administrative buildings predominantly built from a mix of timber, brick and mortar, and/or plaster wall.	
3	Commercial	Chinese-Vietnamese-influenced mercantile shop houses made from timber, brick and mortar, and/or plaster wall or cement, located on commercial and main roads.	
a	Shop house	Residence and shop are confined in the same space. The lower floor is commonly used for business and the upper as a residence.	
b	Shop house in range	Composed of a series of shop houses.	
4	Modern	Modern and imported architecture built from concrete, or a mix of timber and concrete.	
a	Apartment	Modern architecture of 2 to 4 floors in height. This typology is considered incompatible with the townscape.	
b	Imported	Foreign architecture adopted from neighboring countries and abroad. It also includes poorly-designed or mixed-design buildings.	
c	Mixed design public building	Administrative buildings built with mixed designs.	
5	Religious	Oldest architecture on site consisting of more than 11 typologies. The most important is Vihan, the main religious structure that houses the main Buddha in a monastery.	

Source: Summarized from the PSMV (2001a), and the Chaiyong Limthongkul Foundation (1996). Pictures were taken during field survey in 2009.

The most noticeable change observed was the increase of Lao traditional architecture and commercial architecture. In 1999, modern architecture (beige) was the most prevalent architectural group in the landscape, as shown in Figures 22 (a) and 23. Religious (brown) and colonial (green) architecture occupied the middle of the peninsula, as the buildings were used mainly for religious and government purposes, as mentioned in the analysis of building usage. Most of the colonial architecture buildings were utilized as government offices and schools. Commercial architecture (light blue) and Chinese-Vietnamese-influenced shop houses used for touristic commerce businesses were concentrated along the commercial roads in the villages of Xieng Mouane and Vatsene.

Ten years later, Lao traditional architecture (red) had increased and substituted modern architecture. This trend appeared to be more prominent along the riverbank areas than in the middle of the peninsula. A concentration of commercial architecture built up along the commercial roads. The religious and colonial architecture did not experience much change.

The significant increase in Lao traditional architecture was derived from the conversion of modern architecture in existing buildings, and newly-built Lao traditional architecture buildings. Tracking the transition in building materials is summarized in Table 15, and Figures 22 (b) and 22 (c) (Appendix 7). One-third of modern architecture buildings (73 of 206) have been changed to Lao traditional architecture, the biggest number of conversions identified among all architectural groups. Moreover, Lao traditional architecture (33) was the most common architectural group in new buildings. A high number of existing Lao traditional architecture buildings was also maintained (157). However, a number of Lao architecture buildings have changed to modern architecture (22) and commercial architecture (5).

The decline in modern architecture was due to conversion to Lao traditional architecture, as well as to conversion to commercial architecture (10), and demolition of modern architecture buildings (13). A number of existing modern architecture buildings were maintained (123). Although the overall number of modern architecture buildings decreased over ten years, it was found that there were 30 new buildings with modern architecture.

Commercial architecture increased from the conversion of modern architecture buildings (10), Lao traditional architecture (4), and new buildings (7). Colonial architecture decreased slightly from 27 to 26, i.e., by one building, and only 3 new colonial architecture buildings were added. Most of the religious architecture was maintained (150 out of 160 buildings) and 10 buildings were demolished. A total of 15 new religious architecture buildings were added. There were 19 buildings of unknown architecture in 1999. The unknown buildings were later identified, in 2009, as Lao traditional architecture (10), modern (4), commercial (1), and demolished (4).

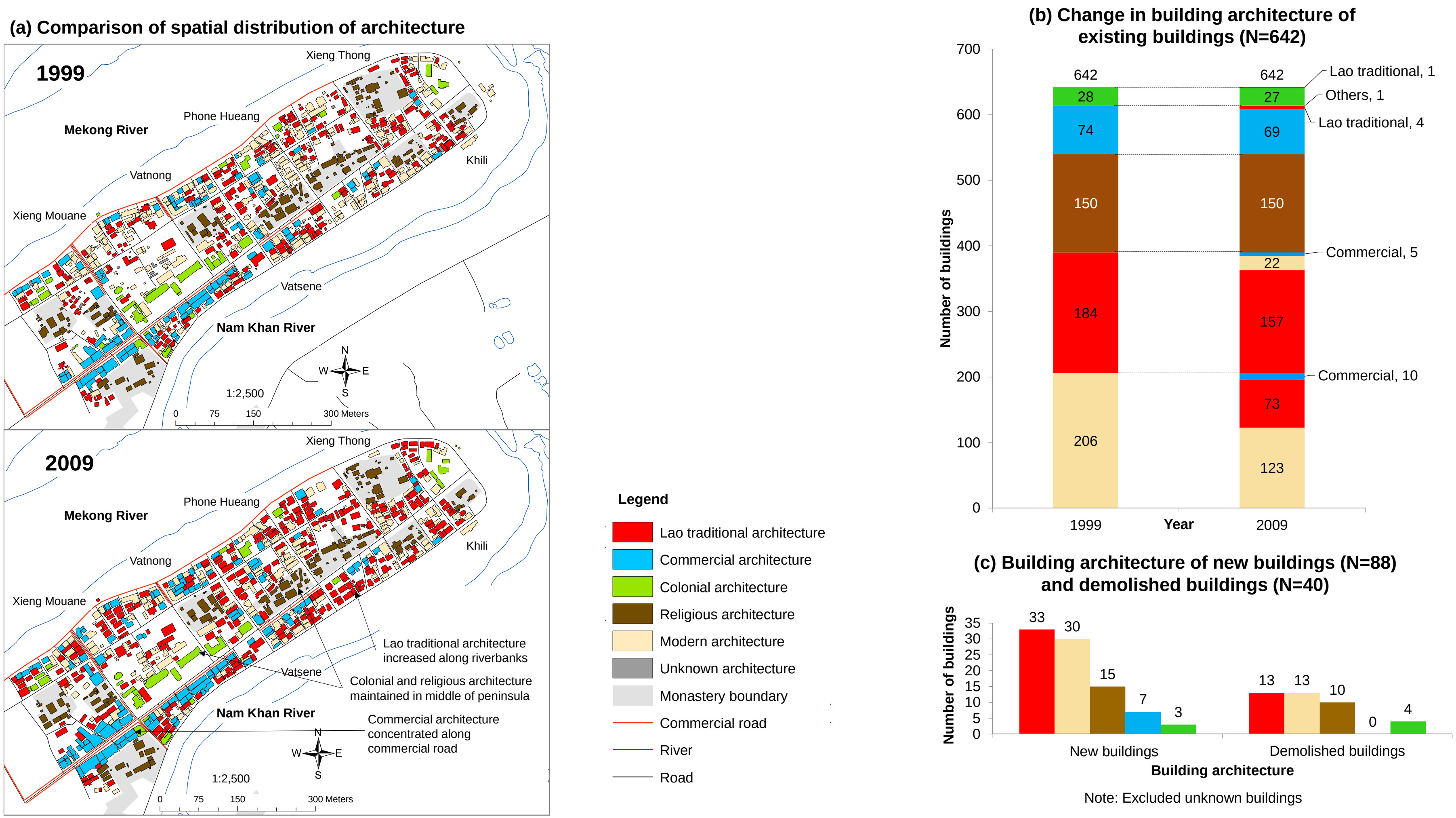

Figure 22. Change in building architecture

Source: (a) Leong et al., 2016, p. 10; (b) and (c) Department of World Heritage, 2009

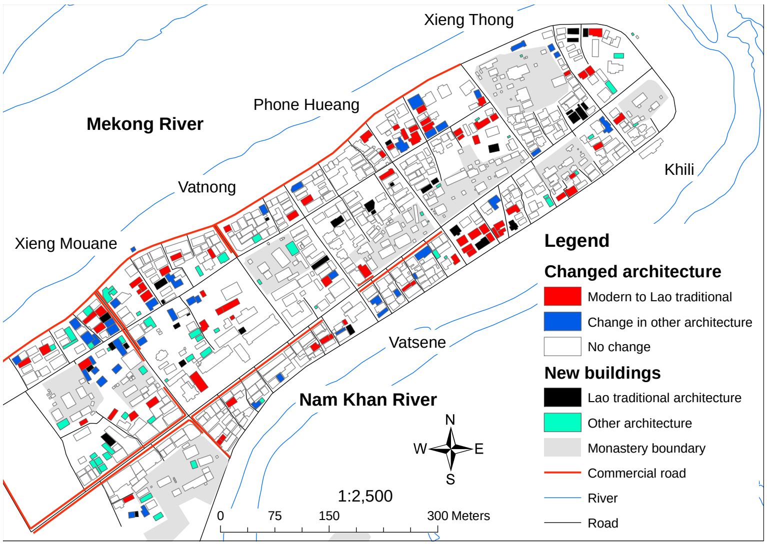

Figure 23. Spatial distribution of changed architecture and new buildings architecture

Source: Leong et al., 2016, p. 11

Table 15. Transition in building architecture between 1999 and 2009

		2009						
		Modern	Lao traditional	Commercial	Colonial	Religious	None	Total
1999	Modern	123	73	10	0	0	13	219
	Lao traditional	22	157	5	0	0	13	197
	Commercial	1	4	69	0	0	0	74
	Colonial	0	1	0	27	0	4	32
	Religious	0	0	0	0	150	10	160
	Unknown[1]	4	10	1	0	0	4	19
	None[2]	30	33	7	3	15	0	88
	Total	180	278	92	30	165	44	789

Note:
[1]Unknown buildings that were mistakenly left out of the map of 1999 because of human error.
[2]Same description as Table 12
Source: Leong et al., 2016, p. 11

4.2.2.1 Inventory and Non-inventory Buildings

It was identified that almost all changes observed in building architecture stemmed from non-inventory buildings. Most of the inventory buildings maintained the same architecture (203 of 205, 99.0%) except for two (1.0%), as illustrated in Figure 24 (a). Of non-inventory buildings, 117 of 452 (25.9%) changed their architecture and 320 (70.8%) maintained the same architecture, as depicted in Figure 24 (d). However, 15 non-inventory buildings were of unknown architecture.

Figure 24 (b) shows that two inventory buildings of Lao traditional architecture (PSMV nos. 11 and 16) have been altered to different types of Lao traditional architecture. One inventory building of colonial architecture was demolished (PSMV no. 281). In Figure 24 (e), the types of architecture maintained in inventories consist of Lao traditional (71), religious (58), commercial (52), and colonial (24). Inventory buildings that retained commercial architecture were concentrated on the commercial roads of the villages of Xieng Mouane and Vatsene. Colonial and religious architecture inventory buildings remained in the middle of the peninsula. Lao traditional architecture inventory buildings were scattered throughout the peninsula.

As for non-inventory buildings in Figure 24 (c), more than half changed from modern architecture to Lao traditional architecture (73, 62.9%) and there were other changes in architecture in 43 (37.1%) cases. The non-inventory buildings which changed their architecture were located more in the riverbank areas than the middle of the peninsula. Figure 24 (f) shows the types of architecture maintained in non-inventory buildings were modern architecture (123), religious (92), Lao traditional (86), commercial (17), and colonial (3).

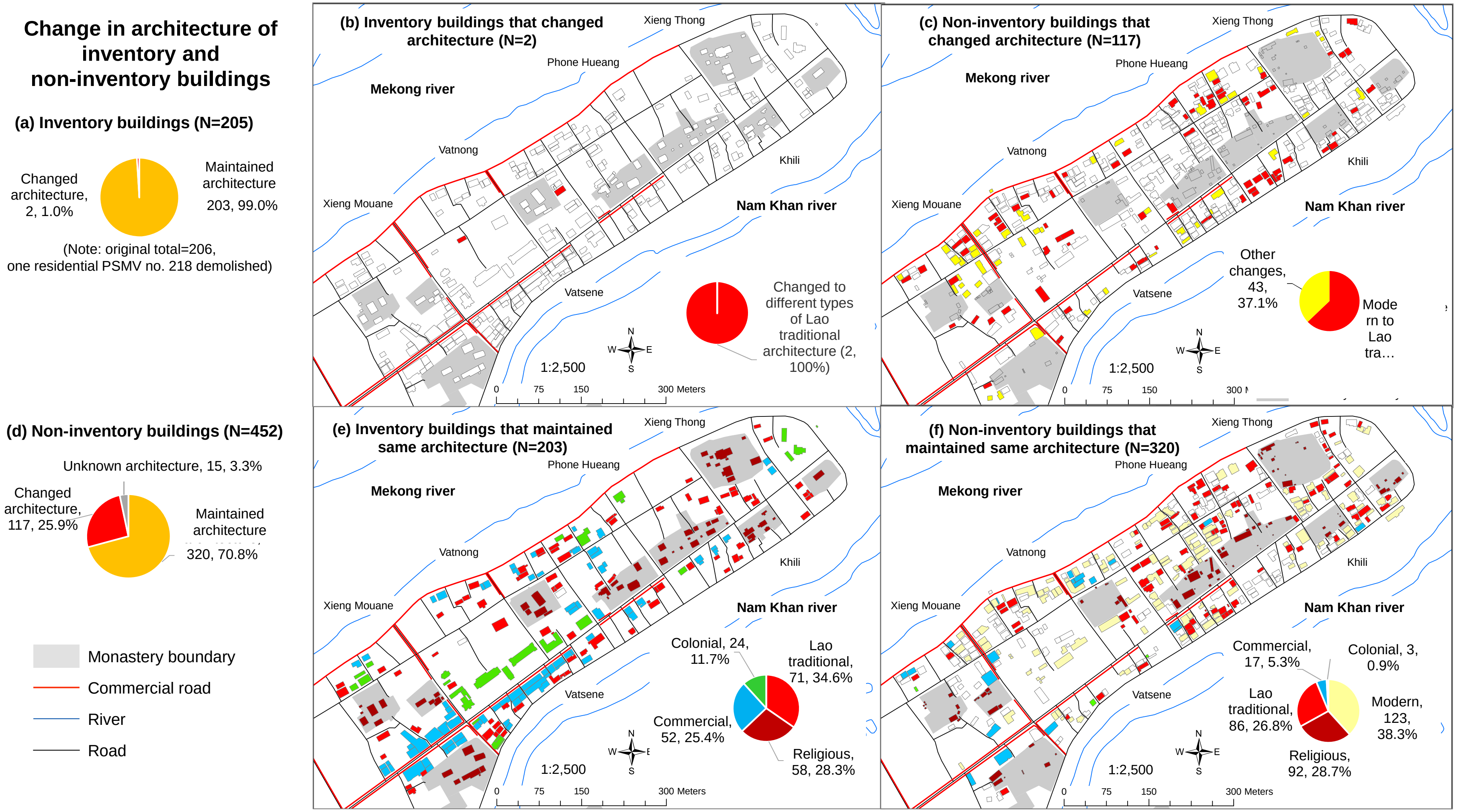

Figure 24. Change in architecture of inventory and non-inventory buildings

Source: Department of World Heritage, 2009

Additional finding

An additional finding was that conversion to touristic use does not necessarily lead to loss of Lao traditional architecture (Leong et al., 2016). Transitions in building usage and building architecture are summarized in Table 16, which shows that a marked number of buildings converted from residential to touristic use have maintained Lao traditional architecture (40). Remaining types of usages that also maintained Lao architecture were residential (95) and other (22). Although residential buildings converted to touristic use also maintained other types of architectures, it was not as distinct as that observed in Lao traditional architecture. It would be worthwhile to investigate further the motivation of residents who maintained Lao architecture despite changing to touristic usage.

Table 16. Transition in building usage and building architecture

	Building usage		
	Residential converted to touristic use	Maintained residential	Other usages changed/ maintained
Changed architecture			
Modern to Lao traditional	27	33	13
Lao traditional to modern	5	13	4
Other changes in architecture	8	7	6
Maintained same architecture			
Lao traditional	40	95	22
Modern	26	66	31
Commercial	19	9	41
Colonial	6	3	18
Religious	0	0	0
Total	131	226	135

Source: Department of World Heritage, 2009

4.2.3 Building Materials Indicator

The buildings in Luang Prabang were built using two groups of building materials: traditional materials and modern materials. Traditional materials were made from different combinations of locally-available resources, such as timber, bamboo, brick in mortar, and plaster. The preparation of brick in mortar and plaster wall involved the use of lime juice and juice from boiled buffalo skin. There were six types of traditional materials, namely: 1) timber; 2) a mix of bamboo and timber; 3) brick in mortar; 4) a mix of timber and brick in mortar; 5) a mix of timber and plaster wall; and 6) a mix of timber, brick in mortar, and plaster wall. Modern materials were made of foreign-introduced materials, such as cement. The two types of modern materials are 1) cement; and 2) a mix of cement and timber. The buildings analyzed were existing buildings (645), new buildings (88), and demolished buildings (44). Unknown buildings (13) were excluded.

The biggest change in building materials was the significant increase of modern building materials (gray) and the shift from traditional materials (red) to modern materials as illustrated in Figure 25 (a) and Figure 26. In 1999, the majority of the buildings used traditional materials. By 2009, the buildings built from modern materials had increased and replaced a number of buildings built from traditional materials throughout the peninsula. The religious and government buildings in the middle of the peninsula and touristic buildings along the commercial roads maintained the use of traditional materials. This corresponds with the unchanged architecture described in Section 4.2.2.

The increase of modern building materials was mainly due to the conversion of materials in existing buildings, and a substantial number of new buildings being constructed using modern materials. Almost a quarter of traditional-materials buildings (112 of 487) was converted to modern materials, which contributed the most to the increase of modern materials, as shown in Table 17 and Figure 25 (b). The evident decrease in traditional materials was attributed to timber and a mix of bamboo and timber (Appendix 8). A second contribution came from new buildings constructed using modern materials (62 of 88), as depicted in Figure 25 (c). In addition, the majority of existing buildings have maintained the same modern materials (187 of 201).

Meanwhile, existing buildings utilizing traditional materials reduced in number from 487 to 341. As a result, in 2009 the number of buildings using traditional materials (379) and that of buildings using modern materials (369) were almost the same. Fewer new buildings utilized traditional materials than did modern materials, (26) and a few marginal existing buildings converted to traditional materials (5).

A small number of building materials were unknown (13). Later, the buildings were identified as being built from modern materials (9) and traditional materials (3). Over the ten years, 44 buildings were demolished, of which 34 originated from traditional materials, 9 from modern materials, and 1 from unknown materials.

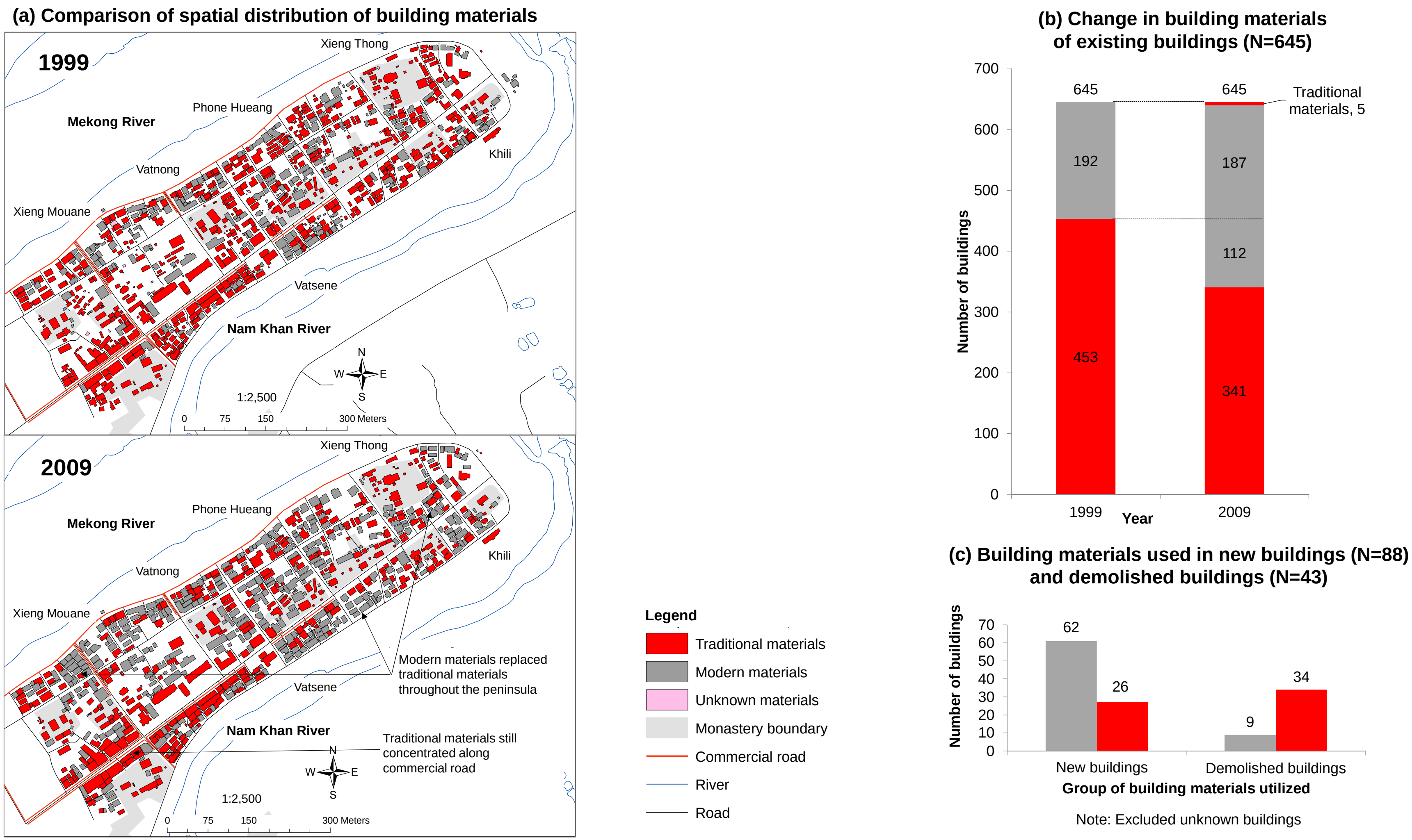

Figure 25. Change in building materials

Source: (a) Leong et al., 2016, pp. 13-14; (b) and (c) Department of World Heritage, 2009

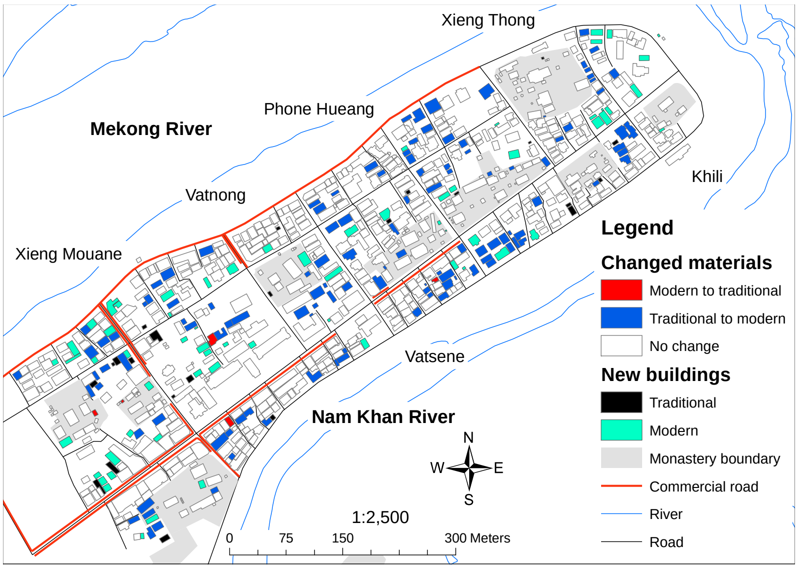

Figure 26. Spatial distribution of changed materials and new buildings materials

Source: Leong et al., 2016, p. 14

Table 17. Transition in building materials between 1999 and 2009

		2009			
		Modern	Traditional	None	Total
1999	Modern	187	5	9	201
	Traditional	112	341	34	487
	Unknown[1]	9	3	1	13
	None[2]	62	26	0	88
	Total	369	376	44	789

Note:
[1]Same description as Table 15
[2] Same description as Table 12
Source: Leong et al., 2016, p. 14

4.2.3.1 Inventory and Non-inventory Buildings

A total of 117 buildings changed materials over 10 years. In the case of inventory buildings as shown in Figure 27 (a), 13 of 205 (6.3%) changed their materials. Other inventory buildings maintained the same materials (192, 93.7%). As for non-inventory buildings in Figure

27 (d), 104 of 452 (23.0%) changed their materials, and 336 (74.3%) retained the same materials. However, the materials of 12 non-inventory buildings were unknown.

Figure 27 (b) illustrates that thirteen inventory buildings changed from traditional to modern materials. Meanwhile Figure 27 (e) depicts that most of the inventory buildings maintained traditional materials (192). Of which, they were government offices, religious buildings, and a group of touristic buildings concentrated on commercial roads in the villages of Xieng Mouane and Vatsene. This corresponds with unchanged building usage in Section 4.2.1 and unchanged architecture in Section 4.2.2.

Among the non-inventory buildings in Figure 27 (c), the majority changed to modern materials (99, 95.2%) and it was observed to be occurring throughout the peninsula. Where else, more non-inventory buildings maintained modern materials (187) than traditional materials (149), as displayed in Figure 27 (f).

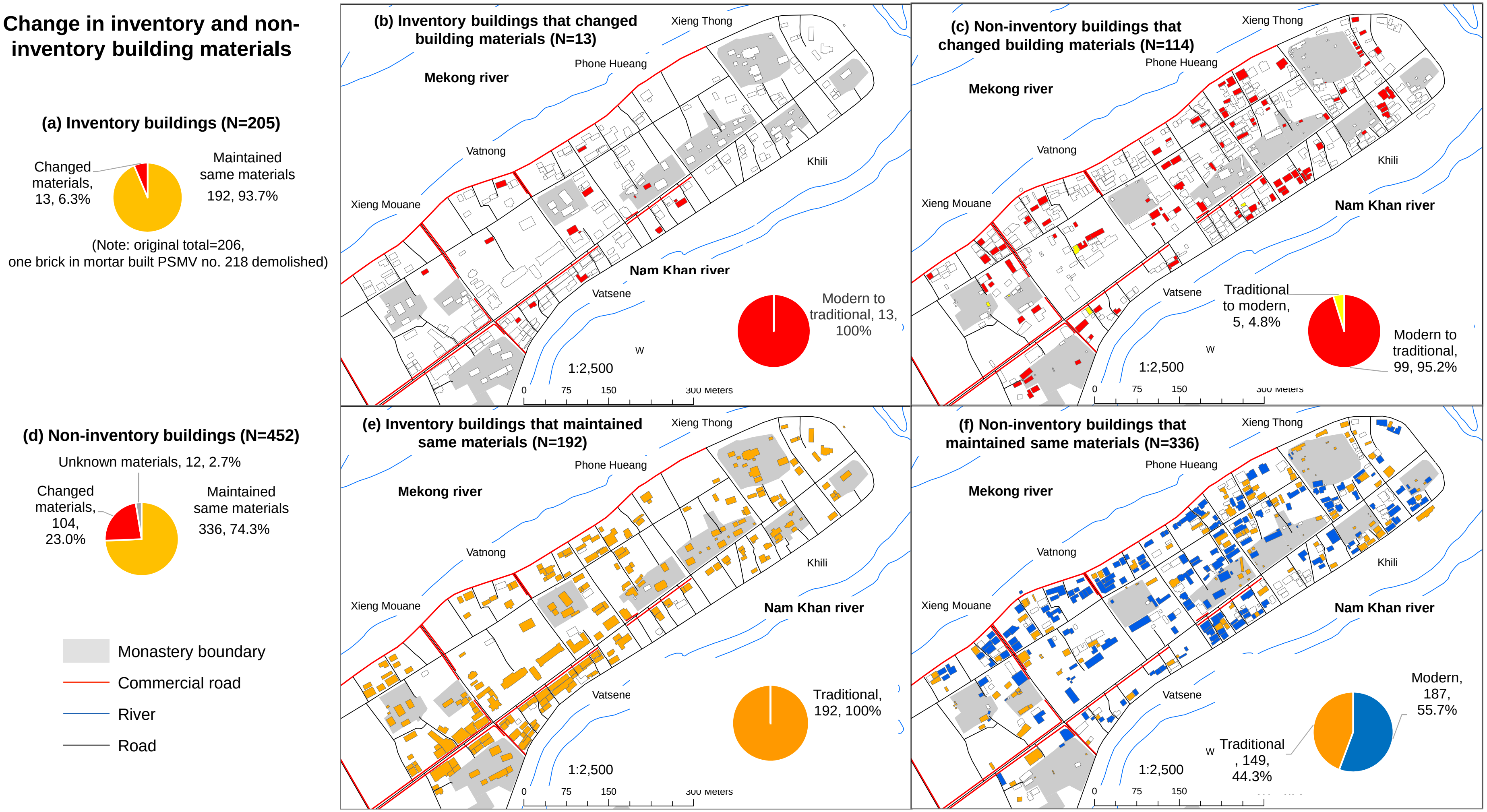

Figure 27. Change in inventory and non-inventory building materials

Source: Department of World Heritage, 2009

4.2.4 Building Roof Materials Indicator

The use of roof materials could be grouped into two categories, namely 1) traditional roof materials; and 2) modern roof materials. In the group of traditional roof materials, there were four types of materials: 1) clay tiles; 2) cement tiles; 3) timber; and 4) bamboo. Modern roof materials consist of 1) zinc; 2) fiber cement; and 3) terrace. The sample size included 613 existing buildings, 82 new buildings, and 43 demolished buildings. The sample excluded 2 buildings with mixed traditional and modern roof materials, 2 buildings of unknown roof materials, and 47 roofless structures. Roofless structures were religious structures in monasteries that do not have roofs, such as stupas and Ou Mong.

The most pronounced change in roof materials was the increase in the use of traditional roof materials (orange) as depicted in Figures 28 (a) and 29. In 1999, the majority of the buildings utilized modern roof materials (blue), which were scattered throughout the six villages. On the other hand, there were fewer buildings with traditional roof materials and they mostly occupied the middle of the peninsula and the commercial road along Nam Khan River. Over the decade, the use of traditional roof materials visibly increased and replaced modern roof materials in several areas along the Mekong and Nam Khan riverbanks. Buildings located in the middle of the peninsula and along the commercial road on Nam Khan River maintained traditional roof materials. This finding corresponds with unchanged architecture (Section 4.2.2) and building materials (Section 4.2.3).

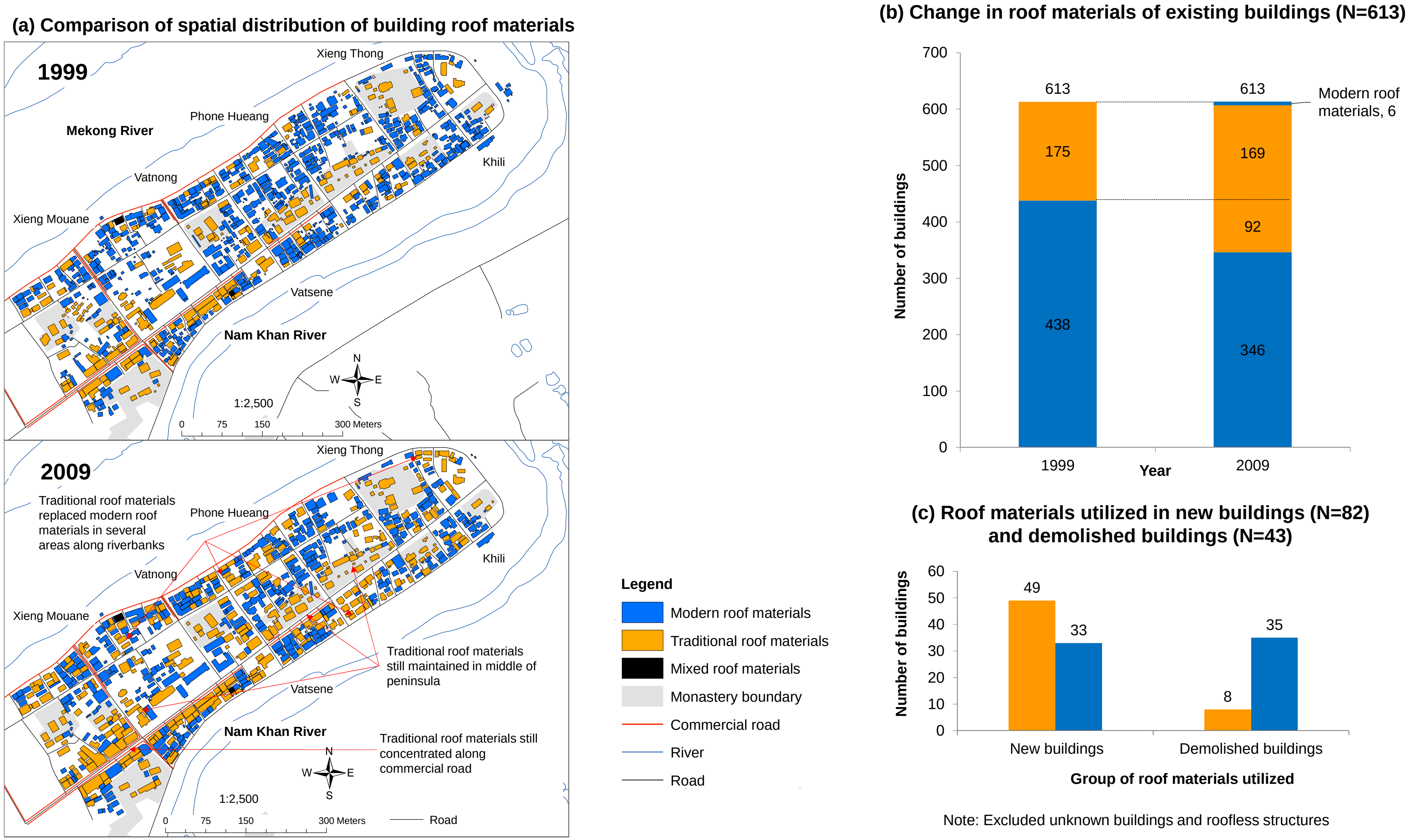

Figure 28. Change in roof materials

Source: (a) Leong et al., 2016, pp. 17-18; (b) and (c) Department of World Heritage, 2009

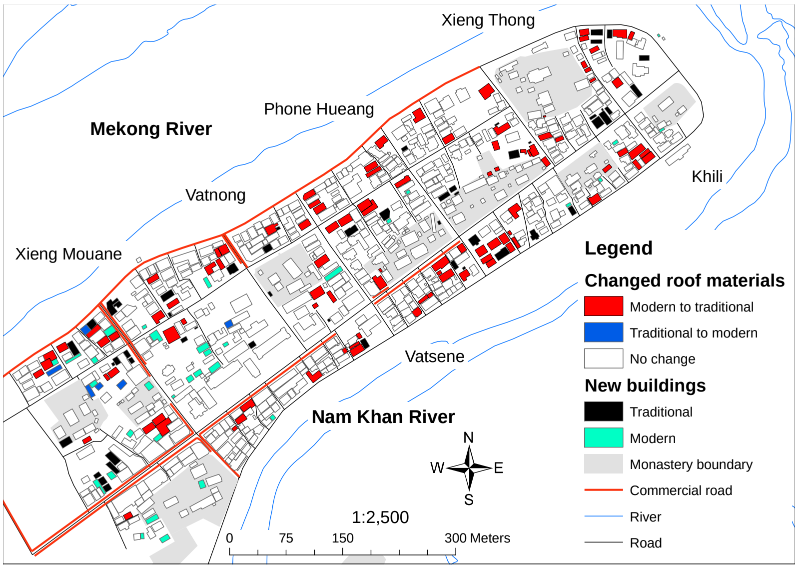

Figure 29. Spatial distribution of changed roof materials and new building roof materials

Source: Leong et al., 2016, p. 18

The surge in traditional roof materials was credited to a high number of conversions from modern roof materials in existing buildings, wide usage in new buildings, and fewer buildings with traditional roof materials being demolished. Tracking changes in roof materials shows that a significant number of modern roof materials were converted to traditional roof materials (92 of 473), as displayed in Table 18 and Figure 28 (b). Further analysis revealed that the significant decline in modern roof materials was attributable to the decrease of corrugated zinc sheets, and their replacement by traditional roof materials such as clay tiles and cement tiles (Appendix 9). As for new buildings, as shown in Figure 28 (c), traditional roof materials (49 of 88) were more widely used than modern roof materials (33). This contributed the most to the increase of traditional roof materials from 183 in 1999 to 295 in 2009. In addition, a relatively higher number of buildings with modern roof materials (35) were demolished compared to ones with traditional roof materials (8), as illustrated in Figure 28 (c). As a result, the number of buildings that used modern roof materials dropped from 473 to 346. In comparison, traditional roof materials converted to modern roof materials were fewer in number (6 out of 183). Buildings that utilized traditional roof materials decreased slightly, from 183 to 169. There were two abnormal cases of buildings mixing roof materials. They were found in a row of shop houses, where different shops were connected but had different roof materials. Roofless structures grew from 41 to 47. The roof materials of two buildings were unknown. Later, it was found that one building used traditional roof materials and another was demolished.

Table 18. Transition in roof materials between 1999 and 2009

		2009					
		Modern	Traditional	None	Mixed materials	Roofless structures	Total
1999	Modern	346	92	35	0	0	473
	Traditional	6	169	8	0	0	183
	None[1]	49	33	0	0	6	88
	Mixed materials[2]	0	0	0	2	0	2
	Unknown[3]	0	1	1	0	0	2
	Roofless structures[4]	0	0	0	0	41	41
	Total	401	295	44	2	47	789

Note:
[1] Same description as Table 12.
[2]Special case of buildings that mixed the use of traditional and modern roof materials. They were built before the inscription of the site.
[3]Same description as Table 15.
[4]Non-habitable structures that do not have roofs, such as stupas and small worship structures.
Source: Leong et al., 2016, p. 19

4.2.4.1 Inventory and Non-inventory Buildings

The inventory buildings that changed roof materials account for 20 of 205 cases (9.9%) and those that maintained the same roof materials account for 182 cases (90.1%), as summarized in Figure 30 (a). Meanwhile, non-inventory buildings that changed their roof materials account for 102 cases of 413 (24.7%) and those that maintained the same roof materials account for 309 cases (74.8%), as illustrated in Figure 30 (d).

An evident decrease was seen in the use of modern roof materials and their substitution by traditional roof materials. This change happened in both inventory and non-inventory buildings as shown in Figure 30 (b) and (c) respectively. The change in roof materials of inventory and non-inventory buildings was observed more on riverbank areas. In inventory buildings, the majority of the roof materials changed from modern to traditional (red) (17 of 20 cases), and there were other changes in the remaining 3 cases. Like inventory buildings, most non-inventory buildings changed their roof materials from modern to traditional (71 of 102).

The majority of the inventory buildings retained their traditional roof materials (137 of a total of 182, 74.9%), as shown in Figure 30 (e). Inventory buildings with traditional roof materials were apparent along the commercial road and in the middle of the peninsula, while inventory buildings with modern roof materials were sparsely located. On the other hand, non-inventory buildings in Figure 30 (f) maintained mainly modern roof materials and were scattered throughout the peninsula (278 of 309, 91.1%).

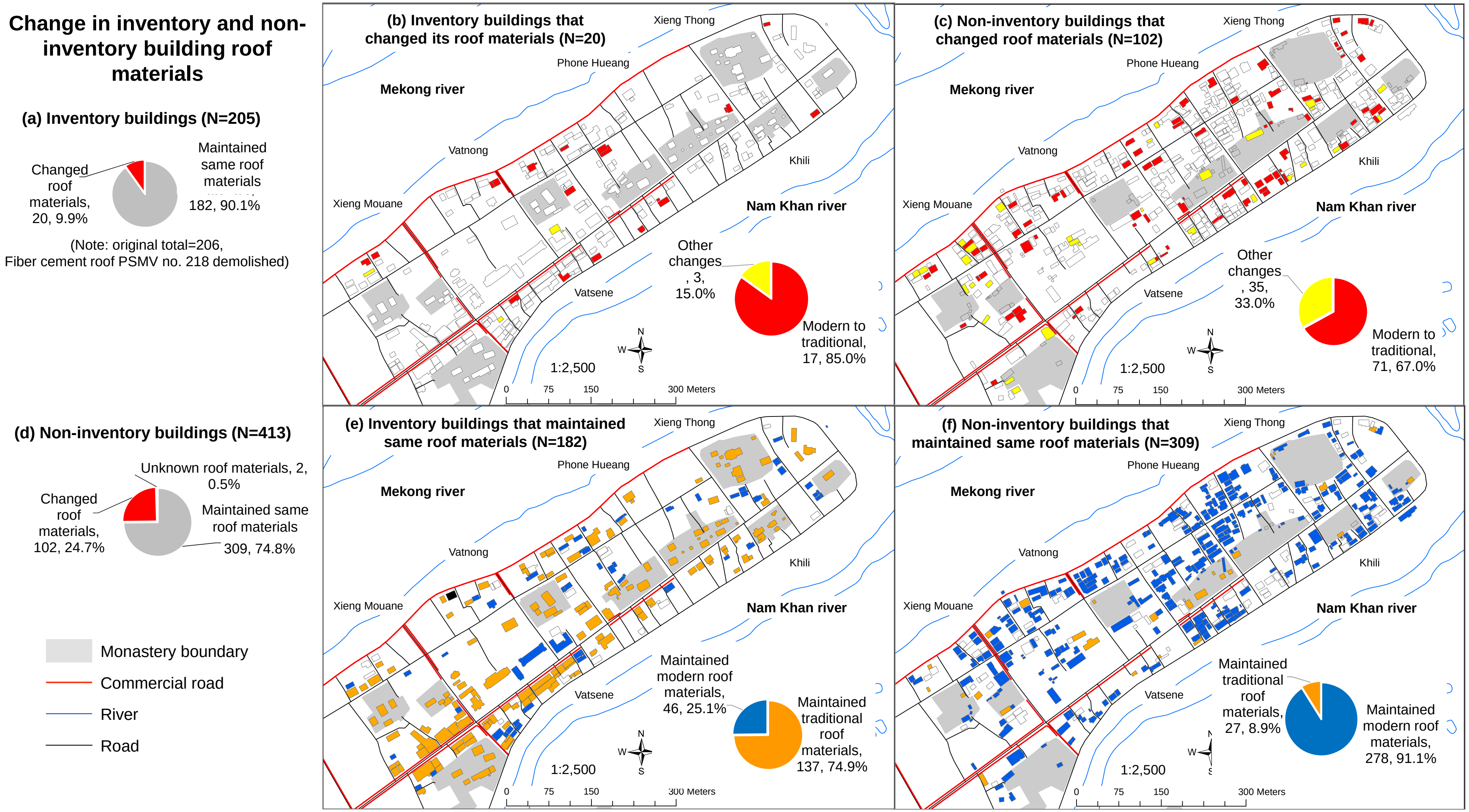

Figure 30. Change in inventory and non-inventory building roof materials

Source: Department of World Heritage, 2009

4.2.5 Building Height Indicator

The purpose of the analysis was to observe the change in building height by examining the number of floors. Buildings investigated have between 1 and 3 floors. The height of one floor is estimated to be 3m, 2 floors, 6m, and 3 floors, 9m. A total of 619 existing buildings, 82 new buildings, and 41 demolished buildings were analyzed. The analysis excluded 44 non-habitable structures. Non-habitable structures were small religious structures in monasteries which do not have any floors.

Building height did not change significantly. In 1999, the majority of the buildings with two floors (green) were concentrated along riverbank areas, as displayed in Figure 31 (a). There were fewer 1-floor buildings (light blue), which were located mostly in the middle of the peninsula. A small number of 3-floor buildings (orange) were scattered throughout the peninsula. Ten years later, building height had changed to between 1 and 2 floors. The maximum height did not exceed 3 floors, and 3-floor buildings had not increased. No distinctive change was observed in the spatial distribution of buildings.

Among the three different building heights, 2-floor buildings dominated the landscape over the ten years. The majority of the buildings retained the same height and more buildings increased height than decreased it. Most 2-floor buildings maintained the same height (374 of 421) and 29 buildings decreased height to 1 floor, as summarized in Table 19 and Figure 30 (b). Meanwhile, more than half of 1-floor buildings retained the same height (153 out of 229) and a quarter of the buildings increased in height to 2 floors (53). The number of 3-floor buildings did not change, remaining at ten. In new buildings, as displayed in Figure 30 (c), 1-

floor buildings (48) were higher in number than 2-floor (34). More 1-floor buildings (23) were demolished than 2-floor buildings (18).

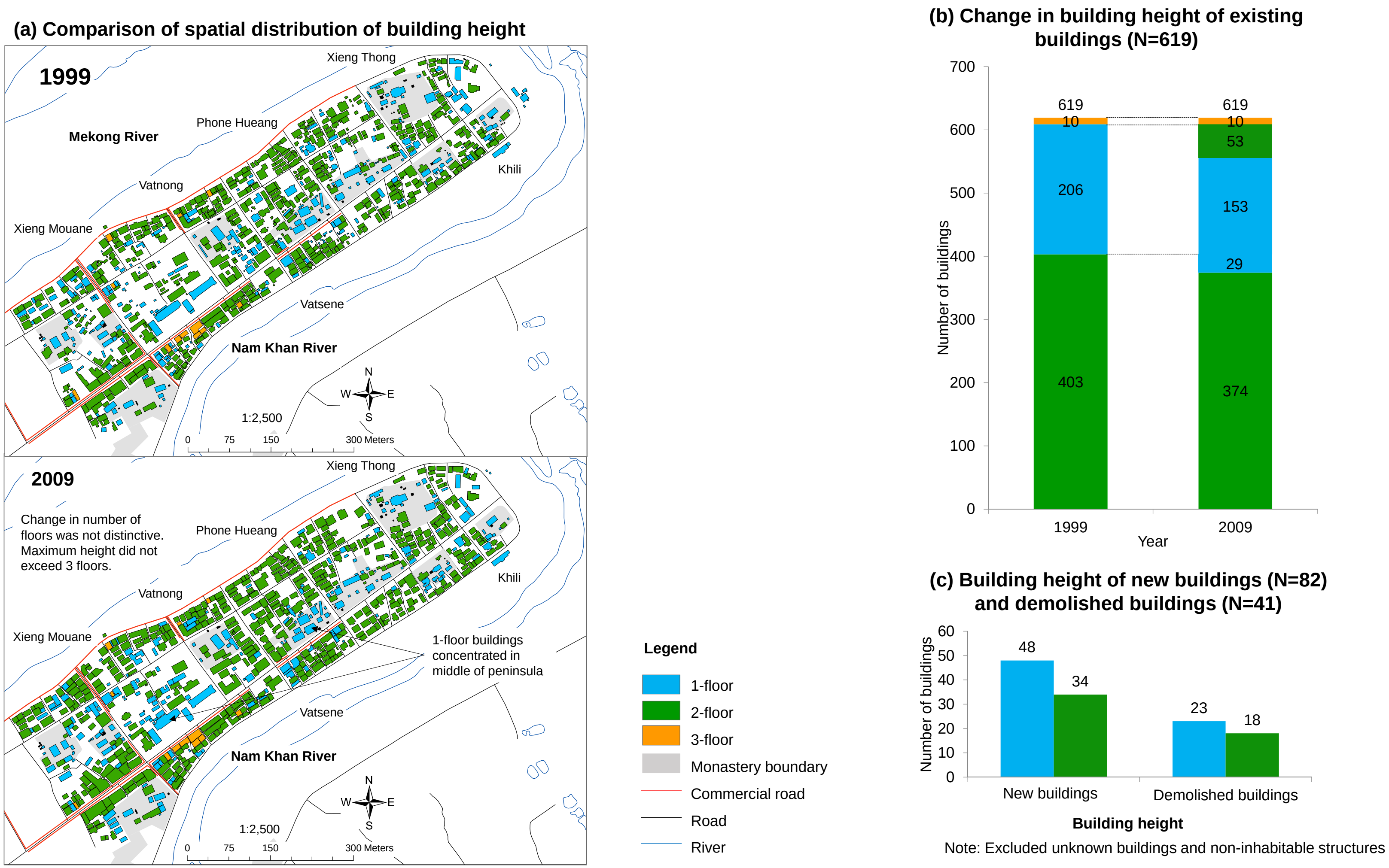

Figure 31. Change in building height

Source: (a) Department of World Heritage, 2009; (b) and (c) Leong et al., 2011

Table 19. Transition in building floors between 1999 and 2009

		2009					
		1-floor	2-floor	3-floor	Non-inhabitable structures	None	Total
1999	1-floor	153	53	0	0	23	229
	2-floor	29	374	0	0	18	421
	3-floor	0	0	10	0	0	10
	Non-habitable structures[1]	0	0	0	41	0	41
	None[2]	48	34	0	3	3	88
	Total	230	461	10	44	44	789

Note:
[1]Small religious structures in monasteries that do not have any floors
[2] Same description as Table 12
Source: Department of World Heritage, 2009; Leong et al., 2011

4.2.5.1 Inventory and Non-inventory Buildings

Among the inventory buildings, only one (0.5%) changed its height while the majority (204, 99.5%) maintained the same height, as shown in Figure 32 (a). As for non-inventory buildings in Figure 32 (d), a total of 19.6% (81) changed their height while the majority retained their original height (333, 80.4%).

Figure 32 (b) depicts that one inventory building reduced its height from 2 to 1 floor. Where else Figure 32 (c) displays that inventory buildings which retained their height were mostly 2-floor (150), followed by 1-floor (51), and, lastly, a small number of 3-floor buildings (3). Two-floor inventory buildings were found throughout the peninsula. One-floor inventory buildings remained mostly in the middle of the peninsula.

Comparison between Figure 32 (c) and (f) shows that there was no distinctive difference observed in the spatial distribution of non-inventory buildings that changed height and those that maintained the same height. The number of non-inventory buildings which increased their height from 1 to 2 floors (53) was greater than the number which decreased their height from 2 to 1 floor (28). Cases of increased (red) and decreased (yellow) building height were scattered throughout the peninsula. Non-inventory buildings that maintained 2 floors account for 224 cases, 1 floor, 102 cases, and 3 floors, 7 cases.

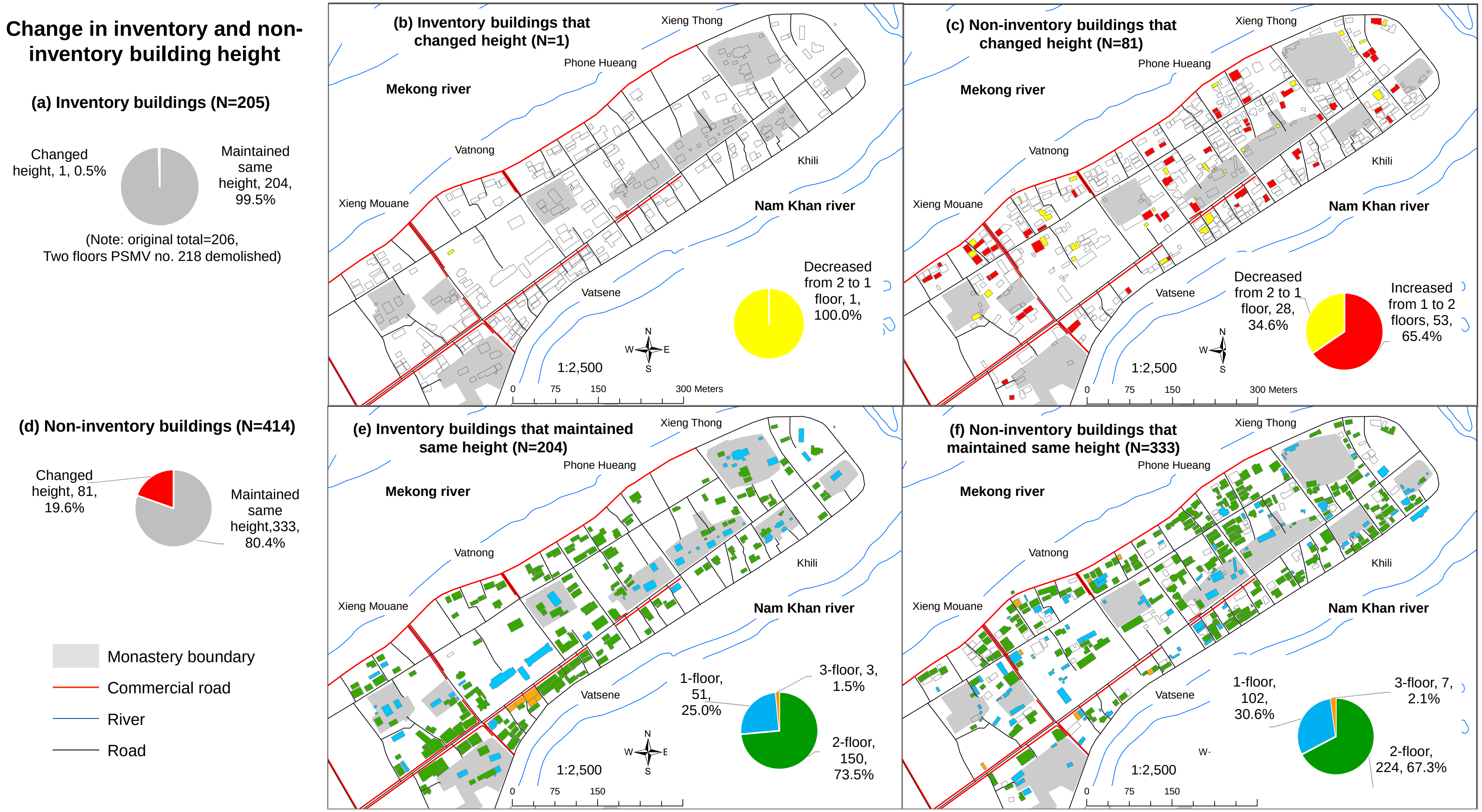

Figure 32. Change in inventory and non-inventory building height

Source: Department of World Heritage, 2009

4.2.6 Building Condition Indicator

The building conditions were assessed during field survey and categorized into good, moderate, and bad conditions (refer to Chapter 3 Methodology, p. 41). A total of 651 existing buildings, 88 new buildings, and 44 demolished buildings were analyzed. However, the condition of 6 buildings was unknown in 1999 and excluded from analysis.

The spatial distribution of building conditions did not show any notable change. In 1999, many of the buildings were in good condition (green) and found throughout the peninsula, as shown in Figure 33 (a). Moderate-condition buildings (yellow) and bad-condition buildings (red) were scattered throughout the peninsula. After a decade, bad-condition buildings seemed to have reduced while good-condition buildings had increased throughout the peninsula.

Significantly more buildings had improved in condition than deteriorated. Transition in building condition is summarized in Table 20 and Figure 33 (b). Good-condition buildings had increased notably, from 361 in 1999 to 472 in 2009, due to improvement from moderate condition, 95, and bad condition, 55. Moreover, more than half of new buildings (61 of 88) were in good condition, as shown in Figure 33 (c). Moreover, a relatively high number of buildings, 256, were able to maintain a good condition, compared to buildings of other conditions. A number of buildings had deteriorated from good to moderate (89), and bad (5), as well as from moderate to bad (23). Overall, bad-condition buildings had dropped substantially, by half, from 133 to 61. Moderate-condition buildings had increased slightly, from 201 to 212.

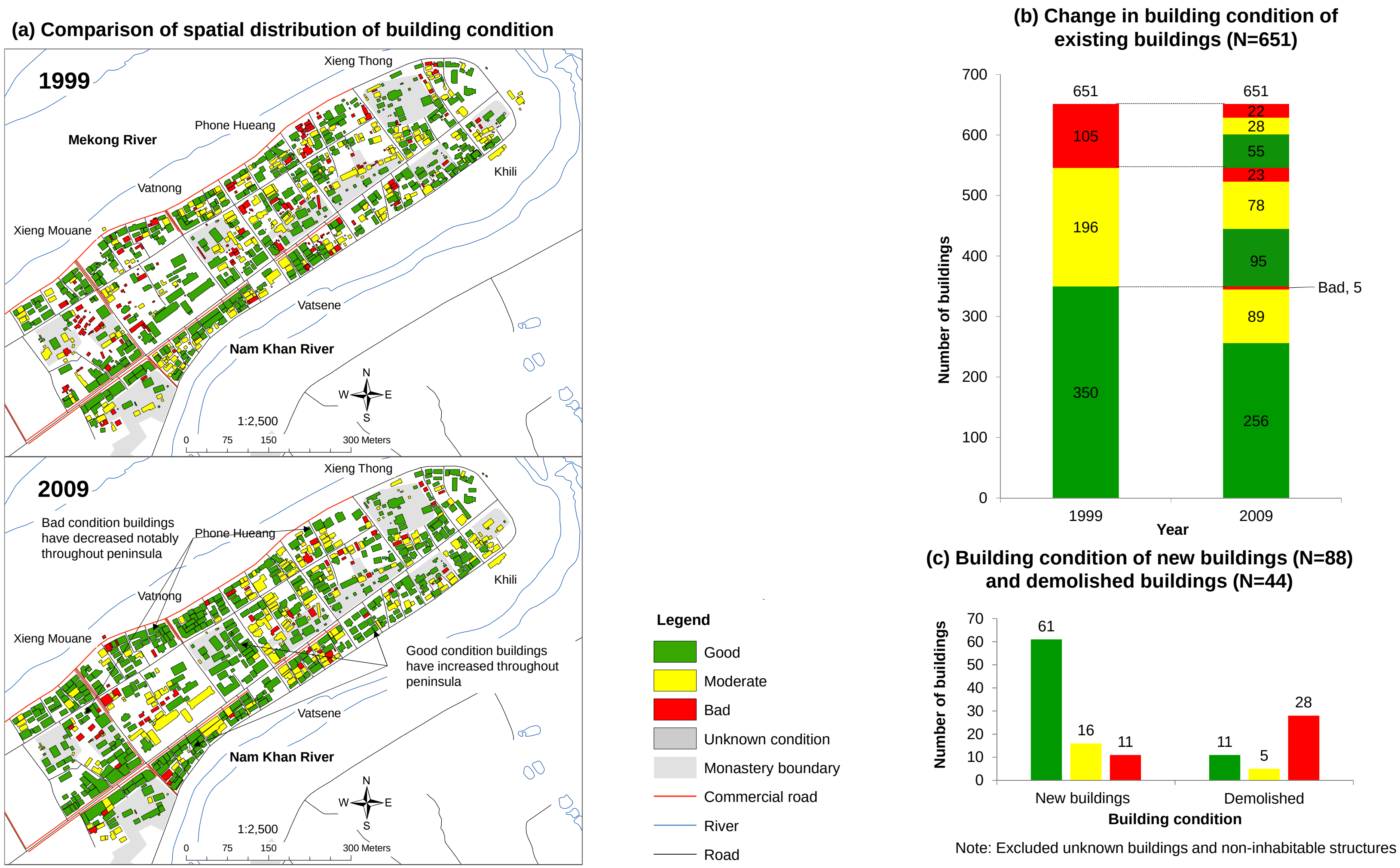

Figure 33. Change in building condition

Source: (a) Department of World Heritage, 2009; (b) and (c) Leong et al., 2011

Table 20. Transition in building condition between 1999 and 2009

		2009				
		Good	Moderate	Bad	None	Total
1999	Good	256	89	5	11	361
	Moderate	95	78	23	5	201
	Bad	55	28	22	28	133
	Unknown[1]	5	1	0	0	6
	None[2]	61	16	11	0	88
	Total	472	212	61	44	789

Note:
[1] Same description as Table 15
[2] Same description as Table 12
Source: Department of World Heritage, 2009; Leong et al., 2011

4.2.6.1 Inventory and Non-inventory Buildings

Overall, non-inventory and inventory buildings had improved their condition. A total of 85 inventory buildings (41.5%) have changed its condition, as illustrated in Figure 34 (a). Of which, a high percentage of inventory buildings had improved (59, 69.4%), compared to those whose condition had deteriorated (26, 30.6%), as shown in Figure 34 (b). The improved inventory buildings (blue) and deteriorated inventory buildings (pink) were located more in the inner peninsula. Meanwhile, 120 inventory buildings in Figure 34 (e) had maintained the same condition (58.5%). The majority of inventory buildings were still in good condition (99, 82.5%) compared to those in moderate (20, 16.7%), and bad condition (1, 0.8%).

As for non-inventory buildings in Figure 34 (d), 210 (46.5%) had changed their condition while 236 had retained the same condition (52.2%). However, the condition of 6 non-inventory buildings (1.3%) was unknown. Figure 34 (c) summarized that non-inventory buildings whose condition had improved numbered 119 buildings (56.7%) while deteriorated non-inventory buildings numbered 91 (43.3%). Moreover, more than half of non-inventory buildings had retained a good condition (157, 66.5%), as depicted in Figure 34 (f).

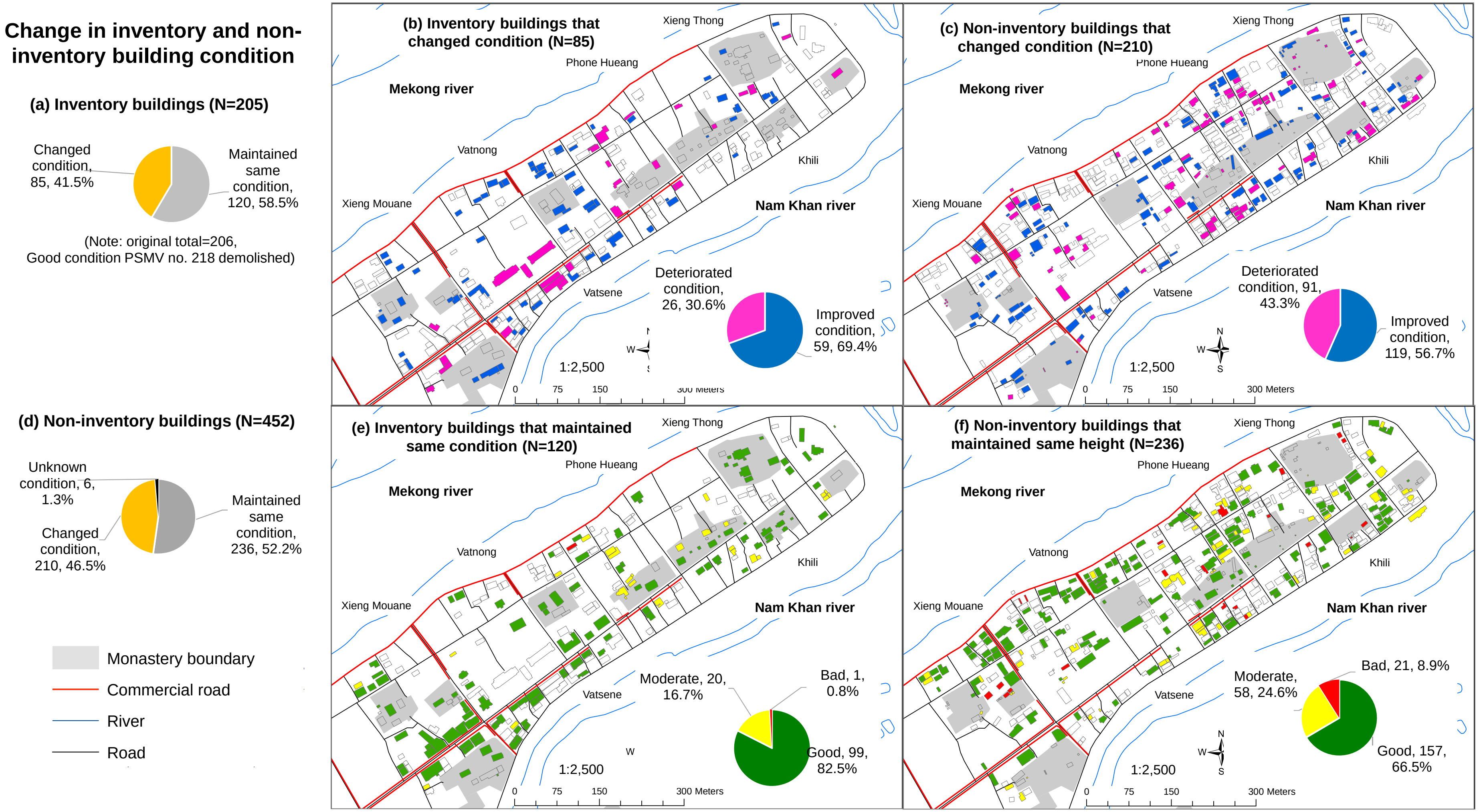

Figure 34. Change in inventory and non-inventory building condition

Source: Department of World Heritage, 2009

4.2.7 Building Area Size Indicator

Building area size was extracted by overlaying the built-up area of 1999 with that of 2009, as illustrated in Figure 35 (a). The size of the pilot site was 204, 591m^2. The built-up area has increased (yellow) as a result of buildings becoming bigger and aligned more closely with each other. Clusters of smaller buildings were replaced by bigger buildings in the middle of the villages of Xieng Mouane and Vatnong. An increase of building area size occurred along riverbank areas more evidently than in the middle of the peninsula. The villages of Xieng Mouane and Vatnong saw a prominent increase in building area size compared to the other villages.

In ten years, the total building area size increased from 79,381m^2 to 90,124m^2, as shown in Table 21. This is attributed to conversion from green space and unoccupied land, 11, 537m^2, and the construction of new buildings that covered an area of 6,743m^2. In total, the increase in building area size amounted to 18,280m^2 and represents 23.9% of the building area size in 1999. This resulted in green space and unoccupied land decreasing from 118,467m^2 to 111,493m^2.

There were cases where buildings decreased in size and were converted back to green space and unoccupied land, accounting for 4,563m^2. Demolished buildings accounted for an area of 2,974m^2. This totals 7,537m^2. Therefore, the increase of building area size is more pronounced than its decrease. Building density refers to total building area over total area. The building density in 1999 was 38.8%; by 2009, it had increased to 44.1%.

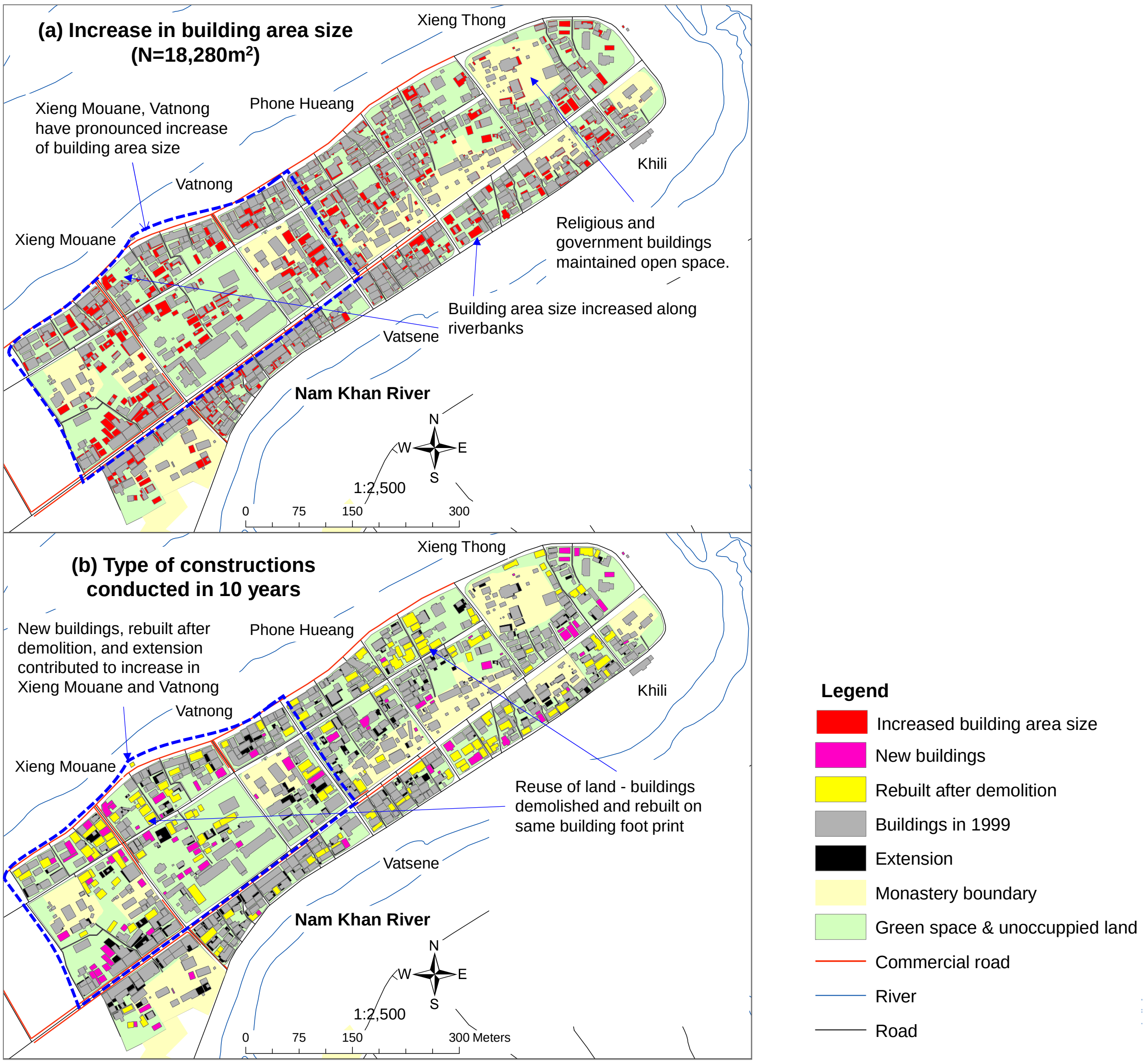

Figure 35. Change in building area size

Source: Department of World Heritage, 2009; Leong et al., 2011

Table 21. Transition in land area size between 1999 and 2009 (m^2)

		2009			
		Green space and unoccupied land	Built land	None	Total
1999	Green space and unoccupied land	106,930	11,537	0	118,467
	Built land	4,563	71,844	2,974	79,381
	None[1]	0	6,743	0	6,743
	Total	111,493	90,124	2,974	204,591

Note:
[1] None in 1999 refers to land occupied by newly constructed buildings, and none in 2009 refers to land of demolished buildings
Source: Department of World Heritage, 2009

The authorized construction archive of the DPL shows that the increase of the built-up area was due to two types of construction activities carried out in the villages, namely new construction and increasing the size of buildings through extension. The different constructions are illustrated in Figure 35 (b). Higher cases of new buildings (blue) and extensions (black) were seen in the villages of Xieng Mouane and Vatnong, which helps to explain the higher increase of building area size there compared to other villages. A notable number of buildings were demolished and rebuilt on the same building footprint, which indicates reuse of land. Reconstructions were mainly carried out when the aesthetic of the building changed, for example, its architecture.

4.2.7.1 Inventory and Non-inventory Buildings

In general, both inventory and non-inventory building area size have increased over the ten years. The analysis excluded land from demolished buildings land and newly-built-on land. As for inventory buildings, there was no distinct increase in building area size, as illustrated in Figure 36 (a) and (c). Inventory building area size increased slightly, from 33,880m^2 to 35,561m^2, that is, by 1,681m^2. This represents 5.0% of the total built land of inventory buildings in 1999. Inventory no. 281, of 135m^2, had been demolished. On the other hand, Figure 36 (b) and (c) show that the building area size of non-inventory buildings increased throughout the peninsula, except in the villages of Xieng Thong and Vatsene, from 42,525m^2 to 47,820m^{2,} i.e., by 5,295m^2 (12.5% of total non-inventory built land in 1999).

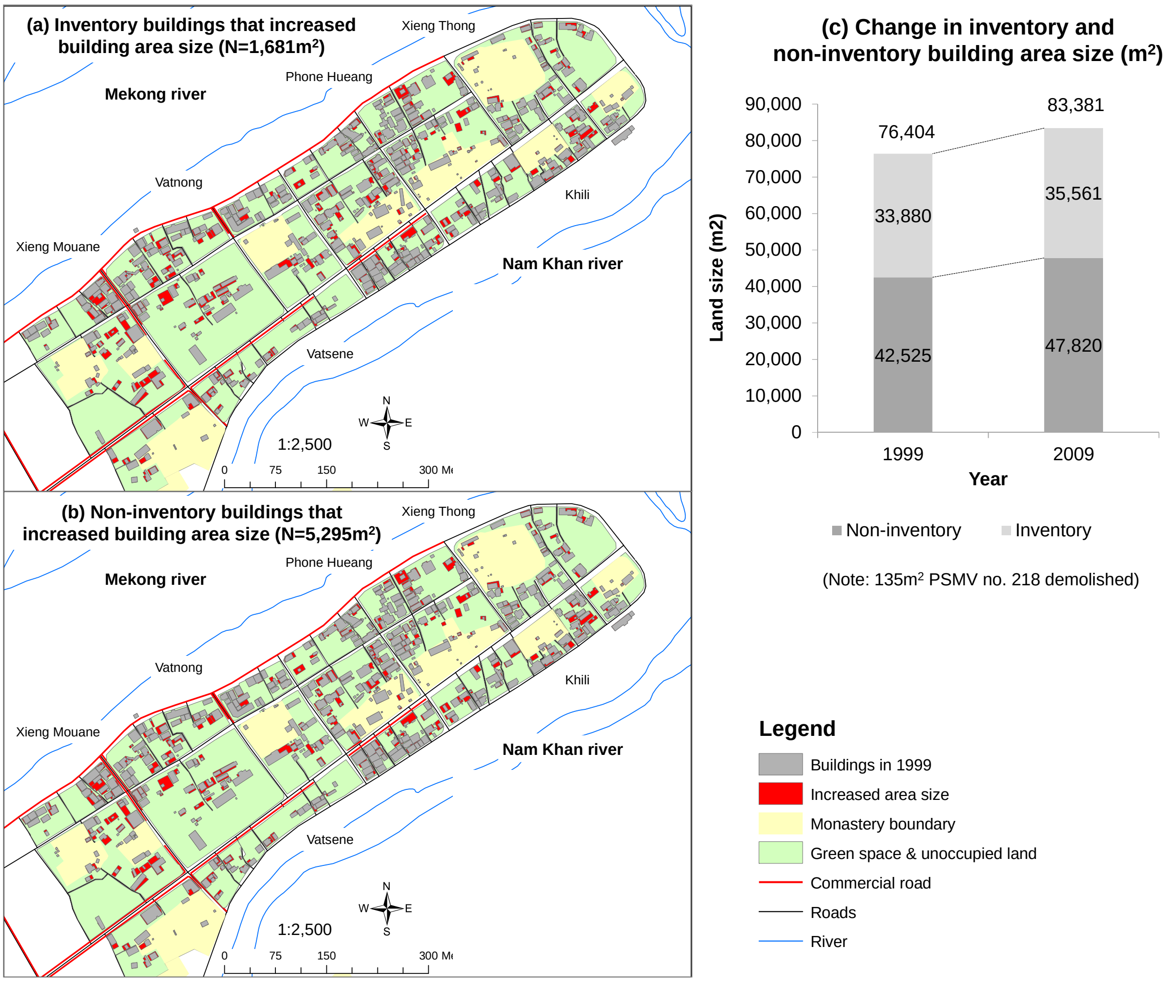

Figure 36. Change in inventory and non-inventory building area size

Source: Department of World Heritage, 2009

4.2.8 Patterns of Changes

Two patterns of change were observed in spatial analysis: 1) inventory buildings did not change much and maintained most of their original attributes; and 2) substantial buildings located along riverbanks changed their attributes. Logistic regression was used to examine and validate the relation between seven indicators with inventory buildings and riverbank location.

4.2.8.1 Inventory Buildings

This logistic regression model validates the relation between inventory buildings and the maintenance of the building attributes of seven indicators. A total of 657 existing buildings were analyzed. The estimate results and odds ratio of inventory buildings are shown in Table 22. Variables $ROOF_{inv}$ and MAT_{inv} have positive coefficients and p-values less than 0.05, indicating that they are significant. The odds of inventory buildings maintaining original building materials is four times, 4.14 greater than for non-inventory buildings. As for roof materials, the odds are two times, 2.85 greater than for non-inventory buildings. This verified the finding obtained from spatial analysis of the roof materials and building materials of inventory buildings.

Table 22. Estimates and odds ratio of inventory buildings that maintained original attributes (N=657)

Variable	Description	Estimate	Odds ratio
USE_{inv}	Maintained original usage	0.37.	1.45
$ROOF_{inv}$	Maintained original roof materials	1.05***	2.85
$ARCH_{inv}$	Maintained original architecture	18.00	65561553.0
$HEIGHT_{inv}$	Maintained original number of floors	17.65	46154268.2
MAT_{inv}	Maintained original building materials	1.42***	4.14
$COND_{inv}$	Maintained original state of building	-0.12	0.88
$AREA_{inv}$	Maintained original building area size	0.31.	1.36

*Note: ***Statistically significant at 0.001 confidence level, at 0.5*
Source: Analysis based on original data from Department of World Heritage, 2009

4.2.8.2 Riverbank Location

This model tests the relation between riverbank location and seven indicators. In this logistic regression model, both existing buildings (N=657) and new buildings (N=88) were analyzed. Table 23 displays the estimate and odds ratio of existing buildings that changed their attributes along the riverbank. Three variables have p-values of less than 0.05 and are considered as significant, namely: $USE_{location}$, $ARCH_{location}$, and $AREA_{location.}$ The existing buildings located along the riverbank have higher odds of changing in three indicators than buildings situated in the middle of the peninsula, namely: 1) two times, 2.32 higher odds to change to touristic use; 2) two times, 2.22 higher odds to change to Lao traditional architecture; and 3) one time, 1.55 higher odds to increase building area size. As for new buildings, the analysis involved six indicators and excluded the building area indicator because it was difficult to gauge and code the area as a categorical variable. The estimates and odds ratio of new buildings are summarized in Table 24. None of the variables are statistically significant. This indicates that the new buildings situated on riverbanks did not have higher odds in exhibiting any of the significant building attributes compared to new buildings in middle of peninsula. Therefore, this logistic regression model helped to validate the observation in the spatial analysis that existing buildings along riverbanks have greater odds of changing to touristic use, changing to Lao traditional architecture, and increasing building area size than existing buildings in the middle of the peninsula.

Table 23. Estimates and odds ratio of existing buildings that changed along the riverbank (N=657)

Variable	Description	Estimate	Odds ratio
$USE_{location}$	Changed to touristic use	0.84***	2.32
$ROOF_{location}$	Changed to traditional roof materials	0.39	1.47
$ARCH_{location}$	Changed to Lao traditional architecture	0.80**	2.22
$MAT_{location}$	Changed to modern building materials	0.10	1.10
$COND_{location}$	Improved building condition	-0.14	0.87
$HEIGHT_{location}$	Increased from 1 to 2 floors	0.39	1.48
$AREA_{location}$	Increased building area size	0.44**	1.55

*Note: ***Statistically significant at 0.001 confidence level, ** at 0.01*
Source: Analysis based on original data from Department of World Heritage, 2009

Table 24. Estimates and odds ratio of new buildings that have significant attributes and are located along riverbank (N=88)

Variable	Description	Estimate	Odds ratio
$USE_{location}$	Used for touristic purposes	0.01	1.01
$ROOF_{location}$	Used traditional roof materials	-0.23	0.80
$ARCH_{location}$	Used Lao traditional architecture	-0.47	0.63
$MAT_{location}$	Used modern building materials	0.02	1.03
$HEIGHT_{location}$	Built at maximum height, 2 floors	0.34	1.40
$COND_{location}$	Built with a good building condition	0.56	1.76

*Note: ***Statistically significant at 0.001 confidence level*
Source: Analysis based on original data from Department of World Heritage, 2009

4.2.9 Summary

Changes identified in the seven indicators are summarized in Table 25. Four indicators have changed significantly, namely: 1) building usage; 2) building materials; 3) roof materials; and 4) building architecture. In building usage, the biggest change was due to increase of private usage. Touristic buildings have increased because of the conversion of existing residential buildings and construction of new touristic buildings. The increase in touristic buildings was apparent along riverbanks and main roads. The increase of touristic use occurred in both inventory and non-inventory buildings. All types of touristic usage have increased, particularly tourist accommodation, e.g., guesthouses.

Building architecture and roof materials changed from modern to traditional elements and building materials changed from traditional to modern materials. Lao traditional architecture has increased due to conversion from modern architecture and the construction of new Lao traditional architecture buildings. The conversion of architecture was contributed by non-inventory buildings. All but three inventory buildings maintained their original architecture. Two inventory buildings changed to different types of Lao traditional architecture. One inventory building, PSMV no.281, was demolished (1 of 206).

Likewise, traditional roof materials increased due to conversion from modern roof materials and the construction of new buildings with traditional roof materials. The conversion involved mostly corrugated zinc roof sheets to clay and ceramic tiles. The change in traditional roof materials was observed in both inventory and non-inventory buildings.

Building materials increased due to conversion from traditional materials and the construction of new buildings with modern materials. The majority of buildings with bamboo and timber were replaced by cement, or a mix of cement and timber. Most of the change in materials occurred in non-inventory buildings. A small number (13) of inventory buildings did change to modern materials.

Building heights changed within 2 floors. More of the existing buildings increased in height. However, a higher number of new buildings were constructed with 1 floor than with 2 floors. The change in building height was contributed to non-inventory buildings. All inventory buildings except one maintained the same height. One inventory building reduced from 2 floors to 1 floor.

The condition of buildings on the pilot site in general have improved. More buildings improved their condition than deteriorated. The majority of new buildings were in good condition. Inventory and non-inventory buildings both improved their condition.

The building area increased by 23.9% (18, 280m^2) due to new buildings and extension of building size. This contributed to increasing building density. Riverbank areas became denser while the middle of the peninsula remained sparsely built. Land use was optimized by demolishing and rebuilding on the same building footprint.

Two additional findings were obtained. It was revealed that a considerable number of buildings maintained Lao traditional architecture despite changing from residential to touristic usage. Another finding showed that the majority of inventory buildings and religious buildings maintained their original attributes. These buildings also maintained their unique spatial distribution in the middle of the peninsula and along commercial roads.

Two spatial patterns obtained from spatial analysis have been verified in logistic regression. First, existing buildings located along riverbanks have greater odds of changing to touristic use and Lao traditional architecture, and of increasing their building area size, than is the case for buildings in the middle of the peninsula. Second, inventory buildings have greater odds of maintaining the same building materials and roof materials than non-inventory buildings.

Table 25. Summary of changes identified in seven indicators

Indicator	Spatial distribution	Changes	Inventory buildings	Non-inventory buildings
Building usage	Increased along riverbanks and main roads	• Existing buildings changed from residential to touristic, especially guesthouses • New buildings mainly touristic use	• Significant change to touristic use along riverbanks (36 of 205, 17.6%) • Maintained religious and government offices in the middle of the peninsula, touristic buildings along commercial roads	• Significant change to touristic use along riverbanks and main roads
Building architecture	Increased along riverbanks	• Existing buildings changed from modern to Lao traditional architecture • New buildings, one-third was Lao architecture	• Marginal change to different Lao architecture (2 of 205, 1.0%) • Maintained religious and colonial architecture in the middle of the peninsula, commercial architecture along commercial roads	• Significant change to Lao traditional architecture along riverbanks
Building materials	Throughout the peninsula	• Existing buildings changed from traditional to modern materials • New buildings mainly used modern materials	• A small number of cases changed to modern materials (13 of 205, 6.3%) • Maintained original materials in the middle of the peninsula and along commercial roads	• Significant change to modern materials throughout the peninsula

Table 25. Summary of changes identified in seven indicators (continue)

Indicator	Spatial distribution	Changes	Inventory buildings	Non-inventory buildings
Roof materials	Increased in certain areas along riverbanks	• Existing buildings changed from modern to traditional roof materials • New buildings - used traditional roof materials	• A small number of cases changed to traditional roof materials (17 of 205, 8.3%) • Maintained original roof materials in the middle of the peninsula and along commercial roads	• Significant change to traditional roof materials along riverbanks
Building height	Not distinctive	• Existing buildings increased height from 1 to 2 floors • New buildings mainly 1-floor	• Marginal change -decrease height from 2 to 1 floor (1 of 205, 0.5%) • Maintained 1-floor in the middle of the peninsula	• Increased height throughout the peninsula
Building condition	Throughout the peninsula	• Existing buildings improved their condition • New buildings - good condition	• Significant - improved condition (59 of 205, 28.8%) • Maintained good condition along commercial roads	• Improved condition throughout the peninsula
Building area size	Increased along riverbank areas and villages located in the inner peninsula (Vatnong and Xieng Mouane)	• Built land increased (18,280m^2, 23.9% of total built land in 1999) from extension of existing buildings and construction of new buildings	• Marginal change (1,681m^2, 5% of inventory built land in 1999)	• Increased by 5,295m^2 (12.5% of non-inventory built land in 1999)

Source: Summarized based on results of Chapter 4 Section 4.2, 2016

4.3 Reasons behind Significant Changes in the Built Environment

Reasons behind significant changes were investigated by local stakeholders such as the Department of World Heritage, and local residents. The DPL also interpreted the results derived from data analysis.

4.3.1 Department of World Heritage

A workshop was conducted with open discussions to find interpretations of the changes identified in the analysis of the built environment, and examine the reasons for the changes from the point of view of the Department of World Heritage, DPL. Local experts of the DPL participated in the workshop. After the workshop, a questionnaire survey was conducted to collect their responses. The respondents were three male architects, three male engineers, and one female architect from the Authorization Unit, Urban Planning Unit, and Environment Unit. The respondents had working experience of between 6 and 10 years in authorizing constructions in compliance with the PSMV, and coordinating development projects. The respondents were presented with the analysis results and briefed on the contents of the questionnaire. They took approximately 7 days to respond to the questionnaire. After the questionnaires were collected and translated, discussion with each respondent was carried out to clarify and correctly comprehend their answers. The discussion took a week to complete. A summary of major findings is presented as follows:

1. Building usage

a. Guesthouses increased more than hotels because it was easier for locals to start a guesthouse business than a hotel business

Conversion to guesthouse made it easier for locals to start a touristic business when they had little capital and could only offer a small number of rooms. According to Khamtane Somphanvilay, Deputy Director of the Department of Tourism, there was a smaller increase in hotels because of the criteria imposed by the Lao National Tourism Administration (LNTA) (personal communication, March 14, 2011). A hotel requires at least 15 rooms, 70% of which need to be larger than $10m^2$, and must provide services compliant with international standards.

b. Government and religious buildings did not change significantly due to lack of funds, limited land, and lack of experience in restoration

Government offices and school buildings faced a lack of funds and limited public land available on the World Heritage Site. Many of the government offices and schools were inventory buildings which involved costly restoration. It was difficult to obtain approval and funds from central government. Moreover, the procedure was time-consuming. On the other hand, religious buildings faced a lack of funds and traditional craftsmanship skills. Well-known monasteries gathered restoration funds from entrance fees, such as Vat Xieng Thong, while other, less popular, monasteries relied on public donations from the local community. Although monasteries have art schools to transfer skills from masters to apprentices on traditional decorative techniques and crafts, apprentices still lacked the experience to build or restore the buildings properly, especially murals on temple walls. Only a handful of craftsman possessed excellent skills and adequate experience. Unlike with public buildings, there was no limitation in land use for monasteries since the PSMV do not impose percentage of land use. Monasteries maintained large open spaces that were important for spiritual ceremonies and local community activities. Moreover, monasteries normally only construct structures that are smaller than the main temple (Aham) such as monks' dormitories, or a meditation hall, stupa and toilet.

2. Building architecture

a. Increase of Lao traditional architecture was due to strict regulation

The increase of Lao traditional architecture and conversion from modern architecture was due to strict regulation on the types of architecture permitted in Zpp-Ua. PSMV Section 1 Article 3 stipulated that only two types of architecture, traditional and commercial, were permitted (MdP, 2001b).

b. Increase of Lao traditional architecture has had a positive impact on preserving traditional elements of the urban landscape

The increase of Lao traditional architecture indicates that buildings were built in accordance with regulations where urban development should preserve the Lao morphology in terms of interaction between buildings, space, and roads. Traditional architecture complemented the landscape harmoniously with other buildings in a few aspects. The traditional architecture has a unique, sharp-angled roof style and roof ridges that align parallel with the rivers and roads. The land use of traditional architecture could only occupy 40% of the total land area, leaving rich green plantations surrounding the house with low fences. The limited percentage of land use in traditional architecture maintained spaces between buildings.

c. Increase of Lao traditional architecture was supported by the increase in touristic usage which has positive and negative impacts

Tourism became the main source for sustaining Lao traditional architecture and, in return, an increase of Lao architecture buildings helped to meet the demands of increasing tourism. Tourism was considered as an important source of income to improve locals' livelihood. The earnings were also invested in the restoration of traditional houses. More touristic facilities and accommodation were needed to cope with the tourism growth. Lao traditional architecture used as touristic buildings help to cater to the demand. Therefore, Lao traditional architecture and tourism formed a relationship that was mutually beneficial.

Although tangible heritage was preserved, intangible heritage deteriorated. The conversion in building usage caused original residents to migrate to outside the World Heritage Site, leaving fewer locals to preserve the culture of alms-giving to monks. However, respondents were divided on this issue. One cited from his ten years' experience that the change in building usage did not necessarily caused the locals to move out, since moving out required large sums of money to procure property and build a new house. Most Lao people have a big family and share land properties. When they started a family business, they moved in with their relatives in nearby villages but still remained within the vicinity of the World Heritage Site. There were also many cases where Lao people who operated guesthouses and commercial businesses continued to reside within the same building. They normally utilized the lower floor for business purposes and the upper floor as living quarters. It would be worth investigating the motivations of locals who maintained Lao traditional architecture despite converting from residential to touristic use.

d. Increase of commercial architecture was lower than Lao traditional architecture because of the limited area designated for commercial architecture

The PSMV stipulated that only two types of architecture were allowed, namely Lao traditional and commercial. However, most of the houses were built with Lao traditional architecture because commercial architecture was restricted to commercial roads. During the French colonial era, Chinese merchants and Vietnamese laborers' settlements flourished along the commercial roads. The PSMV designated commercial roads as the urban front areas for commercial use and confined them to commercial architecture to preserve the continuous facade and roofscape of Chinese-Vietnamese shop houses (MdP, 2001b).

3. Building materials

a. Modern materials have increased due to 12 multiple factors

Local residents who chose to convert to modern materials were influenced by a number of factors, of which nine were identified in the literature (Gao, 2008; Larsen & Marstein, 2000; Li, 2004; UNESCO, 2004). Respondents added three factors from their experience: 1) adaptability to air conditioner; 2) ability to filter noise; and 3) not being affected by government logging policies. Additional factors were derived from consideration of the needs of a modern lifestyle, vulnerability to termites and rodent bites, dampness caused by the rainy season, and policies[10] on reducing logging which could affect the use of timber. Government became stricter in controlling logging in a bid to curb illegal logging and deforestation. The decrease in the logging quota each year has made it more difficult to access timber.

[10] Four policies were implemented to control harvesting and the sales of forest products, namely: PM Logging Ban Decree Nº 67 (1991) and 169 (1993), PM Harvest Control System Order Nº 16 (1994), and the Forestry Law (1996). As a result, the annual harvest of logs reduced sharply from 734,000m^3 in 1999 to 150,000m^3 in 2004/2005 (Ministry of Agriculture and Forestry of Lao PDR, 2005).

b. Quality of materials was the most important factor that influenced locals in choosing building materials

The respondents viewed the quality of materials as the most important factor for locals. The quality of materials referred to the strong inherent characteristics of materials which combined the three factors durability, ability to withstand a wet climate and insects, and ability to filter noise. Most Lao people were willing to invest in building materials, provided the quality was good. For instance, the current quality of timber is degraded compared to the past. Good quality timber has become more costly and difficult to find. In addition, good quality timber has reduced for several reasons, such as: 1) increase in export at a regional level to China, Thailand, and Hong Kong; 2) the practice of slash-and-burn, 3) deforestation; and 4) difficulty in accessing sources of quality timber located in the deep forest of southern Lao PDR.

c. Increase of modern materials has had minimal impact on the landscape

The use of modern materials has had minimal impact on the overall landscape because building materials coated with finishing layers were not visible. The preservation regulation did not restrict the use of specific building materials in non-inventory buildings because other building features have a higher impact than coated building materials, such as the color of paint, type of architecture, building size, and roof design. PSMV Section 1 Article 11.3 allowed the use of concrete, stone, or steel as long as they were not apparent and coated. Article 11.4 further dictated that the colors of external coats should be chosen from the palette of traditional colors recommended in Fascicle n°4 (MdP, 2001b). More importantly, the respondents perceived that the maintenance of traditional materials in inventory buildings was sufficient to ensure the preservation of traditional materials. Inventory buildings were restricted to using building materials identical to original materials during restoration.

4. Roof materials

a. Traditional roof materials have increased due to five multiple factors

The use of traditional roof materials was influenced by four factors, as mentioned in the literature (Gao, 2008; Li, 2004; UNESCO, 2004), namely: 1) availability of materials; 2) affordability; 3) durability; and 4) flexibility of regulation. Respondents identified an additional factor, the importance of the roof in architecture. In total, five factors were identified. The roof was an important feature which accentuated Luang Prabang's traditional architecture. As such, the roof was highly valued in the building design. The signature style of Luang Prabang traditional architecture was a clay-tiled sharp roof of 35 – 60 degrees and its timber structure, which could not be found in Vientiane. They perceived that the increase of traditional roof materials was mainly atrributed to strict regulation. Roof materials in Zpp-Ua were restricted to small tiles of 30cm by 30cm. Only traditional roof materials were produced at the size permitted by the regulation. Corrugated zinc sheets were strictly forbidden. PSMV Title II Section 2 Article 11-3 Material Covers stipulated that the construction of new buildings and restoration of inventory buildings must use small-dimension traditional clay or cement tiles, and prohibited the use of large-dimension fiber cement plates or corrugated zinc sheets (MdP, 2001b).

b. Increase of traditional roof materials has had a positive impact on landscape

The increase of traditional roof materials has had a positive impact on the landscape since roof was the most visible part of the building. As mentioned earlier, the roof has a unique design that accentuated the building architecture. Hence, the roofs affected the visual impact of the overall landscape.

5. Building materials and roof materials

a. Locals were more willing to invest in traditional roof materials than traditional building materials

Both traditional roof materials and traditional building materials were considered costly. However, locals were more willing to pay for traditional roof materials, mainly due to strict regulation on roof materials. Moreover, poor quality timber was sold at a high price while traditional roof materials of acceptable quality were more easily available. The roof was also considered an important feature of Luang Prabang's traditional architecture. The roof structure was easier to construct and readily available labor could be found. The construction of the roof involved hanging the roof-tiles tier by tier, whereas the use of a timber structure, pillars, and beams has to be designed carefully according to the specific measurements mentioned in the regulation. This required skilled craftsmen. It was also important to note that roof materials were highly visible and easily examined during inspection by local government.

6. Building height

a. The increase in building height did not exceed 3 floors because of regulation, the design of Lao architecture, and an optimized use of space.

The change in building height was limited to 2 floors for three reasons: 1) strict regulation; 2) the design of Lao traditional architecture; and 3) an optimized use of space.

PSMV Section 1 Article 10 allowed a maximum height of up to 2 floors (MdP, 2001b). The PSMV was the main reason for building height being effectively controlled. The increase of 2-floor buildings was related to Lao traditional architecture. The Lao house was designed as a 2-floor house on stilts. In addition, the respondents felt that local residents were increasing to the maximum height allowed in order to optimize the use of space.

7. Additional finding

a. Building area size did not increase much because of regulation, lack of area for expansion, and reuse of land

The respondents thought that building area size did not increase much. The increase of building area size was restricted by regulation, lack of area for expansion or new construction, and reuse of land. Firstly, the land use in the core heritage area, Zpp-Ua, was restricted to a permitted percentage of land use stipulated by regulation. PSMV Section 2 Article 9 limited land use to up to 40% of the land plot for non-commercial road areas, and 75% of the land plot for commercial road areas (MdP, 2001b). There were also cases where big buildings were rebuilt as smaller buildings with a greater height. The owners were advised to resize buildings built prior to the awarding of World Heritage status in order to conform to the permitted percentage of land use. Secondly, the peninsula was historically the political and cultural core area of Luang Prabang. The entire area has been dominated by numerous temples, homes of royal families, and administrative colonial buildings. In other words, at the time of inscription, the six villages located on the core heritage site were already dense and there was little room for expansion or new construction. Thirdly, the local residences optimized land use by rebuilding houses on the same building footprint or increasing building height.

4.3.2 Local Residents

The discussion with local experts from the DPL outlined three important aspects that were worth investigating from the local residents' point of view, namely : 1) maintenance of Lao traditional architecture despite changing from residential to touristic use; 2) modern building materials replaced traditional building materials; and 3) traditional roof materials replaced modern roof materials. Spatial distribution of buildings that changed significantly in three aspects is illustrated in Figure 37. It was crucial to comprehend the reasons that such changes occurred. The analysis of responses was divided into locals dwelling in inventory and non-inventory buildings, as their buildings were subject to different regulations.

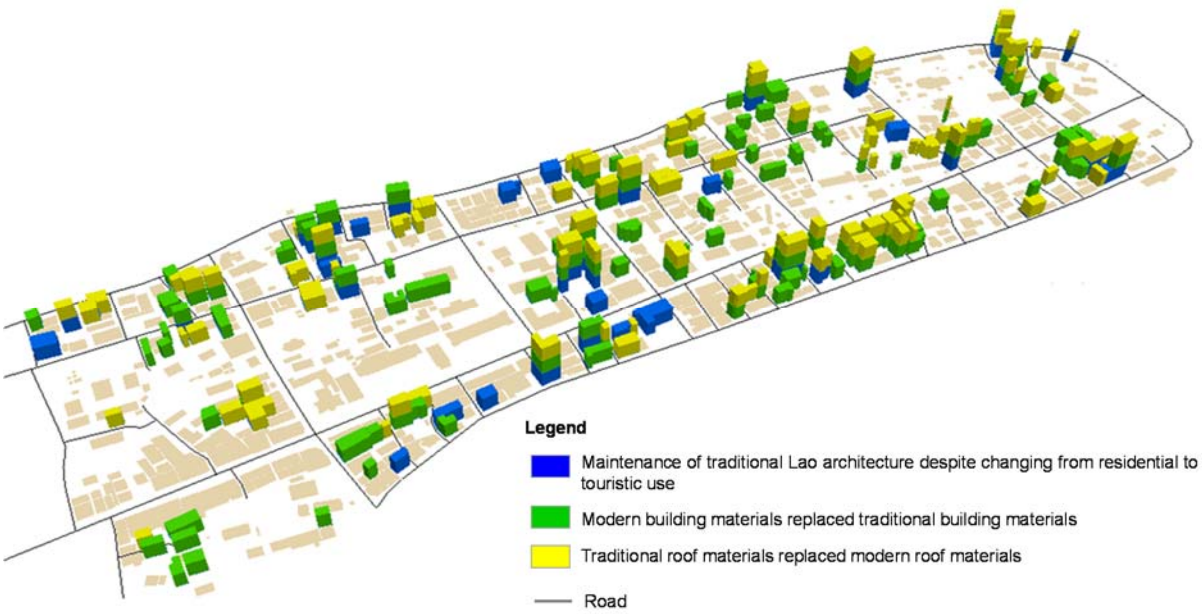

Figure 37. Distribution of buildings that changed significantly in three aspects

Source: Field survey in Luang Prabang, 2009

4.3.2.1 Lao traditional architecture maintained despite changing from residential to touristic use

A total of 40 local residents were interviewed using multiple choice questionnaires to identify their motivation in maintaining Lao traditional architecture despite changing building usage from residential to touristic. The list of plausible motivations used in the questionnaire was identified beforehand from workshop and interviews with local experts of the DPL.

The ratings provided for non-inventory buildings (N=21 respondents, 43 responses) and inventory buildings (N=19 respondents, 32 responses) are shown in Figure 38. For non-inventory buildings, the two major reasons were abiding by regulation (11, 52.4%) and preserving heritage values (11, 52.4%). Local experts pointed out that three reasons were inter-related, namely: following regulation, preserving heritage values, and having structures considered attractive for business. Locals need to abide by the PSMV to obtain a certificate of completion of construction. It was compulsory to have this certificate in order to apply for a tourist business license from the Department of Tourism. Through the application procedures and interaction with the DPL and Department of Tourism, local residents recognized the importance of heritage values. Furthermore, the residents perceived Lao traditional architecture as good for business since it was considered attractive to the foreign tourists who want to experience Lao culture and heritage. Respecting regulations was the prerequisite to get a tourist business license. As for residents living in inventory buildings, as shown in Figure 39, the main reason was that they have to adhere to regulations (52.6%). Other motivations were given lesser responses.

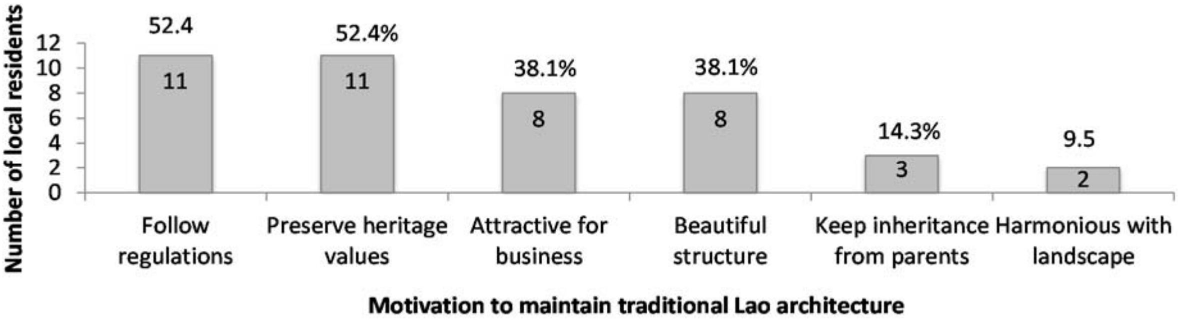

Figure 38. Motivation for local residents in non-inventory buildings to maintain Lao traditional architecture despite changing from residential to touristic use (N=21, response=43)

Source: Department of World Heritage, 2011

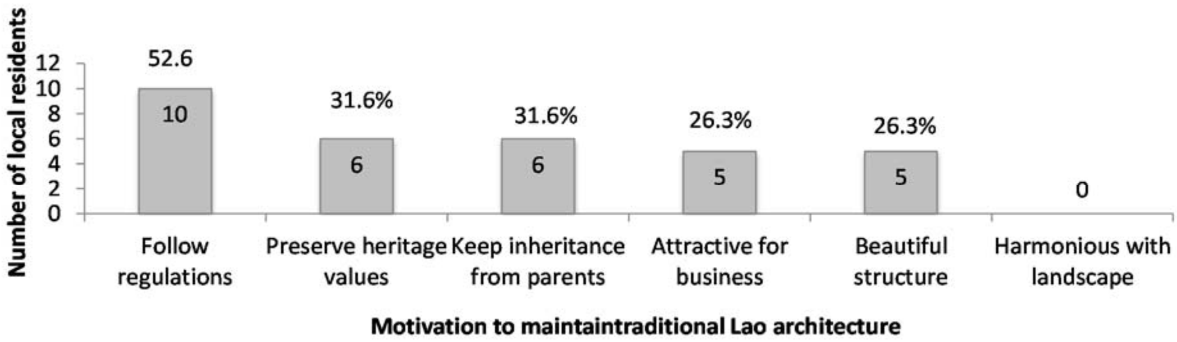

Figure 39. Motivation for local residents in inventory buildings to maintain traditional architecture despite changing from residential to touristic use (N=19, response=32)

Source: Department of World Heritage, 2011

4.3.2.2 Modern building materials replaced traditional building materials

Local residents who converted from traditional to modern materials could be driven by diverse reasons. Twelve factors were identified, based on the inherent characteristics of the materials and external factors that affect their use (Table 26). Nine factors (nos.1-9) were retrieved from the literature (Gao, 2008; Larsen & Marstein, 2000; Li, 2004; UNESCO, 2004) and three additional factors (nos. 10 to 12) were identified by local experts of the DPL. A total of 112 residents who changed to modern materials participated in the survey. The residents were given questionnaires with a four-point[11] Likert scale to rate three aspects respectively: 1) level of importance of the factors; 2) traditional and modern materials' inherent characteristics; and 3) effect of external factors on the use of traditional and modern materials. During the interview, local residents explained their experience in using their materials. The noteworthy explanations gathered were included where appropriate.

Table 26. List of factors that could influence locals in their selection of building materials

No.	Factor	Type	Description
1	Durability of materials	Inherent characteristic	Lifespan of materials in years
2	Cooling effect	Inherent characteristic	Ability to ventilate air within building
3	Affordability	External factor	Ability to purchase materials
4	Availability of materials	External factor	Access to materials
5	Construction technique	External factor	Construction technique in terms time consumed and level of technical difficulty
6	Flexibility of regulation	External factor	Flexibility of the PSMV regulation on types of building materials that can be used
7	Availability of labor	External factor	Presence of skilled craftsmanship
8	Symbol of modernity, status and wealth	External factor	Significance of building materials in representing building owner status and modern lifestyle
9	Ability to withstand wet climate and insects	Inherent characteristic	Ability to withstand rain, flood, and insects bites, e.g., termites and rats
10	Adaptability to air conditioner	Inherent characteristic	Ability to contain the cool air from an air conditioner
11	Ability to filter noise	Inherent characteristic	Ability to filter noise pollution, e.g., human activities and traffic congestion.
12	Not affected by government logging policies	External factor	Not affected by government policies that control annual logging quota for export and domestic use.

Source: Leong et al., 2016, p. 15

[11] Four-point scale: "very important", "important", "less important", and "not important"

In order to obtain the percentage of locals who regarded factors that are important in influencing their use of materials, the positive responses are grouped[12]. The percentage of responses are defined into three categories, as listed in Table 27. In the case where less than 50% of local residents rated the factor as important, the factor is considered as not influential. However, when between 50 to 75% of the residents rated the factor as important, the factor is considered influential. When the percentage of local residents with positive responses exceeded 75%, the factor is regarded as highly influential. A similar categorization applies to ratings for traditional and modern materials' inherent characteristics[13] and external factors[14].

Table 27. Percentage of positive responses defined into three categories

Percentage of positive responses	Important in influencing the use of materials	Inherent characteristic	External factor
Less than 50%	Not influential	Weak	Not good
Between 50% and 75%	Influential	Strong	Good
More than 75%	Very influential	Very strong	Very good

Source: Leong et al., 2016, p.16

The responses of local residents were analyzed according to inventory and non-inventory buildings. In the case of non-inventory buildings, local residents rated five factors as highly influential (more than 75%), as follows: 1) flexibility of regulation; 2) ability to withstand wet climate and insects; 3) durability of materials; 4) availability of materials; and 5) availability of labor. The results are displayed in Figure 40. This explains that the residents gave a great deal of consideration to the type of materials they were allowed to use,

[12] Positive responses such as "very important" and "important" were grouped.
[13] "very strong" and "strong" were grouped
[14] "very good" and "good" were grouped

resistance to the natural processes of decay, the lifespan of materials, accessibility, and the presence of labor. Six other factors are viewed as influential (more than 50%). However, being a symbol of modernity, status, and wealth is not influential (less than 50%), indicating that the aesthetic of building materials is not significant.

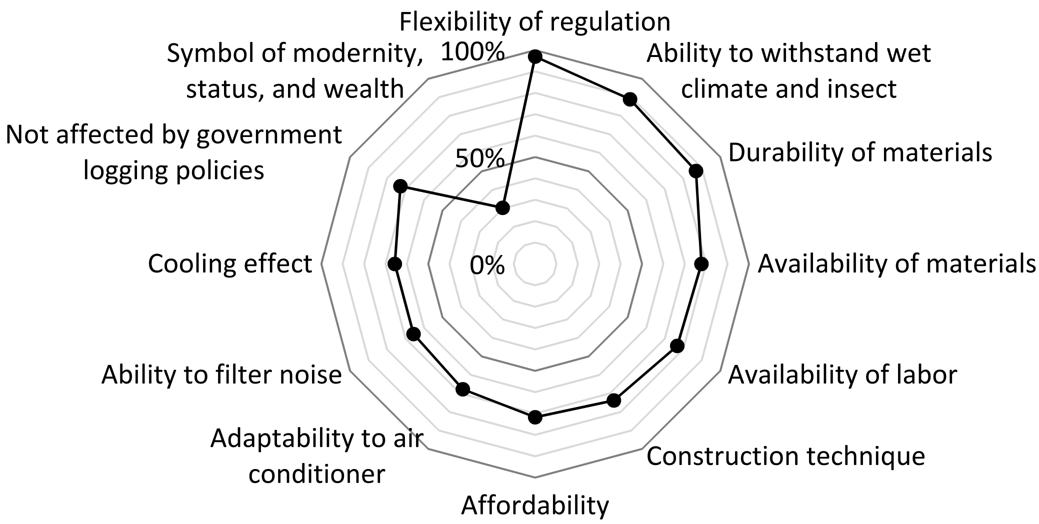

Figure 40. Percentage of local residents in non-inventory buildings who rated important factors that are important in influencing the use of materials (N=99)

Source: Department of World Heritage, 2011

Modern materials have stronger inherent characteristics and better ratings in external factors than traditional materials. Modern materials were rated distinctively higher in 8 factors (more than 75%) and 1 factor (more than 50%), as shown in Figure 41. Only 2 factors were rated less than 50%, whereas traditional materials have a good cooling effect and durability, but rated very low in many other factors. There is a lack of distinction in ratings for flexibility of regulation because regulation did not restrict the use of building materials in non-inventory buildings. This allowed local residents to exercise their choice based on their priorities and interests.

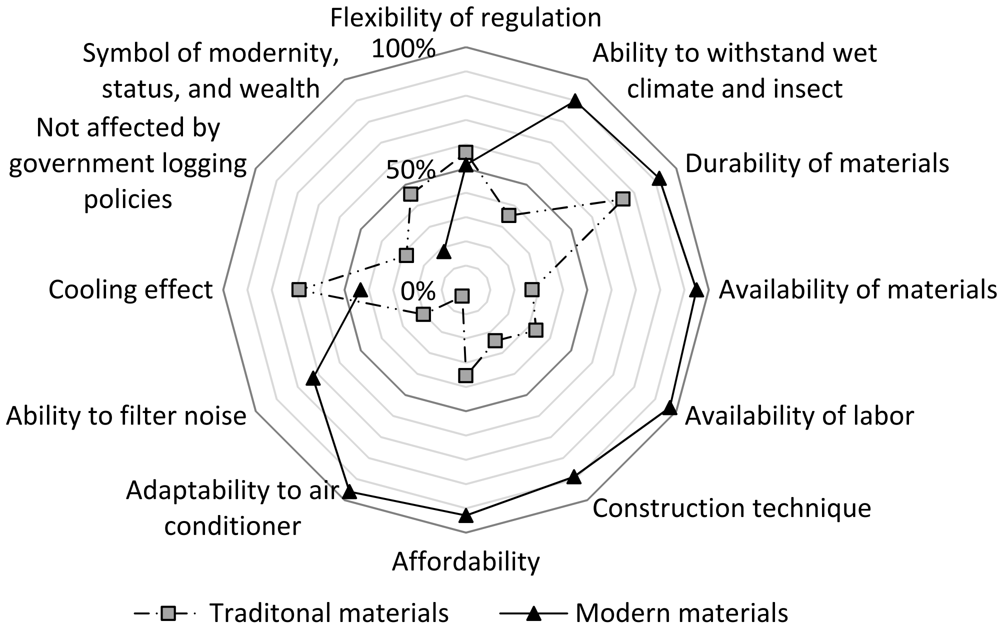

Figure 41. Percentage of local residents in non-inventory buildings who rated materials that have strong inherent characteristics and fare well in the external factors (N=99)

Source: Department of World Heritage, 2011

Hence, modern materials are able to meet the five important requirements that highly influence their choice of materials, namely: 1) flexibility of regulation; 2) ability to withstand wet climate and insects; 3) durability of materials; 4) availability of materials; and 5) availability of labor. Modern materials are also rated higher in other four influential factors which are supporting the change, namely: 1) construction technique; 2) affordability; 3) adaptability to air conditioner; and 4) ability to filter noise. Therefore, locals changed to modern materials as they were more practical, have desirable qualities, and are not restricted by regulation.

For the case of inventory buildings (N=13), residents rated similarly the importance of factors and ratings of different materials, as illustrated in Figures 42 and 43. They recognized that the regulation was strict and that they do not have a choice in deciding the use of building materials. Further investigation and discussion with the DPL revealed that the thirteen inventory buildings were special cases, and reasons for changing materials were not due to inherent characteristics or external factors. They had to change to modern materials for four unavoidable reasons: 1) to safeguard the ground floor against flooding by replacing bamboo weaved walls with cement (7 cases); 2) evolving the use of building space by adding masonry walls to the ground floor (2 cases); 3) limewash brick in mortar was no longer available or manufactured (2 cases); and 4) to prioritize the safeguarding of Buddha statues and monks' dwellings (2 cases). In short, the realities have overwhelmed the existing regulation. Therefore, the DPL had to cater to local needs and allowed the use of modern materials in order to sustain these inventory buildings.

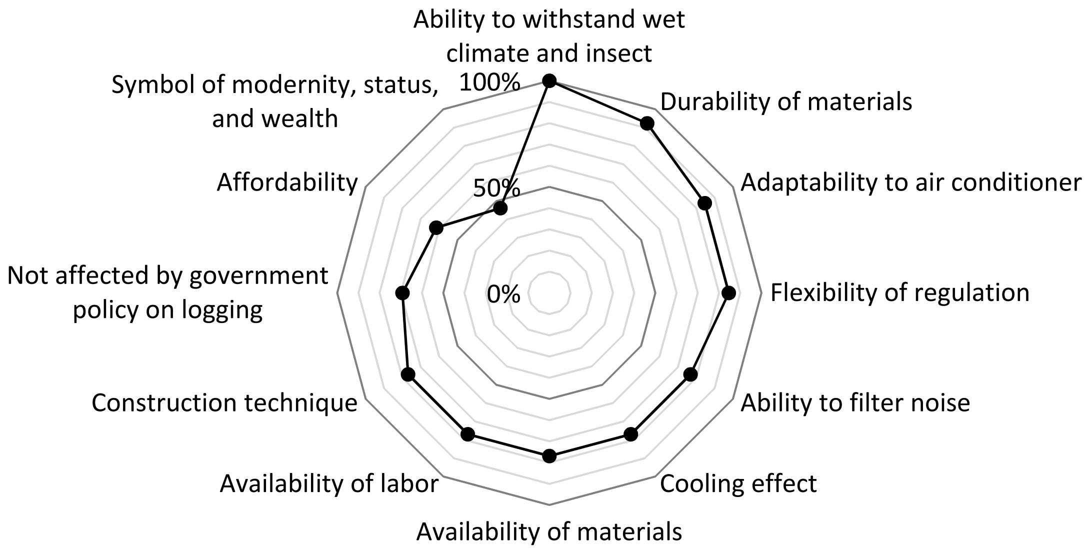

Figure 42. Percentage of local residents in inventory buildings who rated factors that were important in influencing the use of materials (N=13)

Source: Department of World Heritage, 2011

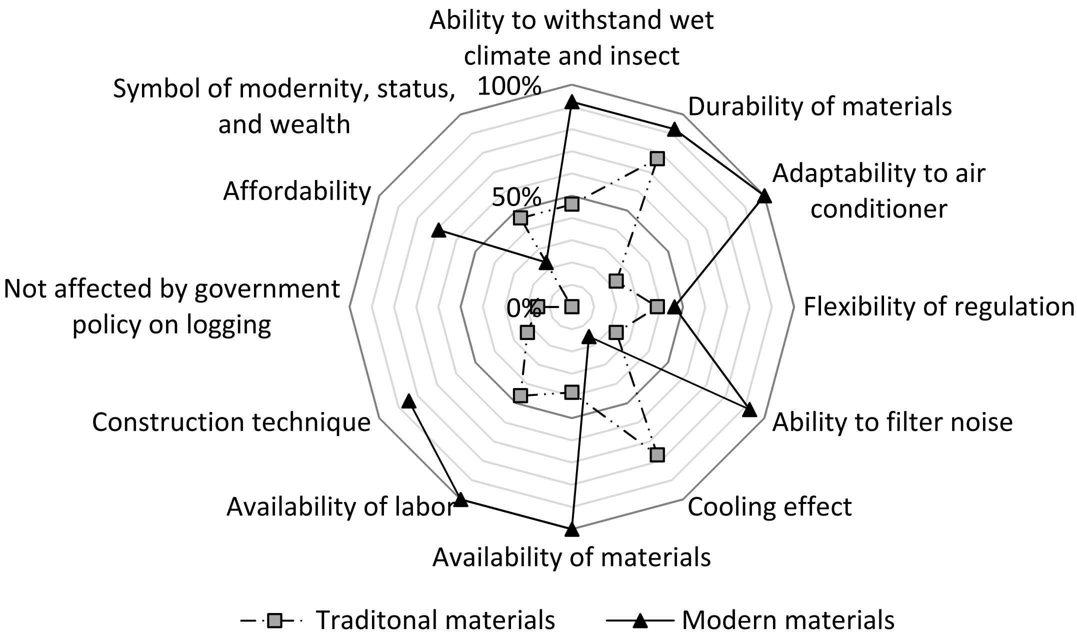

Figure 43. Percentage of local residents in inventory buildings who rated materials that have strong inherent characteristics and fare well in the external factors (N=13)

Source: Department of World Heritage, 2011

Additional findings were gained during the interviews. Local residents elaborated on their experience of using modern materials and traditional materials, which helped to understand the ratings provided. The findings are as follows:

1. Modern materials were advantageous because they were
    a. more soundproof against noise pollution coming from an increased level of human activities and traffic congestion in the core of the heritage area;
    b. better at containing cool air from air conditioner;
    c. better at withstanding floods during the rainy season, and not affected by termites and rats. There have been more floods in recent years, with the worst flooding incident in 2008, when the water level rose to the highest in history;

    d. easier to prepare and maintain by themselves, without hiring labor.

2. Traditional materials were considered disadvantageous because
    a. they were more expensive;
    b. the source of the materials was too far away (in the case of timber), or inaccessible (in the case of limewash brick in mortar and plaster, which are no longer manufactured);
        - Preparation of limewash was too time-consuming and laborious because it required raw materials such as lime juice, straw, palm sugar, and extracted fat from boiled buffalo skin. The use of limewash depended on the local residents' willingness to prepare the mixture.
    c. dwindling number of skilled craftsmen;
        - There was a case where a local resident inherited the skills from his father. However, the work was difficult because certain tools and a large work space were needed to cut the long timber into house pillars and beams.
3. There was little difference between traditional and modern materials in terms of durability. Good quality traditional materials such as rosewood have comparable durability to cement but were too costly.
4. A reverse trend in symbol of modernity, status, and wealth. The local residents no longer perceive cement houses as modern and prestigious. Modern houses were becoming common. Instead, timber has become rare and expensive. The ability to purchase timber and build a wooden house was perceived as a symbol of wealth and status.

There were a few cases where residents have overcome the disadvantages of traditional materials.

e. An architecture from Vientiane, who was the owner of the Ancient Hotel in the village of Phone Hueang, shared that he used a thin layer of wood to cover the cement walls as an alternative solution to compensate the lack of timber. He used this approach to retain the aesthetic appearance of Lao traditional architecture with a minimal use of timber. Although it was beautifully designed and constructed, he faced difficulties in installing wiring because of the small gap between the outer layer of timber and cement bricks.
f. An Australian entrepreneur, who started the Lotus Village Hotel in the village of Vatnong, remarked that the timber in his hotel lasted for a long time and has not been replaced since it was built. This was due to the yearly application of varnish to protect against strong UV rays, and insecticide spray to repel termites.

4.3.2.3 Traditional roof materials replaced modern materials

The increase of traditional roof materials could be driven by five factors (Table 28). Factor no. 1 derived from workshop with the DPL, and factors no. 2 through 5 can be summarized from the literature. A total of 92 residents changed to traditional roof materials. However, 91 residents were interviewed and one resident did not participate. A similar method to that employed for the interview about building materials was administered for roof materials.

Table 28. List of factors that could influence locals in their selection of roof materials

No.	Factor	Type	Definition
1	Importance of roof in architecture	External factor	Roof highly valued in building architecture to accentuate the sharp-angled traditional roof design
2	Flexibility of regulation	External factor	Flexibility of the PSMV regulation on types of roof materials that can be used
3	Affordability	External factor	Ability to purchase roof materials
4	Availability of materials	External factor	Access to roof materials
5	Durability	Inherent characteristic	Lifespan of materials in years

Source: Compiled from the literature (Gao, 2008; Li, 2004; UNESCO, 2004) and interview with the DPL, 2011

Local residents in non-inventory buildings felt that the importance of the roof in architecture and the flexibility of regulation highly influenced their selection of roof materials, as shown in Figure 44. This illustrates that the aesthetic of roof design and type of roof materials permitted are significant. In addition, they also viewed three other factors as influential, namely, the durability, affordability, and availability of roof materials.

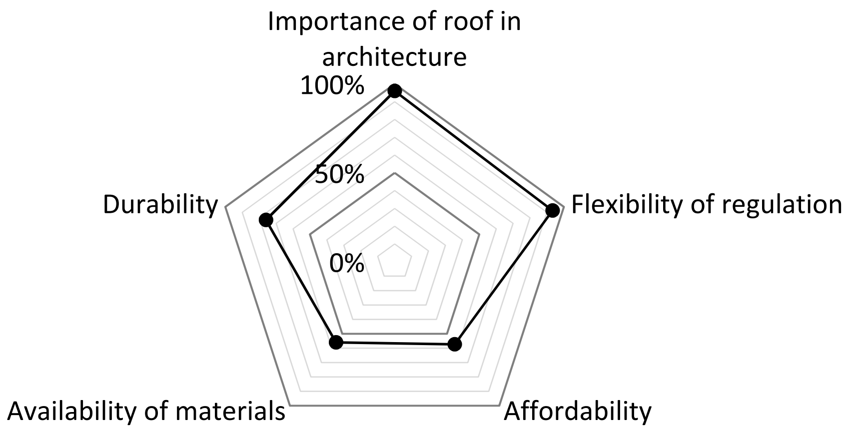

Figure 44. Percentage of local residents in non-inventory buildings who rated factors that were important in influencing the use of roof materials (N=75)

Source: Department of World Heritage, 2011

In rating inherent characteristics and external factors, traditional roof materials clearly stand out from modern roof materials in terms of importance of the roof in the architecture factor, as depicted in Figure 45. It was explained that the roof with a sharp angle of 35 – 60 degrees has a dramatic effect on the overall architecture. Traditional roof materials were the only ones produced in smaller dimensions and easily laid out to construct the sharp-angled roof. Meanwhile, modern roof materials produced in larger dimensions were not flattering for the roof design. Traditional roof materials have good durability and are easily available, but have low affordability. Modern roof materials, on the other hand, are rated for their good durability, very good availability, and very good affordability. The ratings are not distinctly different for the flexibility of regulation factor because strict regulation dictated the use of traditional roof materials and locals have no choice in deciding which roof materials to use. In short, traditional roof materials can meet the requirement of two highly influential factors and two influential factors. This overweighs the affordability factor. Therefore, residents changed from modern to traditional roof materials in non-inventory buildings because of the importance of accentuating a sharp-angled roof design, strict regulation, good durability, and good accessibility to materials.

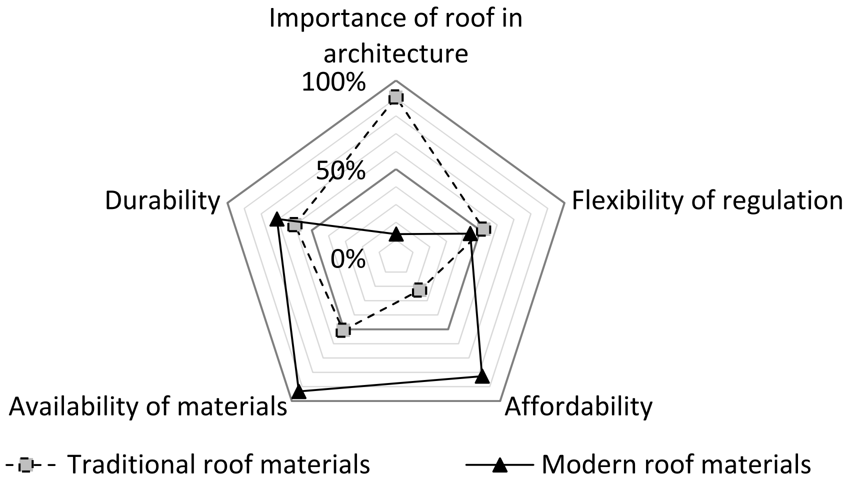

Figure 45. Percentage of local residents in non-inventory buildings who rated roof materials that have good inherent characteristics and fare well in the external factors (N=75)

Source: Department of World Heritage, 2011

As for inventory buildings (N=16), locals provided ratings on the importance of factor ratings on different materials similar to non-inventory buildings, as displayed in Figures 46 and 47. All factors were influential and traditional materials clearly stood out from non-traditional materials in one external factor as well, the importance of the roof in architecture. They viewed preservation regulation as being inflexible on the use of non-traditional roof materials. Therefore, the inventory buildings also changed to traditional roof materials because of the importance of the roof and strict regulation.

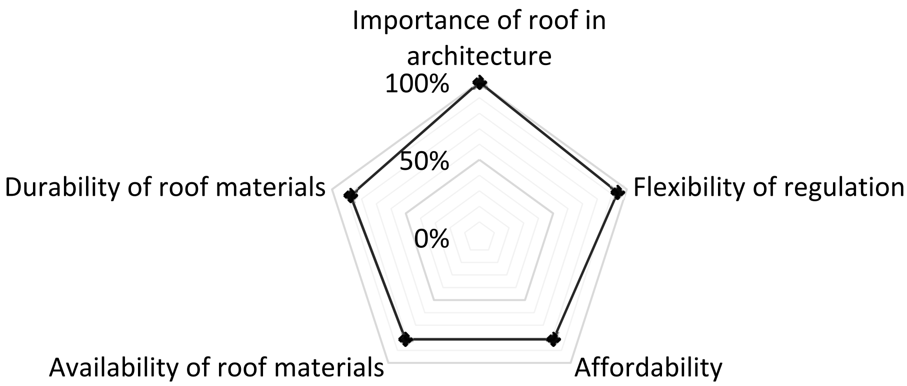

Figure 46. Percentage of local residents in inventory buildings who rated factors that were important in influencing the use of roof materials (N=16)

Source: Department of World Heritage, 2011

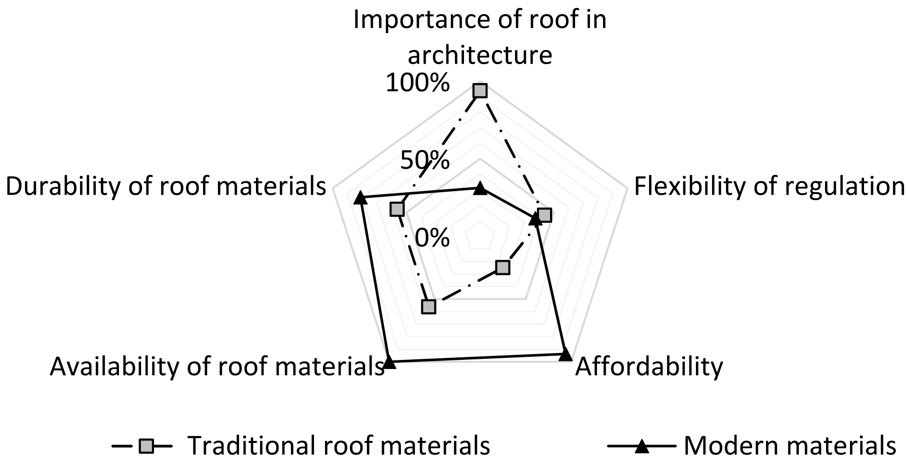

Figure 47. Percentage of local residents in inventory buildings who rated roof materials that have good inherent characteristics and fare well in the external factors (N=16)

Source: Department of World Heritage, 2011

Additional findings obtained during interviews revealed local residents' experience in using traditional roof materials and modern roof materials. Traditional roof materials were considered:

1. less durable because the materials were vulnerable to impact and broke easily when dropped;
2. accessible because the local manufacturers were located in Luang Prabang[15];
3. costly.[16]

4.4 Relation between Touristic Use and Significant Changes

The 9th hypothesis outlined that the increase of touristic use is related with the significant changes in built environment. Specific hypotheses were developed to be tested based on the results of analysis of seven indicators in Section 4.2. Three indicators have changed significantly namely, building architecture, building materials, and roof materials. Hence, the increase of touristic use is investigated in relation to the increase of Lao traditional architecture, modern building materials, and traditional roof materials. The specific hypotheses derived are as follows:

H9: Increase of touristic use and the significant changes in built environment are related.

H9a: Increase of touristic use and increase of Lao traditional architecture are related.

H9b: Increase of touristic use and increase of modern building materials are related.

H9c: Increase of touristic use and increase of traditional roof materials are related.

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[15] Only Luang Prabang still manufactured traditional roof materials since there was a demand for them.

[16] On average, traditional roof materials were cheaper than modern roof materials. Since traditional tiles were small, more tiles were required for a meter square e.g., 145 to 160 pieces of clay tiles versus 11 pieces of fiber cement. Information on roof materials pricing and manufacturers obtained from discussion with Construction and Restoration Unit, DPL as of February, 2011.

Chi-square test of independence is used to test the association between increase of touristic use and changes in three indicators. The analysis was divided into existing buildings and new buildings respectively.

4.4.1 Existing Buildings

The variables used for existing buildings are described in Table 29. The unknown buildings were excluded in the analysis. In the case of building roof materials, roofless structures and non-habitable structures were excluded as well. The results of the Chi-square on the association between change to touristic use and change in other variables are displayed in Table 30. The test assumed two hypotheses: 1) a null hypothesis, where two variables, for example USE and ARCH variables, were independent; and 2) an alternative hypothesis where two variables were dependent. Similar hypotheses applied for other variables.

All three variables have Chi-square observed values which fall into the critical region, 3.841 with a p-value lower than the significance level of alpha, 0.05. The degree of freedom is 1 with a critical region of 3.841 because the contingency table of the variables analyzed is 2 x 2. The results of all three variables are statistically significant and this rejected the null hypothesis that the USE variable and other three variables are independent. It was revealed that the USE variable and other variables are dependent for existing buildings. This implies that change to touristic use is related to the significant changes in architecture, building materials, and roof materials. The change to touristic use is associated with the change to Lao traditional architecture, change to modern building materials, and change to traditional roof materials.

Table 29. Variables used in the Chi-square test of independence for existing buildings

Variables	Description
USE	Changed from other usages to touristic use
ARCH	Changed from other types of architecture to Lao traditional architecture
MAT	Changed from traditional to modern materials
ROOF	Changed from modern to traditional roof materials

Source: Analysis based on original data from Department of World Heritage, 2009

Table 30. Values of Chi-square test of independence of existing buildings (N=657)

	ARCH	MAT	ROOF
Chi-square (Observed value)	13.655	12.864	69.566
Chi-square (Critical value)	3.841	3.841	3.841
Degree of freedom	1	1	1
p-value	0.000 ***	0.0003 ***	< 0.0001 ***

*Note: ***Statistically significant at 0.001 confidence level*
Source: Analysis based on original data from Department of World Heritage, 2009

4.4.2 New Buildings

The variables used for analysis of new buildings are summarized in Table 31. A similar null hypothesis and alternative hypothesis as those adopted for existing buildings were used. The results of the Chi-square test of independence are displayed in Table 32. ROOF variable is statistically significant since observed values that fall into the critical region with a p-value less than 0.05. ARCH and MAT variables' observed values are not significant. This rejected the null hypothesis that the USE variable and ROOF variable are independent. However, the null hypothesis is accepted for ARCH and MAT variables. This suggests that new buildings used for touristic purposes were related with the use of traditional roof materials.

Table 31. Variables used in Chi-square test of independence for new buildings

Variable	Description
ARCH	Used Lao traditional architecture
ROOF	Used traditional roof materials
MAT	Used modern building materials

Source: Analysis based on original data from Department of World Heritage, 2009

Table 32. Values of Chi-square test of independence of new buildings (N=88)

	ARCH	MAT	ROOF
Chi-square (Observed value)	3.302	0.108	7.645
Chi-square (Critical value)	3.841	3.841	3.841
Degree of freedom	1	1	1
p-value	0.069	0.742	0.006 **

*Note: ***Statistically significant at 0.001 confidence level, ** at 0.01*

Source: Analysis based on original data from Department of World Heritage, 2009

4.5 Relation between the PSMV and Significant Changes

A total of 745 buildings were surveyed. Buildings analyzed were divided into existing buildings (N=594) and new buildings (N=82). Existing buildings analyzed excluded demolished buildings (44) and buildings with unknown attributes (63).

4.5.1 Existing Buildings

The original categorical data table has 7 columns (known as variables) and 594 rows (known as objects). A table coded into 0 (absence of significant change) and 1 (presence of significant change) is known as an indicator matrix, which is a binary representation of different categorical values of each variable. The indicator matrix is converted into a Burt matrix, a symmetric square contingency table that cross-tabulates in the form of frequencies for all pairs of variable categories. MCA decomposes the Burt matrix to find the pairwise associations which account for the greatest proportion of inertia and displays them on a reduced number of dimensions.

Greenacre (2007) recommended that the number of dimensions to retain should correspond with eigenvalues > 1/Q where Q is the number of variables. Eigenvalues are the variance extracted by each dimension. In this study, the number of variables is 7. As shown in Table 33, the first two dimensions have eigenvalues of more than 1/7 or 0.14. Inertia is the percentage of eigenvalues or variance explained by principal component. As mentioned in Chapter 3 Section 3.9, the usual MCA computation of inertia underestimates the quality of fit and needs to be adjusted (Greenacre, 2007). Adjusted inertia was used in this analysis. The first dimension's adjusted inertia accounts for 89.242%. This shows a very strong single dimension to explain the variability present in the data set and is considered sufficient for interpretation. On the other hand, dimension 2 only accounts for 0.157% of adjusted inertia, which was negligible. Therefore, only one dimension is retained for interpretation. Low dimension reduction is only possible if there is dependency between variables. If they are independent of each other, dimensions cannot be reduced. Hence, there is dependency between the 7 variables.

Table 33. Greenacre-adjusted inertia and decomposition of variables for existing buildings

Dimension	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	0.310	0.150	0.137	0.137	0.108	0.084	0.082
Inertia (%)	31.012	14.987	13.688	12.844	10.809	8.424	8.235
Cumulative %	31.012	45.999	59.687	72.531	83.341	91.765	100.00
Adjusted Inertia	0.038	0.000					
Adjusted Inertia (%)	89.242	0.157					
Cumulative %	89.242	89.399					

Source: Analysis based on original data from Department of World Heritage, 2009

The principle coordinates of variables in the first dimension are summarized in Table 34 and plotted in Figure 48. In MCA, the closer the variable's location to the origin, the more similar the variable's profile to the average profile. In the plot, the response variables for the presence of a significant change (suffix 1) are on the positive side of dimension 1, and those for the absence of a significant change (suffix 0) are on the negative side. The separation of 1's and 0's on different sides of dimension 1 shows the important difference between having, and not having a significant change in building attributes. The presence of significant change is more dispersed, indicating larger variance and distinct difference from others. Meanwhile, absences of significant change are closely located with each other, showing smaller variance. In addition, the points are also closer to the average profile, 0, which means there are few differences between those buildings that did not change significantly.

Considering the relative distance of the points from the origin, increased height, changes to traditional roof materials, traditional architecture, and modern buildings materials appear to be located furthest, and contribute to explaining the deviation from independence in the sample. This is also reflected by the higher value of contribution in Table 34.

HCA was subsequently applied as a complementary method to MCA in order to confirm the groups obtained with MCA. The principal coordinates of retained dimension 1 are used as quantitative values for HCA. The clustering was performed using Ward's merging criterion and squared Euclidean distance. HCA analysis identified three groups of clusters, as depicted in Figure 49; the grouping of variables is summarized in Table 35.

Table 34. Principal coordinates and contribution of variables on the first dimension

Significant trend	Variable	Principal coordinates	Contribution
Changed to touristic use	touristic-0	-0.255	0.024
	touristic-1	0.937	0.087
Changed to traditional architecture	trad_architecture-0	-0.205	0.017
	trad_architeture-1	1.378	0.113
Changed to modern building materials	modern_materials-0	-0.306	0.035
	modern_materials-1	1.362	0.157
Changed to traditional roof materials	trad_roof-0	-0.292	0.034
	trad_roof-1	1.847	0.214
Increased height	increase_height-0	-0.170	0.012
	increase_height-1	1.974	0.142
Improved building condition	improve_cond-0	-0.303	0.031
	improve_cond-1	0.793	0.080
Increased building area size	increase_land-0	-0.359	0.028
	increase_land-1	0.331	0.026

Note: Suffix 1 corresponds to the presence of significant trend of change in the indicator, suffix 0 represents the absence of significant trend of change.
Source: Analysis based on original data from Department of World Heritage, 2009

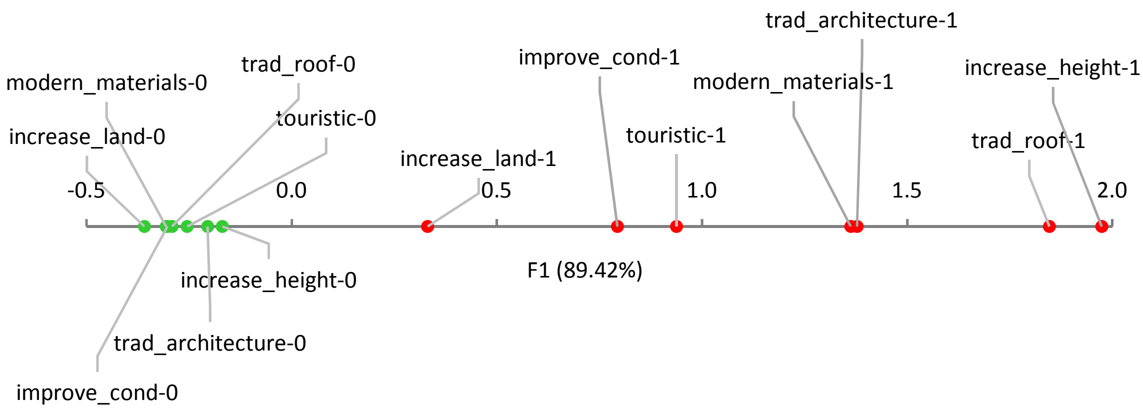

Figure 48. Factorial map of existing buildings

Note: Point in red with suffix 1 corresponds to the presence of significant change. Point in green with suffix 0 represents the absence of significant change.
Source: Analysis based on original data from Department of World Heritage, 2009

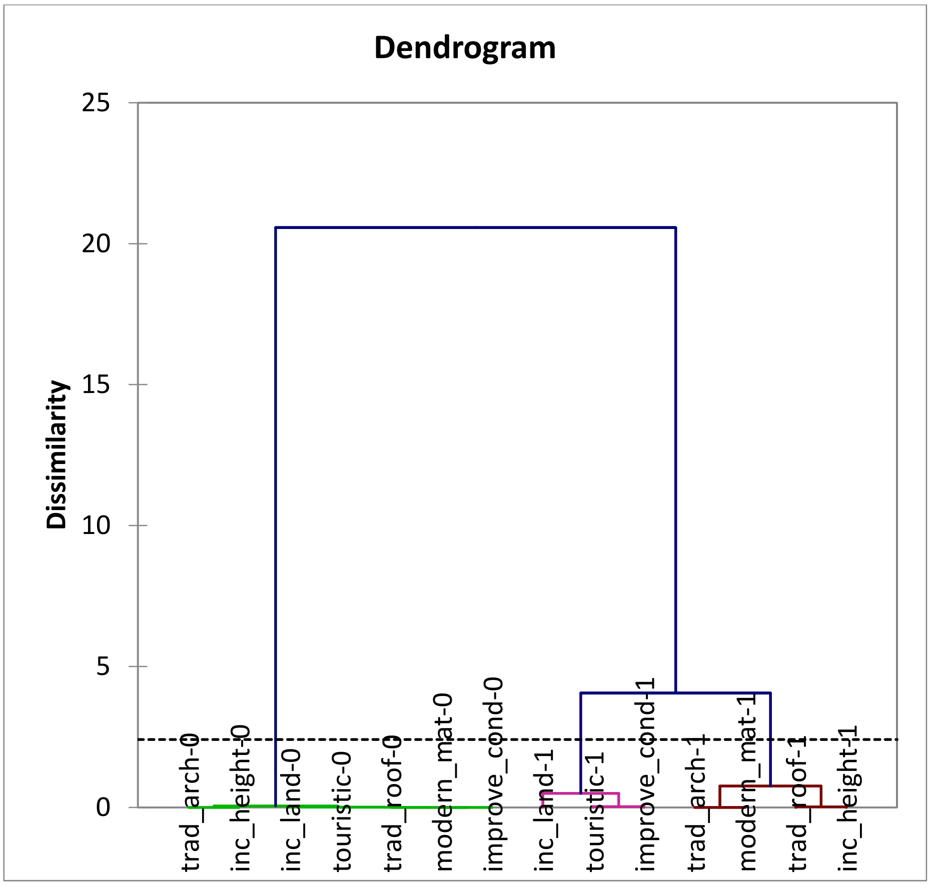

Figure 49. Dendrogram of existing buildings

Source: Analysis based on original data from Department of World Heritage, 2009

Table 35. Three groups of building characteristics identified in existing buildings

Group	Variable	Building characteristics
Group 1	trad_architecture-1	Changed to traditional architecture
	modern_materials-1	Changed to modern building materials
	trad_roof-1	Changed to traditional roof materials
	increase_height-1	Increased building height
Group 2	touristic-1	Changed to touristic use
	improve_cond-1	Increased building area size
	increase_land-1	Improved building condition
Group 3	touristic-0	Did not change to touristic use
	trad_architecture-0	Did not change to Lao traditional architecture
	modern_materials-0	Did not change to modern materials
	trad_roof-0	Did not change to traditional roof materials
	increase_height-0	Did not increase height
	improve_cond-0	Did not improve condition
	increase_land-0	Did not increase building area size

Source: Analysis based on original data from Department of World Heritage, 2009

These three groups of buildings were cross-examined with GIS to identify specific characteristics. This revealed that the three groups of buildings have distinct characteristics, as follows:

a. Group 1

This group is comprised of buildings that changed significantly in four main attributes, namely, architecture, building materials, roof materials, and height. The buildings have changed from modern to Lao traditional architecture, traditional to modern building materials, and modern to traditional roof materials, and increased in height from 1 to 2 floors. The change in architecture involved demolition and reconstruction of the entire building. As such, the entire building completely changed. The four attributes of reconstructed buildings were chosen according to regulation and building design. For example, the old dilapidated houses were formerly modern architecture with the height of 1 floor, as shown in Figure 50. They were built using traditional materials, e.g., timber, and covered with modern roof materials, e.g., corrugated zinc sheets. These buildings were replaced and rebuilt as Lao traditional architecture, 2 floors high, using modern materials, e.g., a mix of timber and cement, as shown in Figure 51. Traditional roof materials, e.g., clay tiles, were utilized as well.

b. Group 2

The buildings changed in three aspects, namely, building usage, building area size, and building condition. The buildings have changed to touristic use, improved their condition, and increased their building size. The change to touristic usage is accompanied by an increase of land occupancy and restoration of the buildings.

c. Group 3

The buildings in this group are non-touristic buildings that did not change much or did not change at all. It was revealed the majority are inventory buildings, and religious buildings that maintained same attributes. The remaining buildings have other usages e.g. residential and did not change much in the ten years.

Figure 50. Example of physical appearance of houses that have been demolished

Source: Picture taken during field survey in Luang Prabang, 2011

Figure 51. Example of physical appearance of houses rebuilt as Lao architecture

Source: Picture taken during field survey in Luang Prabang, 2011

4.5.2 New Buildings

Six variables are used for MCA, excluding building area size indicator. As with existing buildings, the absence and presence of significant attributes are dichotomized into 0 and 1. The criterion to retain the number of dimensions is an eigenvalue more than 1/6 or 0.17. Two dimensions have eigenvalues bigger than 0.17, as shown in Table 36. The first dimension's adjusted inertia represents 88.304%, a high percentage, to explain the variability in the dataset. The second dimension only accounts for 0.187%, which is a small fraction of the variation. Hence, the first dimension is sufficient for interpretation. The principal coordinates and contribution of each variable in the first dimension are summarized in Table 37.

The principal coordinates for each variable are mapped to show the association of variables in Figure 52. Mapping of the variables depicts that new buildings with significant attributes are positioned on the negative side of the dimension, as opposed to new buildings with non-significant attributes on the positive side. There is no important interaction between new buildings with significant attributes and not significant attributes. This indicates there is no relation between them, which is similar to existing buildings.

Table 36. Greenacre-adjusted inertia and decomposition of variables for new buildings

	F1	F2	F3	F4	F5	F6
Eigenvalue	0.426	0.179	0.150	0.118	0.067	0.059
Inertia (%)	42.636	17.862	15.042	11.824	6.735	5.900
Cumulative %	42.636	60.499	75.541	87.365	94.100	100.000
Adjusted Inertia	0.097	0.000				
Adjusted Inertia (%)	88.304	0.187				
Cumulative %	88.304	88.491				

Source: Analysis based on original data from Department of World Heritage, 2009

Table 37. Principal coordinates and contribution on first dimension

Significant attribute	Variable	Principal coordinates	Contribution
Non-touristic usage	touristic-0	0.597	0.064
Touristic usage	touristic-1	-0.504	0.054
Use of traditional materials	modern_mat-0	0.818	0.076
Use of modern materials	modern_mat-1	-0.333	0.031
Height 1 floor	height_2flrs-0	0.600	0.083
Height 2 floors	height_2flrs-1	-0.865	0.120
Use of modern architecture	trad_architecture-0	0.429	0.043
Use of traditional architecture	trad_architecture-1	-0.649	0.066
Not good condition	good_cond-0	1.271	0.175
Good condition	good_cond-1	-0.487	0.067
Use of modern roof materials	trad_roof-0	0.883	0.128
Use of traditional roof materials	trad_roof-1	-0.644	0.094

Note: Suffix 0 represents the absence of significant attributes and 1 stands for the presence of significant attributes.
Source: Analysis based on original data from Department of World Heritage, 2009

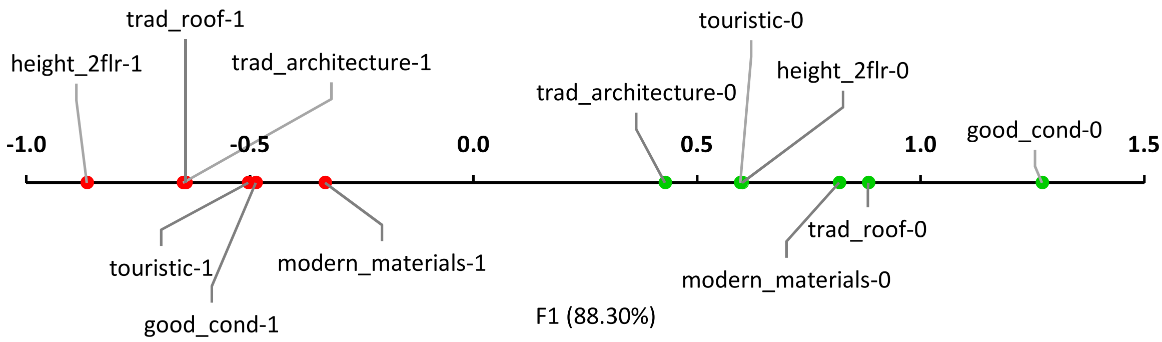

Figure 52. Factorial map of new buildings

Note: Point in red with suffix 1 corresponds to the presence of significant change. Point in blue with suffix 0 represents the absence of significant change.
Source: Analysis based on original data from Department of World Heritage, 2009

The dendrogram of new buildings in Figure 53 shows that three group of clusters were identified. The three groups identified are summarized in Table 38.

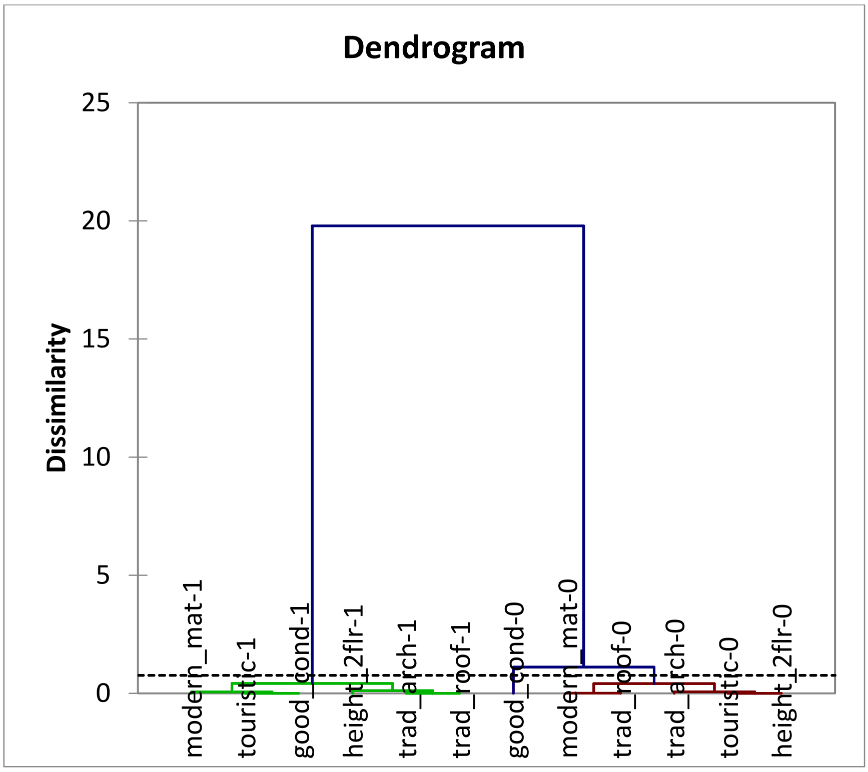

Figure 53. Dendrogram of new buildings

Source: Analysis based on original data from Department of World Heritage, 2009

Table 38. Three groups identified in new buildings

Group	Variable	Building characteristics
Group 1	touristic-1	Touristic use
	trad_arch-1	Lao traditional architecture
	modern_mat-1	Modern building materials
	trad_roof-1	Traditional roof materials
	2_flrs-1	Building height 2 floors
	good_cond-1	In good condition
Group 2	good_cond-0	Not in good condition
Group 3	touristic-0	Non-touristic use
	trad_arch-0	Non-Lao traditional architecture
	modern_mat-0	Traditional materials
	trad_roof-0	Modern roof materials
	2_flrs-0	1 floor

Source: Analysis based on original data from Department of World Heritage, 2009

The group of buildings of distinct characteristics are described as follows:

a. Group 1

Group 1 is characterized by touristic buildings. These new touristic buildings have physical attributes of Lao traditional architecture, height of 2 floors, and were in good condition. They also utilized modern building materials and traditional roof materials. The new touristic buildings have all main attributes following the specification of the PSMV.

b. Group 2

Group 2 buildings were not in good condition. This group includes temporary structures and small religious structures for example stupas.

c. Group 3

The buildings in this group are used for non-touristic purposes and have non-Lao traditional architecture. These buildings also used traditional building materials and modern roof materials. The buildings were 1 floor high. It was discovered that these buildings were unauthorized houses, used mainly by impoverished residents. The 1-floor buildings were poorly designed, with mixed modern architecture styles. They utilized traditional building materials, e.g., timber and bamboo, and modern roof materials, e.g., corrugated zinc sheets.

4.6 Summary of Results and Major Findings

4.6.1 Significant Factors for the Sustainable Application of GIS

The on-site assessment revealed that Luang Prabang was suffering from several problems which hamper the sustainable application of GIS such as severe lack of available data; inefficient data management; lack of a reliable digital base map; and a complex scale of implementation. Comparison of case studies of GIS application in five developing countries in

Asia has identified six common factors that are important for the sustainable use of GIS. Three of the six factors were incorporated in the design of GIS application in Luang Prabang, namely: 1) availability of reliable and compatible data; 2) an appropriate implementation scale to efficiently reflect the GIS objectives; and 3) continuous emphasis on balancing operational costs, updating data, and implementing training program to assist users. A GIS application was designed for Luang Prabang with the aim of catering for specific needs, tackling local constraints, and adapting its use to the local environment. Three components of the GIS were developed to counter the lack of data availability and management, namely: 1) data collection; 2) development of an appropriate database; and 3) development of a reliable digital base map. A pilot site of six villages was considered of appropriate scale to apply the GIS because it represented one-third of the total inventory buildings on the heritage site. An appropriate GIS application provided systematic management and retrieval of data to analyze the built environment of Luang Prabang between 1999 and 2009.

4.6.2 Significant Changes in the Built Environment

4.6.2.1 Significant Changes of Seven Indicators

The significant changes in the built environment were identified through spatial analysis of seven indicators, and are summarized as follows:

1. Building usage indicator: There was an evident shift in building usage from residential to touristic use, and the emergence of new touristic buildings along riverbanks as well as main roads.
2. Building architecture indicator: Lao traditional architecture has increased, and replaced modern architecture along riverbanks.

3. Roof materials indicator: traditional roof materials have increased, and replaced modern roof materials throughout the peninsula.
4. Building materials indicator: modern materials have increased, and replaced traditional materials throughout the peninsula.
5. Building height indicator: average building height has increased and did not exceed 3 floors.
6. Building condition indicator: the number of improved-condition buildings has increased throughout the peninsula.
7. Building area size indicator: building areas have increased along riverbanks, and this has contributed to the increase of building density.
8. Additional findings:
    1. Locals have maintained Lao traditional architecture despite changing from residential to touristic use.
    2. Most inventory buildings did not change much and maintained original attributes. However, one of 206 inventory buildings, PSMV no. 218, has been demolished and thirteen inventory buildings have changed from traditional to modern materials.

4.6.2.2 Patterns of Changes

Two spatial patterns of changes were identified in the spatial analysis. The patterns validated by logistic regression as statistically significant are:

1. Buildings located along riverbank areas have greater odds of changing to touristic use, changing to Lao traditional architecture, and increasing building area than buildings situated in the middle of the peninsula.

2. Inventory buildings have greater odds of maintaining original building materials and roof materials than non-inventory buildings in certain areas such as middle of peninsula and commercial roads.

4.6.3 Reasons behind Changes in the Built Environment

Local stakeholders, such as local experts of the DPL and local residents, have provided the reasons behind changes occurring in the built environment. Workshop with the DPL presented reasons for changes of all seven indicators. The reasons were summarized as follows:

1. Building usage indicator: touristic use increased due to a growing demand to provide accommodation to cope with the sharp influx of tourists.
2. Building architecture: Lao traditional architecture has increased and replaced modern architecture because of strict regulation imposed on building typology.
3. Roof materials indicator: traditional roof materials have increased and replaced modern roof materials due to five factors such as a) durability, b) affordability, c) availability of materials, d) importance of roof in architecture, and e) flexibility of regulation.
4. Building materials indicator: modern materials have increased and replaced traditional materials due to twelve factors such as a) durability, b) affordability, c) availability of materials, d) cooling effect, e) construction technique, f) flexibility of regulation, g) availability of labor, h) symbol of modernity, status and wealth, i) ability to withstand wet climate and insects, j) adaptability to air conditioner, k) ability to filter noise, and l) not affected by government logging policies.

5. Building height indicator: average building height has increased without exceeding the maximum height permitted because of the regulation, the design of Lao traditional architecture, and optimized use of space.
6. Building area size indicator: building area size has increased because of increased human activities and demand for land use. However, the increase was considered small because of strict regulation on land use, lack of land for expansion, and reuse of land.
7. Building condition indicator: the number of improved-condition buildings has increased because of improvement in locals' livelihood and the willingness of business owners to invest in restoration.

Three aspects were identified as worth investigating further with local residents, namely, modern building materials have replaced traditional building materials, traditional roof materials have replaced modern roof materials, and maintenance of Lao traditional architecture despite changing from residential to touristic use. Reasons given by local residents are as follows:

1. Locals maintained Lao traditional architecture, despite changing from residential to touristic use because respecting the PSMV was the pre-requisite to obtaining a touristic business license.
2. Traditional roof materials have increased and replaced modern roof materials because regulations dictated the use of specific roof materials, the importance of accentuating roof design in building architecture, good durability, and good accessibility to materials.

3. Modern materials have increased and replaced traditional materials because of their desirable qualities and practicality, and it was permitted by the regulation.
4. Additional findings:

   a) One inventory building, PSMV no. 218, was demolished due to lack of finance.

   b) Thirteen inventory buildings changed to modern materials because of realities that overwhelmed the existing regulations, such as the safety of inhabitants, religious needs, inaccessible materials, and an evolving use of building space. In order to sustain the inventory buildings, the DPL catered to the needs of residents and allowed the inventory buildings to employ modern materials.

In addition, DPL has also interpreted the impact of changes of three indicators on the landscape:

1. The increase of Lao traditional architecture has had a positive impact because it has reinforced traditional elements of the HUL.
2. The increase of traditional roof materials has had a positive impact on the landscape because the roof was the most visible feature of a building, and highly affects the overall landscape.
3. The increase of modern materials has had minimal impact on the landscape because coated building materials were not visible in the landscape.

4.6.4 Relation between Touristic Use and Significant Changes

The relation between touristic use and significant changes, identified in three indicators, was tested using the Chi-square test of independence. The results show that in existing buildings, the change to touristic use is related to all significant changes in three indicators:

1. change to Lao traditional architecture
2. change to traditional roof materials
3. change to modern materials

In new buildings, the relation with touristic use is only observed in use of traditional roof materials.

4.6.5 Relation between the PSMV and Significant Changes

MCA and HCA have identified three groups of distinctive building characteristics in the built environment, of which two are related to the PSMV. The first group of buildings shows that change of four indicators, namely, architecture, building materials, roof materials, and height, are associated with each other. The buildings were demolished and rebuilt according to regulation and design. The rebuilt buildings have the characteristics of Lao traditional architecture, a maximum height of 2 floors, and have utilized modern materials and traditional roof materials. In new buildings, there is one group that possessed specific building characteristics related to the PSMV. The second group consists of buildings that did not change much, which includes inventory buildings and religious buildings. They maintained most of their original attributes in accordance with the PSMV. The analysis for new buildings included six indicators and excluded building area size. It is observed that all six indicators are associated with each other. This illustrates that new touristic buildings have the characteristics of Lao traditional architecture and a maximum height of 2 floors, were in good condition, and utilized modern materials and traditional roof materials.

CHAPTER 5: DISCUSSION

This chapter interprets the major findings to approach the study objective, provides answers to research questions based on the existing knowledge discussed in the literature review, and reviews the outcome of the hypotheses.

5.1 Significant Factors for the Sustainable Application of GIS

First research question addresses the following:

What are the significant factors for the sustainable application of GIS in Luang Prabang?

A GIS application designed for Luang Prabang was instrumental in analyzing the built environment. The GIS application demonstrated the importance of taking into consideration the local context, as pointed out by Mennecke and West (2001), Ramasubramanian (1999), and Box (1999). Box (1999) warned that the inability to adapt its use and tackle local constraints have resulted in the failure of GIS introduction. Hence, comparative case studies were carried out to identify significant factors in applying GIS sustainably (Leong et al., 2008; Takada et al., 2008). Among the six factors identified, three factors employed contributed in overcoming local constraints, and were incorporated into the design of the GIS application.

One factor that played a significant role was the availability of reliable and compatible data. One of the biggest problem encountered in Luang Prabang was the severe lack of reliable data. Suitable maps and digital data were limited in developing countries since attaining data was costly, time-consuming, and laborious (Mennecke & West, 2001). This study agrees with Box (2003) that the cost and resources of producing a base map could be overcome by integrating multiple maps of different scales from different local departments and adopting appropriate data standards to make data compatible for sharing. Similar approach was applied and it worked in Luang Prabang. Georeferencing of five different maps has produced an accurate base map and resolved inaccuracies of building shape, size, and location (Leong et al., 2010; Takada et al., 2009). Essential data collected were verified by the Construction and Restoration Unit of DPL and coherent with PSMV standard because the method of survey and data categorization was adopted according to PSMV criteria (MdP, 2001a). Therefore, appropriate data collection and development of a reliable digital base map were crucial to overcome lack of reliable data. It helped to ensure the accuracy of spatial analysis and compatibility with PSMV, as well as reduce redundant data.

An appropriate implementation scale to efficiently reflect the objectives of GIS factor was instrumental in tackling the complexities of applying GIS in Luang Prabang. It would be best to analyze the changes that occurred in the entire World Heritage Site. Luang Prabang has more than 4,000 buildings in 29 villages. However, developing a large digital base map and conducting mass data collection would be too costly and complicated, as shown in the case of the Bangkok Metropolitan Administration, Thailand (Bishop, 2000). This study concurs with Bishop (2000) and Mennecke and West (2001) recommendation to start with a smaller scale of GIS application for a specific use and analysis. The locals would be more likely to experience the benefits from such an example of GIS application. A pilot site of six villages in the core heritage area, Zpp-Ua, was chosen in consultation with the Construction and Restoration Unit (Leong et al., 2010, 2016). Application of GIS at a smaller scale has proven to be more feasible in introducing GIS. Demonstration of pilot study enabled DPL to recognize the benefits of GIS technology and DPL has since expanded the pilot base map to cover the entire World Heritage Site.

Another factor applicable is the continuous emphasis on balancing operational cost, updating data, and implementing training program to assist users. A sustainable GIS needs to consider three aspects, namely, maintenance cost, maintenance of system through updating data, and continuous training. This study supports Box (1999) in the case of Hue, Vietnam that GIS could be sustained by fulfilling all three requirements. In Hue, they saved cost by using a self-developed GIS software and conducted gradual training based on users' capacity. Their users were satisfied that needs were met, and this encouraged the updating of data. Similarly, in Luang Prabang, three aspects were considered. Data management was strategized at minimum cost based on an existing database system (Sitthirath et al., 2010; Takada et al., 2009). PostgreSQL, a FOSS relational database management system was utilized and it was available at no cost. The GIS was applied to analyze the changes in the built environment, which the DPL needed urgently in response to the World Heritage Committee's recommendation (Boccardi & Logan, 2008). The GIS application introduced was able to fulfill the DPL's needs. This motivated the DPL to maintain the GIS application by expanding the base map in 2010 and updating data in 2016. Although this study did not include a training program, the DPL's local staff were actively involved in all phases of the development of the GIS application. For example, all stages, from pilot site selection till interpretation of data analysis, were jointly conducted with local DPL staff. Hence, the local staff was capable of operating the GIS. Considerations of operational cost, maintenance of data, and active involvement of local institutions have contributed in sustaining the use of the GIS.

Although it was initially deemed too difficult to introduce GIS, the incorporation of three significant factors into its application have made it possible to analyze the landscape in the constrained environment of Luang Prabang. Therefore, potential constraints can be addressed by integrating possible solutions into the design.

5.2 Significant Changes in the Built Environment

The second research question of this study addresses the significant changes in the built environment of Luang Prabang.

What are the significant changes in the built environment of Luang Prabang between 1999 and 2009?

Eight hypotheses were derived to answer this research question:

H1: Touristic use has replaced residential use

H2: Modern architecture has replaced Lao traditional architecture

H3: Modern building materials have replaced traditional building materials

H4: Modern roof materials have replaced traditional roof materials

H5: Average building height has increased

H6: Building density has increased

H7: Number of improved-condition buildings has increased

H8: Changes of built environment have occurred throughout the core heritage area

Five hypothesized changes on building usage (H1), building materials (H3), building height (H5), building density (H6), and building condition (H7) are supported by this study. Touristic use have increased in Luang Prabang due to change from residential use in existing buildings and construction of new touristic use. After inscription of world heritage title, most of the historic cities experienced an increase in touristic related activities and businesses (Johnson & Thomas, 1995; Kammeier, 2008; Peters, 2013). Touristic use has replaced residential use similar to what is witnessed in HUL Lijiang (Li, 2008; Peters, 2013) and Hoi An (Galla, 2012). Where else, the surge of new touristic use is consistent with Lijiang (Li, 2008), Macao (Imon, 2008, 2013), George Town, and Melaka (UNESCO, 2009; King, 2015).

The buildings have shifted to use modern materials rather than traditional materials, increased height, and increased density. The buildings were restored to a better condition. Although the changes in materials, height, density, and building condition corresponds with other HULs, they did not affect the Luang Prabang negatively. The buildings did not change entirely to modern design except for building materials. The increase in building height did not affect the built environment and increase in building density was not significant. Where else, large scale development has occurred in other HULs where bigger, higher, and modern buildings were built as hotels, shopping malls, luxury apartments, casino, and touristic facilities. This was observed in Lijiang (Li, 2008; Feng and Nishimura, 2008; Gao, 2008), Hoi An (Galla, 2012), Macao (Imon, 2008, 2013), George Town, and Melaka (King, 2015; UNESCO, 2009). In the case of Macao, large casino and luxury high rise apartments have negatively transformed the built environment (Imon, 2008, 2013). The finding on modern materials also concurs with the past reports and studies on Luang Prabang (Boccardi & Logan, 2008; UNESCO, 2004a; Vonvilay, 2015). The findings on change in building height and building density agrees with Boccardi and Logan (2008) as well.

On the other hand, modern design buildings have been reverted to traditional style and traditional roof materials, contradicting the existing studies. As such, two hypotheses on building architecture (H2) and roof materials (H4) are not supported. The reasons for opposing the hypotheses are discussed later, under Section 5.3 “Reasons behind significant changes in the built environment of Luang Prabang” and 5.4 “Relation between touristic use and significant changes”. As discussed earlier, other historic cities tend to construct modern design and use modern materials. In Luang Prabang, it was unexpected to find that traditional elements had replaced modern elements for architecture and roof materials, contrary to what is observed in other HULs such as Hoi An (Galla, 2012), Lijiang (Gao, 2008; Feng & Nishimura, 2008; Li, 2004, 2008), Macao (Imon, 2008, 2013), George Town, and Melaka (King, 2015; UNESCO, 2009). This finding also opposes with WHC monitoring report (Boccardi & Logan, 2008) that Lao traditional architecture has decreased due to preference for modern architecture. The only literature that coincides with this finding is Vonvilay (2015). He found that houses were transformed into Lao traditional architecture and changed to traditional roof tiles, but locals have modernized the interior with modern materials to accommodate modern lifestyle. However, he only studied the transformation of five houses. Therefore, this study is able to provide empirical evidence based on larger sample to support the finding on change in architecture and roof materials.

Contrary to past studies, the built environment has changed more along the riverbank areas and original building attributes in certain areas have been maintained by inventory buildings. Hypothesis stating that change in built environment would occur throughout core heritage area (H8), is not supported by this study. Two spatial patterns observed in spatial analysis and validated by logistic regression, helped to clarify the areas that have changed and did not change in the built environment. The first spatial pattern is that change in built environment occurred more along riverbank areas. Existing buildings located along riverbanks had greater odds of changing to touristic use and Lao traditional architecture, and increasing their building area size than the buildings in the middle of the peninsula. This illustrates that riverbanks were more lucrative for touristic businesses compared to middle of peninsula. This finding disagrees with Dearborn and Stallmeyer (2009 and 2010)'s observation that majority houses scattered throughout the peninsula have been renovated or reconstructed to meet the needs of tourism. Only a few of houses located in middle of peninsula still retained its original usage and physical appearance. The second spatial pattern identified is original building materials and roof materials have been maintained in certain areas by inventory buildings. It was statistically significant that more of inventory buildings maintained their original building materials and roof materials than non-inventory buildings. Spatial analysis shown the inventory buildings that maintained the materials were mostly concentrated in the middle of peninsula and along commercial roads. The unique spatial distribution of inventory buildings has its importance and represents the different historical influences from the Lao, French and Chinese-Vietnamese (Ateliers de la Péninsule, 2004; MdP, 2001b). This signifies two important aspects for the pilot site located in the core heritage area of Luang Prabang (MdP, 2001b; UNESCO, 2004a). First, the maintenance of inventory buildings shows that significant historical monuments were retained. Second, the maintenance of inventory buildings' original building materials and roof materials is closely linked to the authenticity of the HUL (ICOMOS, 1995). Dearborn and Stallmeyer (2009 and 2010) observed that both inventory and non-inventory buildings have changed their physical appearance which were randomly located in the core heritage area. However, their sample only comprised of 19 buildings and they did not employ statistical methods to validate the spatial patterns. Therefore, this study is able to clearly identify the spatial pattern of change in built environment compared to Dearborn and Stallmeyer (2009 and 2010), the only other study, to author's knowledge, that has examined the built environment. This study has proven with analysis of entire cohort of buildings that the spatial pattern of change is statistically significant.

The findings has practical implication to DPL who are responsible for the local heritage management. Limited studies had been carried out to quantify the changes to the built environment of Luang Prabang. Therefore, this is the first study, to author's knowledge, to visualize, analyze, and compare how the World Heritage Site has changed since Luang Prabang was awarded that status. It is able to show the impact of time and circumstances, based on the heritage values defined during inscription (Stovel, 2002). It has been pointed out that a HUL is a living city and yet the landscape is not visible to many people, in particular, urban policy-makers (Turner, 2010). This was due to the lack of ability to perceive the whole urban landscape. Mapping is needed to view the entire landscape, in order to comprehend its layout and evolution. Therefore, maps of landscape characteristics are important for policy-makers to manage change (Whitehand & Gu, 2010). This study has provided a visualization of the landscape that will help local stakeholders to comprehend and grasp clearly the extent of change and its impact.

5.3 Reasons behind Significant Changes in the Built Environment

The research question 3a asked the following:

> What are the reasons behind the significant changes in the built environment of Luang Prabang?

The GIS was a useful resource in identifying all buildings that had changed significantly. Thereby, this study was able to interview the whole cohort of local residents who had changed their buildings and no sampling was employed which differs from the previous studies (Dearborn & Stallmeyer, 2009, 2010; Vonvilay, 2015). This constitutes as a significant contribution of this study. Multiple reasons were obtained from the DPL and local residents. However, the main reason prevalent in all three significant changes was the strict implementation of the PSMV.

In building architecture, locals changed from modern architecture to Lao traditional architecture because of the strict PSMV on the building typology. This demonstrated that locals transformed the building architecture conforming to the PSMV. The locals also maintained same Lao traditional architecture despite changing from residential to touristic use because of the prerequisite that regulations had to be respected in order to obtain a business license. The DPL has coordinated with the Department of Tourism to ensure the transformation of buildings conforms to the PSMV in spite of the demand to cater to touristic businesses. This differed from what Gao (2008) and ICOMOS (2005) observed. It was discovered that developers' tendency to build to cater to the market rather than preserving traditional characteristics of the heritage site (Gao, 2008), and development pressure resulted in construction of modern houses and demolition of traditional architecture (ICOMOS, 2005). The relation between Lao traditional architecture and touristic use as well as PSMV is further discussed in Section 5.4 and 5.5 respectively.

In the case of building materials, locals preferred to use modern rather than traditional ones because it was permitted by regulation, and the materials had desirable qualities and were more practical to use. Locals who changed to modern building materials were influenced by 11 out of 12 factors namely: 1) flexibility of preservation regulation; 2) durability of materials; 3) availability of materials; 4) availability of labor; 5) construction technique; 6) affordability; 7) cooling effect; 8) ability to withstand a wet climate and insects, 9) ability to filter noise; 10) not affected by government logging policies; and 11) adaptability to air conditioner. The influence of multiple factors is consistent with past studies, except for one factor, symbol of modernity, wealth, and status (Gao, 2008; Larsen & Marstein, 2000; Li, 2004; UNESCO, 2004a). Symbol of modernity, status, and wealth was rated as not influential, which indicates that the aesthetic of building materials was not important. This is contrary to the claim that televised images of modern concrete buildings from abroad and modern lifestyles have influenced the locals to perceive that modern materials were more prestigious, and modern concrete buildings were better (Gao, 2008; Li, 2004; UNESCO, 2004a; Vonvilay, 2015). During the interviews with locals, it was revealed that wooden houses were considered more prestigious and a symbol of wealth, rather than concrete. Locals felt that timber was becoming rare and the ability to purchase expensive timber was a symbol of wealth and status. On the other hand, cement houses were becoming common. However, there could be a risk of local preference for modern materials, as pointed out by Larsen and Marstein (2000) and UNESCO (2004a). The lack of demand for traditional materials could lead to the loss of traditional skills and craftsmanship.

This study has found three new factors that influenced the use of building materials and were not listed in past studies (Gao, 2008; Larsen & Marstein, 2000; Li, 2004; UNESCO, 2004) such as: 1) ability to filter noise; 2) not being affected by government logging policies; and 3) adaptability to air conditioner. Moreover, this study has identified influential factors through a quantitative survey. The past studies did identify diverse factors but did not rate them quantitatively (Gao, 2008; Li, 2004; UNESCO, 2004a; Vonvilay, 2015).

This study also revealed that local experts have different perception on change of building materials compared to Boccardi & Logan (2008). Boccardi and Logan (2008) viewed that change from traditional to modern materials in general were not compliant with regulations. However, both local experts and local residents felt that change to modern materials in non-inventory buildings was not against PSMV that has been approved by UNESCO (Leong et. al, 2016). Moreover, from local experts' point of view, the change to modern materials in non-inventory buildings was not a negative change because it has minimal impact to the overall landscape and it was sufficient to preserve traditional materials in inventory buildings only.

As for the case of roof materials, five factors have influenced the residents' decision to change from modern to traditional roof materials namely: 1) availability of materials; 2) affordability; 3) durability; and 4) flexibility of regulation, and 5) the importance of the roof in architecture (Leong et al., 2016). Although traditional roof materials were less affordable than modern roof materials, locals preferred to use them because they were the only materials allowed by PSMV, their use accentuates the roof design, and they offer good accessibility and good durability. Four factors have influenced the use of roof materials, as observed in past studies (Gao, 2008; Li, 2004; UNESCO, 2004a) and this study has contributed in identifying a new factor, the importance of the roof in architecture. As with building materials, this study has identified influential factors and compared different materials through a quantitative survey which was not available in past studies (Gao, 2008; Li, 2004; UNESCO, 2004a).

5.4 Relation between Touristic Use and Significant Changes

The research question 3b examines the relation between touristic use and other significant changes in the built environment of Luang Prabang. The specific hypotheses were developed later as a consequence of results gained from hypotheses H1-H7. The research question and hypotheses formulated are listed below:

What is the relationship between the increase of touristic use and significant changes in the built environment of Luang Prabang?

H9: Increase of touristic use and the significant changes in built environment are related.

H9a: Increase of touristic use and increase of Lao traditional architecture are related.

H9b: Increase of touristic use and increase of modern building materials are related.

H9c: Increase of touristic use and increase of traditional roof materials are related.

All three hypotheses are supported. A Chi-square test of independence has shown that the increase of touristic use in existing buildings is indeed related to significant changes observed in all three indicators. The change to touristic use in existing buildings has contributed to the change to Lao traditional architecture, modern materials, and traditional roof materials. However, as regards to new buildings, the construction of new touristic buildings is only related with use of traditional roof materials.

This results were unexpected and disputes with existing literature that rapid development and tourism growth in the historic cities would diminish the traditional or vernacular characteristics of a heritage site (Boccardi & Logan, 2008; Gao, 2008; ICOMOS, 2005; Imon, 2008, 2013, Li, 2004). In other words, modern, fast-paced, and large scale development was carried out to accommodate to tourism market with little regard to preserving traditional characteristics (Gao, 2008). It was also highlighted by ICOMOS's analysis on threats faced by 614 World Heritage Sites in developing and developed countries that the impact of tourism growth and urban development were the emergence of new architectural styles and decline of traditional architecture (ICOMOS, 2005). This results also contradicts with the influential WHC report that Lao characteristics has declined especially Lao traditional architecture due to conversion to touristic accommodation (Boccardi & Logan, 2008). However, this study has revealed otherwise. Although change to touristic use did led to the change to modern materials as expected, the increase of conversion to touristic use has surprisingly encouraged the conversion from modern architecture and roof materials to traditional ones. Luang Prabang case has demonstrated that growth of touristic buildings do not necessarily resulted in the loss of Lao characteristics as asserted in literature. Instead, it has contributed in strengthening the traditional characteristics of the heritage site. Vonvilay (2015) is the only other study that revealed similar finding on transformation to Lao traditional architecture and traditional roof materials, however he did not examine the relation between change to touristic use and change in architecture as well as roof materials. Therefore, this study is the first, to author's knowledge, to provide empirical data to verify the link between increase of touristic buildings and the changes in built environment of Luang Prabang.

5.5 Relation between the PSMV and Significant Changes

The research question 3c examines the following:

What is the relationship between the Safeguarding and Preservation Plan and significant changes in the built environment of Luang Prabang?

MCA and HCA validated that two groups of buildings with specific building characteristics have emerged in the built environment because of regulations. The first group of buildings has changed in four aspects in accordance with the PSMV. The locals changed their buildings to Lao traditional architecture, utilized modern materials, and traditional roof materials, and increased to the maximum height allowed. The PSMV has, thus, influenced the local people's decision as to how to change their buildings. Traditional architecture and roof materials were revived. This finding agrees with UNESCO (2004a) that regulatory means could be effective in overcoming the obstacles to conservation when it was enforced by local authorities.

The second group of buildings is represented by those that did not change much and maintained their original attributes, such as inventory and religious buildings. The formation of the two groups of buildings indicates that the PSMV has had a significant influence and has shaped the built environment. This demonstrates that the PSMV was operational and the locals felt the need to respect regulations. This finding helps to clarify the mixed findings presented in literature. It contradicts Sitthivan (2005a, 2006), Dearborn and Stallmeyer (2009, 2010), and Boccardi and Logan (2008). They observed that the PSMV was not operational and the landscape had transformed in a negative manner. On the other hand, this finding supports Vonvilay (2015) and ADB report (Mabbit, 2006). Strict implementation of PSMV has accomplished in coordinating urban development and restricting transformation of buildings, thereby preserving heritage values of Luang Prabang (Mabbit, 2006; Vonvilay, 2015).

Learning from the case of Luang Prabang, visualization of urban landscape characteristics and analysis of their changes are important for policy-makers because it is difficult to perceive an entire landscape and its evolution without mapping its layout. The local government has implemented preservation regulations to ensure development occurs without compromising the OUV. The PSMV, the current regulatory tool enforced, is applicable and functioning to preserve the heritage site (Leong et. al, 2016).

CHAPTER 6: CONCLUSION

This chapter concludes the thesis by reflecting on the objectives of this study and summarizing the major findings corresponding with them. It presents limitations of the study and proposals for future research.

6.1 Summary

6.1.1 Significant Factors for the Sustainable Application of GIS

Few studies have attempted to analyze and quantify the changes in the built environment of Luang Prabang. To the best of the author's knowledge, no study has attempted to visualize, and conduct spatial analysis of the built environment to provide empirical evidence as to how Luang Prabang's HUL has changed. The change of each building on the World Heritage Site offers invaluable information and has a pronounced effect on the overall landscape. As such, this study aimed to visualize and analyze significant changes that occurred in the built environment. This being the first study to do so, the introduction of GIS technology needed to be considered carefully since it is not easy to implement GIS in developing countries. Three out of six factors identified from comparative case studies were incorporated in the GIS application to tackle constraints that hamper GIS introduction. They were: 1) availability of reliable and compatible data; 2) continuous emphasis on balancing operational cost, updating data, and implementing training program to assist users; and 3) an appropriate implementation scale to efficiently reflect the objectives of GIS. The application of the three factors was instrumental in overcoming the severe lack of available data, inefficient data management, lack of a reliable base map, and complexity of large-scale implementation. It also contributed to encouraging the Department of World Heritage to continuously utilize GIS in heritage management. Hence, this study was able to develop three crucial components of GIS application for the Luang Prabang context. The components comprised data collection, development of an appropriate database, and development of a reliable digital base map.

6.1.2 Significant Changes in the Built Environment

A pilot site of six villages was visualized and compared between 1999 and 2009 to analyze significant changes. The selection of data was framed between 1999 and 2009 and defining indicators of change in the Luang Prabang context were based on their relevance to heritage values. The measurement of change in the heritage context needs to be based on two criteria (Stovel, 2002): 1) the use of indicators that relate to authenticity and integrity, which supports the OUV of the heritage site; and 2) the use of the original state of the landscape at the time of its inscription as a baseline for comparison. Therefore, this study adopted seven pertinent indicators of change identified by the PMSV. The seven indicators are important building attributes related to heritage values and vulnerable to change over time (MdP, 2001b). The PSMV map documented in 1999 reflected most closely the original state of the landscape.

The built environment has changed notably in four indicators, namely, building usage, building architecture, building materials, and roof materials. First, there was an evident shift in building usage from residential to touristic use, especially guesthouses along riverbanks and main roads. Second, Lao traditional architecture replaced modern architecture along riverbanks. Third, modern building materials replaced traditional building materials throughout the peninsula. Fourth, traditional roof materials replaced modern roof materials in several areas along riverbanks. The changes identified in the three remaining indicators were less prominent. The average building height increased but did not exceed the permitted maximum. Building density increased marginally. A number of buildings improved their condition. Additional findings have shown that residents maintained the existing Lao traditional architecture despite changing from residential to touristic use. This study found that traditional elements have replaced modern elements in architecture and roof materials in Luang Prabang, which is opposed to other HULs. Therefore, this has had a positive impact on the overall HUL.

Two spatial patterns of changes observed in spatial analysis and validated by logistic regression, namely: 1) more buildings located along riverbanks changed to touristic use, changed to Lao traditional architecture, and increased area size than buildings in the middle of the peninsula; and 2) more inventory buildings have maintained their original building materials and roof materials than non-inventory buildings in certain areas such as middle of the peninsula and commercial roads. The maintenance of inventory buildings is essential for preserving the OUVs of Luang Prabang World Heritage Site.

6.1.3 Reasons behind Significant Changes in the Built Environment

Multiple reasons have caused significant changes to occur in the built environment. Touristic buildings have increased and replaced residential buildings due to increasing demand for tourist accommodation. Lao traditional architecture has replaced modern architecture due to strict regulation. Modern building materials have replaced traditional building materials need because this was permitted by the regulations, and they had desirable qualities and were practical to use. Traditional roof materials have replaced modern materials because of strict regulation, the importance of accentuating roof design, good durability, and good accessibility. In addition, residents have maintained Lao traditional architecture even though they have changed from residential to touristic use because respecting PSMV was the prerequisite imposed to obtain a business license.

In existing buildings, it was revealed that change to touristic use in existing buildings is associated with all significant changes in three indicators, respectively: 1) change to Lao traditional architecture; 2) change to modern materials; and 3) change to traditional roof materials. Contrary to what was observed in other HULs, the increase of touristic use did not contribute to transforming the Historic Urban Landscape of Luang Prabang negatively. It has contributed to increase of Lao traditional architecture and traditional roof materials instead.

It was observed that the common reason behind the significant changes was the strict implementation of the PSMV. MCA and HCA validated that the PSMV has had a significant influence on the built environment. Locals have changed building architecture, building materials, roof materials, and height in accordance with the PSMV. Meanwhile, they have also maintained the attributes of inventory and religious buildings. In short, the PSMV has influenced local residents' decisions about changing their buildings. Therefore, the built environment has changed within the limits of the preservation regulations. The empirical evidence obtained was able to clarify the state of conservation of Luang Prabang. Moreover, the empirical evidence, supported by reasons to change from the local perspective, was instrumental in comprehending the changes in Luang Prabang.

6.2 Limitations and Future Research

This study has three limitations, which can be expanded into future research topics. First, this study only reflected the significant changes in the built environment, and local perspectives on change, in six villages. The pilot site was chosen for its suitability in this study context. The analysis could be expanded to a larger area. There are 29 villages and more than 4000 buildings in Luang Prabang World Heritage Site which need to be analyzed.

Second, this study utilized the time frame of 1999 to 2009. The study needs to be updated with recent data to capture the current state of the HUL. More data from different timelines could be included to analyze temporal changes and modeling to predict the future trend of changes.

Third, this study only analyzed the built environment, which represents only one aspect of heritage values that need to be preserved. Intangible heritage needs to be included by employing cultural mapping. The documentation of tangible and intangible resources would be helpful to reflect the overall OUV.

List of Academic Achievements

Journals

1. Leong, C., Takada, J., & Yamaguchi, S. (2016). Analysis of the changing landscape of a World Heritage Site: Case of Luang Prabang, Lao PDR. *Sustainability*, *8*(8), 747.
2. Leong, C., Takada, J., Hanaoka, S., & Yamaguchi, S. (2017). *Impact of tourism growth on the changing landscape of a World Heritage Site: Case of Luang Prabang, Lao PDR.* (To be submitted soon).

Publications in International Conferences with Peer Review

1. Yamaguchi, S., Takada, J., & Leong, C. (2009). Application of ICT and GIS use in Sustainable Development in Luang Prabang, Lao PDR, *UNESCO-ICCROM 2nd Asian Academy for Heritage Management Conference: Urban Heritage and Tourism Challenges Opportunities,* Macao S.A.R, China, 1-3 December 2009.
2. Leong, C., Yamaguchi, S., & Takada, J. (2008). Assessment on local condition in GIS use in Sustainable Development of World Heritage Site: Case of Luang Prabang, Lao PDR, *44th International Society of City and Regional Planning (ISOCARP)*, Dalian, China, 19-23 September 2008.

Publications in International Conferences without Peer Review

1. Leong, C., Yamaguchi, S., & Takada, J. (2010). Introducing GIS (Geographical Information System) to monitor development in world heritage site of developing country: Case of Luang Prabang, Lao PDR. *3rd Joint International Conference on Information and Communication Technology, Electronic and Electrical Engineering (JICTEE)*, Vientiane, Lao PDR, 21-24 December 2010, 503-507.

2. Sitthirath, R., Phomphadith, S., Savatvong, K., Leong, C., Yamaguchi, S., & Takada, J. (2010). Application of Free and Open Source Database Management System for Heritage Management in Luang Prabang, Lao PDR, *3rd Joint International Conference Telecommunications (JICTEE)*, Vientiane, Lao PDR, 21-24 December 2010, 498-502.

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1. Leong. C., Yamaguchi, S., & Takada, J. (2011). Analyzing change in built environment of World Heritage Site: Case of Luang Prabang, Lao PDR, *Japan Society for International Development (JASID) 22nd Conference*, Nagoya, 26-27 November 2011.

2. Leong, C., Yamaguchi, S., & Takada, J. (2010). Geo-analysis on changing trend of buildings in World Heritage Site, Luang Prabang, Lao PDR, *Japan Society for International Development (JASID) 21st Conference*, Tokyo, 4 December 2010, 229-230.

3. Takada, J., Yamaguchi, S., Leong, C. (2009). GIS Development in World Heritage Sites in Developing Countries, Prevent from becoming “Heritage in Danger”: Luang Prabang,

Lao PDR, *Japan Society for International Development (JASID) 20th Conference*, Beppu, 21-22 November 2009, 164-167.

4. Leong, C., & Kawaguchi, Y. (2008). Assessment of Application of ICT for Promoting Sustainable Development in World Heritage Sites: Case of Luang Prabang of Lao PDR, *Japan Society for International Development (JASID) 9th Spring Conference*, Tokyo, 7 June 2008, 149-152.

5. Takada, J., Yamaguchi, S., & Leong, C. (2008). GIS and Regional Development: Potential Problems and Feasible Solutions, *Japan Society for International Development (JASID) 19th Conference*, Hiroshima, 22-23 November 2008, 350-353.

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APPENDIX

Appendix 1: Field Survey Form

No:	Building Survey Form

Name: | Village: | Year of construction:

GPS No: | X: | Y:

Preservation: ☐ UNESCO (Inv No: ___________) ☐ PSMV (Inv. No: __________) ☐ Merit preservation ☐ Green Space
☐ Obstructing ☐ Can be replaced

Industry: ☐ Resident ☐ Guest House ☐ Hotel ☐ Restaurant ☐ Tour agency ☐ Souvenir
☐ Temple ☐ Government Office ☐ Other: _______________ Others______________________

Original usage: ☐ Empty land ☐ Resident ☐ Commerce ☐ Other: ___________ | No. of Storey:

Type of Architecture:	Original architecture	Mark the location of the building
 ☐ Simple gable	☐	
 ☐ Single gable with veranda	☐	
 ☐ Single gable with kitchen	☐	
 ☐ Double gable	☐	
 ☐ Imported architecture	☐	
 ☐ Shop house	☐	
 ☐ Shop house in range	☐	
 ☐ Colonial	☐	
 ☐ Apartment	☐	

Building material: ☐ Timber ☐ Brick ☐ Plaster ☐ Others: ______________

Main structure condition: ☐ Good ☐ Moderate ☐ Bad

Roof Material: ☐ Terrace ☐ Bamboo ☐ Cement tiles ☐ Clay tiles ☐ Zinc ☐ Fiber cement

Checked by: _______________ Date: _______________

Appendix 2: Questionnaire for Department of World Heritage

Name:

Position in DPL:

Building usage

1. Touristic usage for both general buildings and inventory buildings is increasing (refer to Figure 1.1 and Figure 1.3). Although both categories of building have a similar trend, inventory buildings are considered more attractive for tourists and have stricter regulations in the PSMV. How does this affect the inventory buildings' conversion for touristic usage?

2. The number of school, government, and religious buildings did not change much for general buildings and inventory buildings (refer to Figure 1.2 and Figure 1.4). What are the major reasons for the lack of significant change (e.g., government policy-which article, needs, limited land, motivation, lack of funds)?

Building architecture

3. Traditional architecture is increasing throughout the six villages (refer to Figure 2.1). Would this be consider as a positive or negative impact on preserving the heritage site?

4. Traditional architecture is increasing with touristic usage and this contributed to the increased number of traditional architecture structures built (refer to Figure 2.2). Would this still be considered as a positive or negative impact on preserving the heritage site?

5. The increase in commercial architecture is relatively low compared to the increase in traditional architecture (refer to Figure 2.1). In the PSMV, new commercial architecture buildings can only be built along commercial roads. Is this because people follow the regulations? Are there any other reasons?

Building materials

6. Non-traditional building materials are increasing. The UNESCO Tourism Impact on Luang Prabang (2004) identified 6 factors influencing the choice of building materials (refer to Figure 3.1):

a. Cost, b. Availability, c. Durability, d. Cooling effect of material, e. Flexibility of design, f. Construction technique

What are the other reasons for people to choose non-traditional materials?

7. In your opinion, how will the increase in the use of non-traditional materials affect the townscape of the town?

Building architecture and materials

8. While traditional architecture continues to increase, non-traditional materials buildings are also increasing (refer to Figures 2.1 and 3.1). How will this affect the townscape?

Roof materials

9. Traditional roof materials are increasing despite the high cost (refer to Figure 4.1). What are the main reasons in your opinion?

How will this affect the townscape?

10. Traditional materials and traditional roof materials are both considered expensive. However, traditional materials are decreasing while traditional roof materials are increasing (refer to Figure 4.2). What are the reasons for people's willingness to invest more in traditional roof materials than traditional building materials?

Building height

11. The changes observed in building height are as follows (Additional analysis; refer to Figure 8.1).

  a. Small increase of 1-floor buildings
  b. Significant increase of 2-floor buildings
  c. No increase of 3-floor buildings

Would the changes be considered as positive or negative toward preserving the townscape?

Could the changes in building height be due to the PSMV? What are the other reasons?

Appendix 3: Questionnaire for Local Residents

Maintenance of Lao traditional architecture despite changing from residential to touristic use

Target: Residents that changed from residential to touristic use and maintained Lao traditional architecture

Sample: 40

Purpose: To investigate the following

a. Reasons for maintaining traditional architecture despite changing usage;
b. Impact of usage change on migration of local people;
c. Attractiveness of the buildings for tourists;
d. Contribution of touristic usage to supporting and maintaining traditional architecture.

Questions:

1. Who was the owner in 1999 and now?

☐ Same owner
☐ Different owner

(If different, please specify owner's origin: Luang Prabang/ Vientiane/ Outside Laos/________)

2. If the building is rented out, who is renting the building?

☐ Lao people from Luang Prabang
☐ Lao people from outside Luang Prabang
☐ Foreigners

3. Who manages the touristic building?

☐ Owner family
☐ Lao people from Luang Prabang
☐ Lao people from outside Luang Prabang
☐ Foreigners

4. If the owner family manages the building, where does the family stay?

☐ 1st floor of the building
☐ 2nd floor of the building
☐ Another house within World Heritage Site
☐ Another house outside of World Heritage Site
☐Others: ____

5. What is attractive about your building to tourists? (can choose more than one)

☐ Good location (e.g. main road)
☐ Located within World Heritage Site
☐ Beautiful
☐ Architecture
☐ Good touristic facilities/ service
☐ Affordable goods/ rooms
☐ Others: ____

6. What is the reason for choosing or keeping traditional architecture? (can choose more than one)

☐ Attractive for business
☐ Keep inheritance from parents
☐ Beautiful
☐ Heritage values
☐ Follow regulations
☐ Others: ____

7. In your opinion, what are the aesthetic values of traditional architecture? (can choose more than one)

☐ Roof design
☐ Timber structure
☐ Lao decoration on ornaments, window and railings
☐ Historical values of Lao architecture
☐ Others: ____

8. How do you use your income to maintain and make the traditional architecture building attractive to tourists? (can choose more than one)

☐ Restore to maintain good condition
☐ Change deteriorating material
☐ Repaint walls
☐ Repair parts of buildings (e.g., roof)
☐ Improve and decorate building façade
☐ Improve the interior of buildings
☐ Improve facilities (e.g., air conditioner, hot water, furniture)
☐ Others: ____

Modern building materials have replaced traditional building materials

Target: Residents who converted from traditional building materials to modern building materials

Sample: 120

Purpose: To investigate the reasons for choosing modern building materials over traditional building materials

Please rate each factor for choosing the use of traditional building materials and modern building materials.

No	Factors	Description	Rate level of importance		Rate traditional materials		Rate modern materials	
1	Affordability	Ability to purchase materials	☐ Very important	(3)	☐ Not expensive	(3)	☐ Not expensive	(3)
			☐ Important	(2)	☐ Fairly expensive	(2)	☐ Fairly expensive	(2)
			☐ Fairly important	(1)	☐ Expensive	(1)	☐ Expensive	(1)
			☐ Not important	(0)	☐ Very expensive	(0)	☐ Very expensive	(0)
2	Availability	Access to material	☐ Very important	(3)	☐ Highly available	(3)	☐ Highly available	(3)
			☐ Important	(2)	☐ Available	(2)	☐ Available	(2)
			☐ Fairly important	(1)	☐ Fairly available	(1)	☐ Fairly available	(1)
			☐ Not important	(0)	☐ Not available	(0)	☐ Not available	(0)
3	Durability	Lifespan of materials	☐ Very important	(3)	☐ Very long (> 50 years)	(3)	☐ Very long (> 50 years)	(3)
			☐ Important	(2)	☐ Long period (30-50 years)	(2)	☐ Long period (30-50 years)	(2)
			☐ Fairly important	(1)	☐ Medium period (10 – 29 years)	(1)	☐ Medium period (10 – 29 years)	(1)
			☐ Not important	(0)	☐ Short period (< 10 years)	(0)	☐ Short period (< 10 years)	(0)
4	Cooling effect	Ability to ventilate air within building	☐ Very important	(3)	☐ Very Cool	(3)	☐ Very Cool	(3)
			☐ Important	(2)	☐ Cool	(2)	☐ Cool	(2)
			☐ Fairly important	(1)	☐ Fairly cool	(1)	☐ Fairly cool	(1)
			☐ Not important	(0)	☐ Not cool	(0)	☐ Not cool	(0)
5	Construction technique	Choice of construction technique based on time consumed and level of difficulty	☐ Very important	(3)	☐ Very convenient	(3)	☐ Very convenient	(3)
			☐ Important	(2)	☐ Convenient	(2)	☐ Convenient	(2)
			☐ Fairly important	(1)	☐ Fairly convenient	(1)	☐ Fairly convenient	(1)
			☐ Not important	(0)	☐ Not convenient	(0)	☐ Not convenient	(0)
6	Ability to withstand wet climate and insects	Ability to withstand rain, flood, and insects bites	☐ Very important	(3)	☐ Very strong	(3)	☐ Very strong	(3)
			☐ Important	(2)	☐ Strong	(2)	☐ Strong	(2)
			☐ Fairly important	(1)	☐ Fairly strong	(1)	☐ Fairly strong	(1)
			☐ Not important	(0)	☐ Not strong	(0)	☐ Not strong	(0)

No	Factors	Description	Rate level of importance		Rate traditional material		Rate modern material	
7	Availability of labor	Presence of skilled labor	☐ Very important	(3)	☐ Highly available	(3)	☐ Highly available	(3)
			☐ Important	(2)	☐ Available	(2)	☐ Available	(2)
			☐ Fairly important	(1)	☐ Fairly available	(1)	☐ Fairly available	(1)
			☐ Not important	(0)	☐ Not available	(0)	☐ Not available	(0)
8	Adaptability to air conditioner	Ability to contain the cool air from an air conditioner	☐ Very important	(3)	☐ Very Cool	(3)	☐ Very Cool	(3)
			☐ Important	(2)	☐ Cool	(2)	☐ Cool	(2)
			☐ Fairly important	(1)	☐ Fairly cool	(1)	☐ Fairly cool	(1)
			☐ Not important	(0)	☐ Not cool	(0)	☐ Not cool	(0)
9	Ability to filter noise	Ability to filter noise pollution	☐ Very important	(3)	☐ Very good	(3)	☐ Very good	(3)
			☐ Important	(2)	☐ Good	(2)	☐ Good	(2)
			☐ Fairly important	(1)	☐ Fairly good	(1)	☐ Fairly good	(1)
			☐ Not important	(0)	☐ Not good	(0)	☐ Not good	(0)
10	Symbol of modernity, status, and wealth	Representation of building materials for building owner status	☐ Very important	(3)	☐ Very significant	(3)	☐ Very significant	(3)
			☐ Important	(2)	☐ Significant	(2)	☐ Significant	(2)
			☐ Fairly important	(1)	☐ Fairly significant	(1)	☐ Fairly significant	(1)
			☐ Not important	(0)	☐ Not significant	(0)	☐ Not significant	(0)
11	Not affected by government logging policy	Forestry policies that decrease annual logging quota for export and domestic use which affects use of timber	☐ Very important	(3)	☐ Not affect	(3)	☐ Not affect	(3)
			☐ Important	(2)	☐ Fairly affect	(2)	☐ Fairly affect	(2)
			☐ Fairly important	(1)	☐ Affect	(1)	☐ Affect	(1)
			☐ Not important	(0)	☐ Highly affect	(0)	☐ Highly affect	(0)
12	Flexibility of regulation	Flexibility of the PSMV regulation on type of building materials that can be used	☐ Very important	(3)	☐ Very flexible	(3)	☐ Very flexible	(3)
			☐ Important	(2)	☐ Flexible	(2)	☐ Flexible	(2)
			☐ Fairly important	(1)	☐ Fairly flexible	(1)	☐ Fairly flexible	(1)
			☐ Not important	(0)	☐ Not flexible	(0)	☐ Not flexible	(0)

Traditional roof materials replaced modern roof materials
Target: Residents who changed from modern roof materials to traditional roof materials
Sample: 92
Purpose: To investigate the reasons for choosing traditional roof materials over modern roof materials
Please rate each factor for choosing the use of traditional roof materials and modern roof materials.

No	Factors	Description	Rate level of importance		Rate traditional roof material		Rate modern roof material	
1	Affordability	Ability to purchase materials	☐ Very important	(3)	☐ Not expensive	(3)	☐ Not expensive	(3)
			☐ Important	(2)	☐ Fairly expensive	(2)	☐ Fairly expensive	(2)
			☐ Fairly important	(1)	☐ Expensive	(1)	☐ Expensive	(1)
			☐ Not important	(0)	☐ Very expensive	(0)	☐ Very expensive	(0)
2	Availability	Access to materials	☐ Very important	(3)	☐ Highly available	(3)	☐ Highly available	(3)
			☐ Important	(2)	☐ Available	(2)	☐ Available	(2)
			☐ Fairly important	(1)	☐ Fairly available	(1)	☐ Fairly available	(1)
			☐ Not important	(0)	☐ Not available	(0)	☐ Not available	(0)
3	Durability	Lifespan of materials	☐ Very important	(3)	☐ Very long (> 50 years)	(3)	☐ Very long (> 50 years)	(3)
			☐ Important	(2)	☐ Long period (30-50 years)	(2)	☐ Long period (30-50 years)	(2)
			☐ Fairly important	(1)	☐ Medium period (10 – 29 years)	(1)	☐ Medium period (10 – 29 years)	(1)
			☐ Not important	(0)	☐ Short period (< 10 years)	(0)	☐ Short period (< 10 years)	(0)
4	Flexibility of regulation	Flexibility of the PSMV regulation on type of roof tiles that can be used	☐ Very important	(3)	☐ Very flexible	(3)	☐ Very flexible	(3)
			☐ Important	(2)	☐ Flexible	(2)	☐ Flexible	(2)
			☐ Fairly important	(1)	☐ Fairly flexible	(1)	☐ Fairly flexible	(1)
			☐ Not important	(0)	☐ Not flexible	(0)	☐ Not flexible	(0)
5	Importance of roof in building architecture	Importance of roof design on building architecture	☐ Very important	(3)	☐ Very important	(3)	☐ Very important	(3)
			☐ Important	(2)	☐ Important	(2)	☐ Important	(2)
			☐ Fairly important	(1)	☐ Fairly important	(1)	☐ Fairly important	(1)
			☐ Not important	(0)	☐ Not important	(0)	☐ Not important	(0)

Appendix 4: Relation between the PMSV and Significant Changes

Steps taken to perform MCA are listed below (Nenadic & Greenacre, 2005):

1. Data need to be converted to binary values. Each variable is dichotomized into presence of significant change (coded as 1) and absence of significant change (coded as 0). Binary coding of variable is known as indicator matrix $\mathbf{Z}$.
2. Obtain Burt matrix $\mathbf{C}$, a contingency table from indicator matrix $\mathbf{Z}$: $\mathbf{C} = \mathbf{Z}^T \mathbf{Z}$. Matrix $\mathbf{C}$ contains diagonal matrices that show frequencies of variables.
3. Divide $\mathbf{C}$ by n, total number of frequencies to obtain correspondence matrix $\mathbf{P}$

$$\mathbf{P} = \{p_{ij}\} = \frac{c_{ij}}{n} \text{ where } n = \sum_{ij} c_{ij} \quad (1)$$

4. Calculate row masses r_i and column masses r_j

5. Since Burt matrix is square symmetric, perform eigenvector-eigenvalue decomposition

$$\mathbf{S} = \{s_{ij}\} = \frac{(p_{ij} - r_i r_j)}{\sqrt{r_i r_j}} \quad (2)$$

to obtain eigenvectors $\mathbf{U} = \{u_{is}\}$ from decomposition and eigenvalues λ_s^2 from $\mathbf{S} = \mathbf{V} \Lambda \mathbf{V}^T$.

6. Obtain standard coordinate of i-th row or column for s-th dimension as

$$a_{is} = v_{is} / \sqrt{r_i} \quad (3)$$

and principal coordinate as

$$f_{is} = a_{is}\lambda_{is} \tag{4}$$

7. Computation of MCA of inertia in each dimension underestimates the quality of fit and needs to be adjusted where Q represents number of variables.

$$\lambda_s^{\text{adj}} = \left(\frac{Q}{Q-1}\right)^2 \left(\lambda_s \frac{1}{Q}\right)^2 \tag{5}$$

8. Choose number of dimensions to retain according to following criteria: eigenvalue that exceeded $1/Q$, scree plot (plot of total variance related to each dimension), and interpretability of MCA (Jobson, 1992; Charriere et al., 2012).
9. Plot map to show association between variables.

Steps taken to perform HCA (agglomerative technique) for N records in dataset as follows (Lebart, 1994; Riviere, 2010):

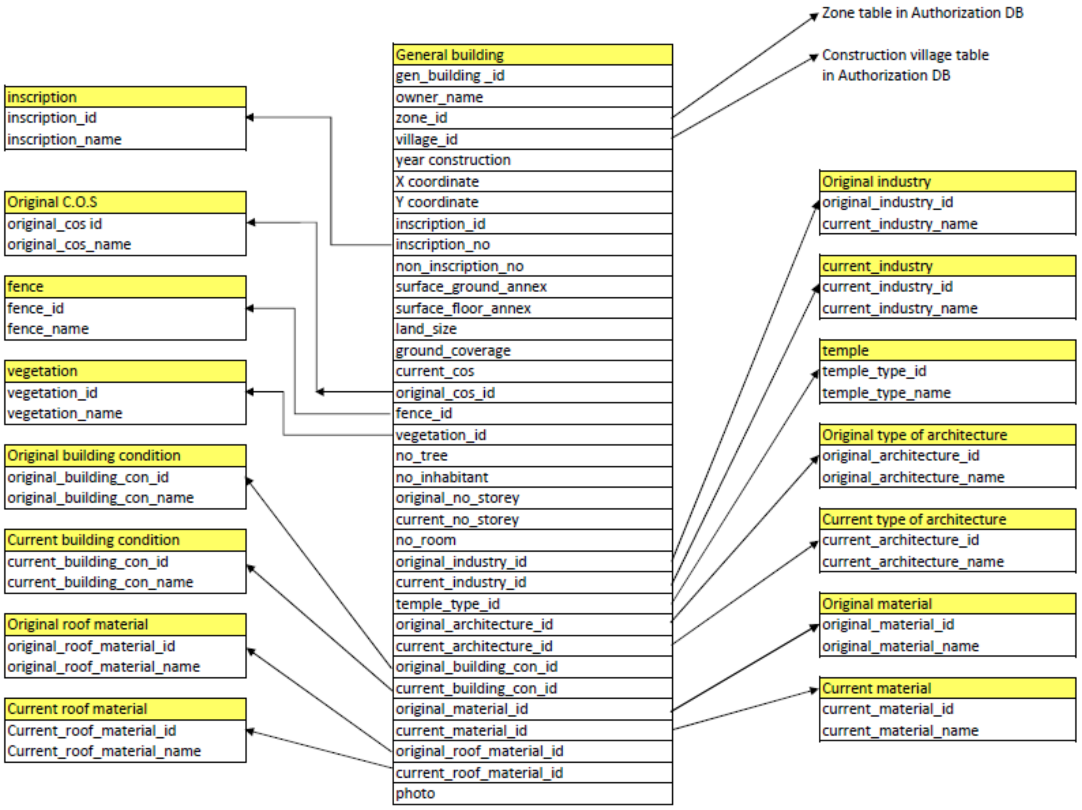
1. Assign a cluster for each observation. For example, form N clusters and each cluster contains only one record.
2. Calculate distance D for each cluster pair X_i and X_j create a $N \times N$ proximity matrix D
3. Identify closest (most similar) pair of clusters and merge into a single cluster. The number of clusters is reduced by one, $N-1$.
4. Compute distances (similarities) between new cluster and each of the remaining $N-2$ clusters from Step 1.
5. Update proximity matrix D by
   - Deleting rows and columns corresponding to the closest clusters in Step 3.
   - Adding a row and column for new cluster with the distances from Step 4.

6. Repeat steps 2 through 5 until all items are clustered into a single cluster of N observations.

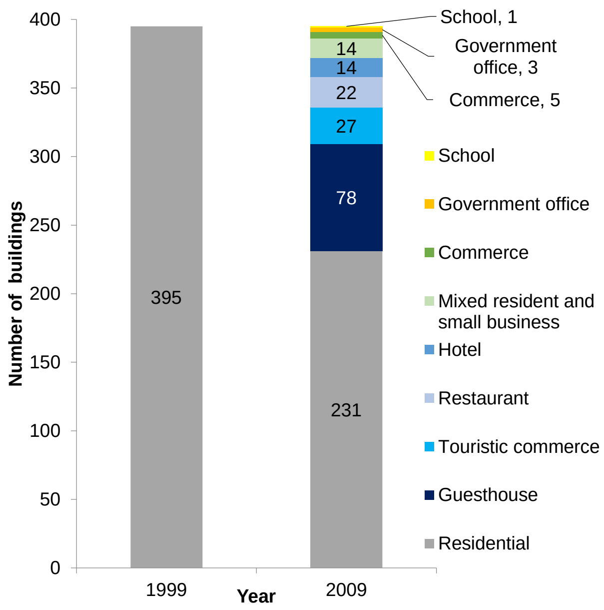
Ward's method algorithm was utilized to calculate squared Euclidean distance (similarity). Hence, the distance between two clusters, say pair (r) and (s), is defined as the average distance between all records of the two clusters with adjustment of covariance. There is minimum loss of inertia at each step to keep clusters homogenous. Ward's method has shown good compatibility with correspondence analysis and classification (Benzecri, 1992; Lebart, 1994). Ward clustering provides decomposition of inertia with respect to the nodes of a dendogram, and is similar to the decomposition in the correspondence analysis context (Greenacre, 2007; Markos, 2010).

Automatic truncation of a dendogram is determined by the criterion that the increase of dissimilarity is strong when it is combining groups which are already homogenous. This is the level where it decides to stop aggregating observations (Addinsoft, 2016). The dendogram is automatically truncated to retain the number of clusters using Shannon's entropy. It is based on the largest decrease in Shannon's entropy between a node and the next one. It minimizes using $1/(entropy\ (node\ (i-1)-entropy\ (node\ (i)))$ and truncates when minimum level is reached (Addinsoft, personal communication, March 21, 2016).

Appendix 5: ER Diagram of General Building Database

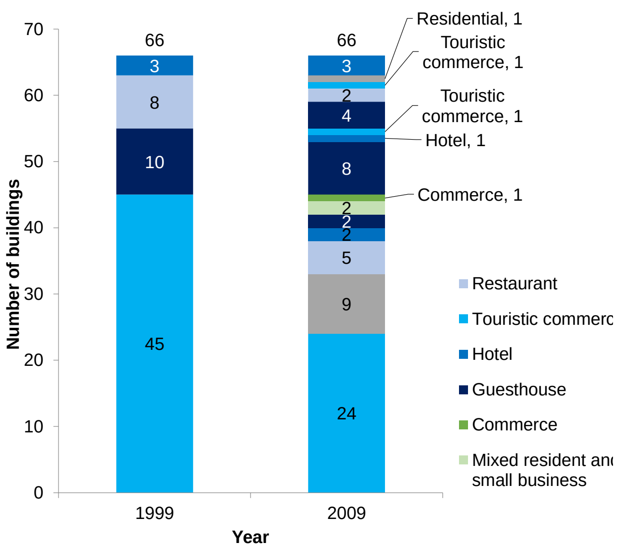


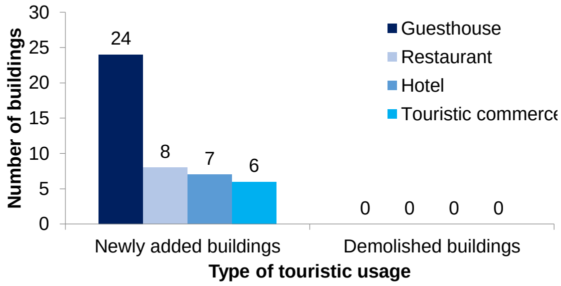
Appendix 6: Building Usage



Change in residential usage (N=395)

Source: Department of World Heritage, 2009





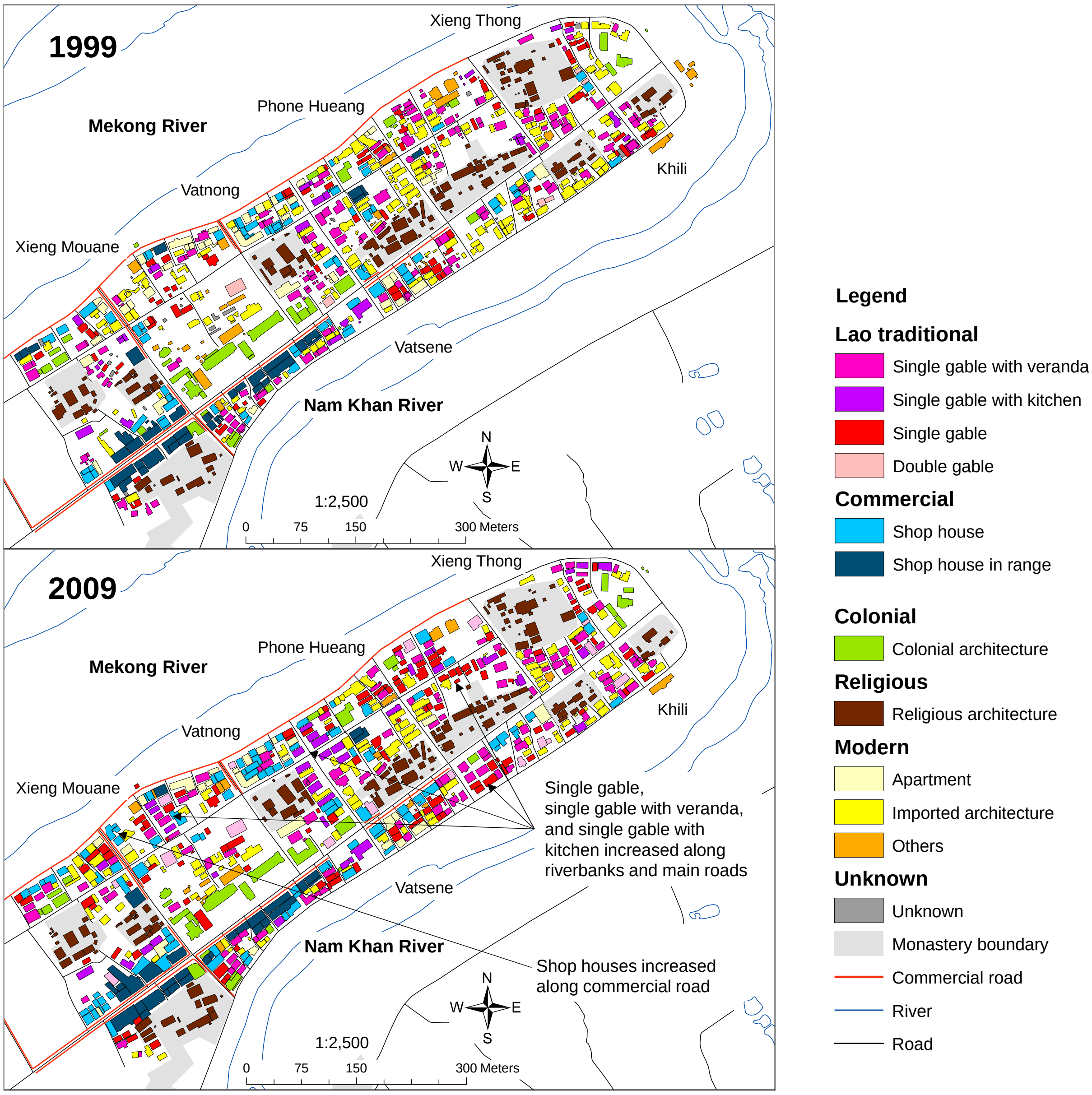
Change in touristic usage (N=66)

Source: Department of World Heritage, 2009

Touristic new buildings (N=45) and demolished buildings (N=0)

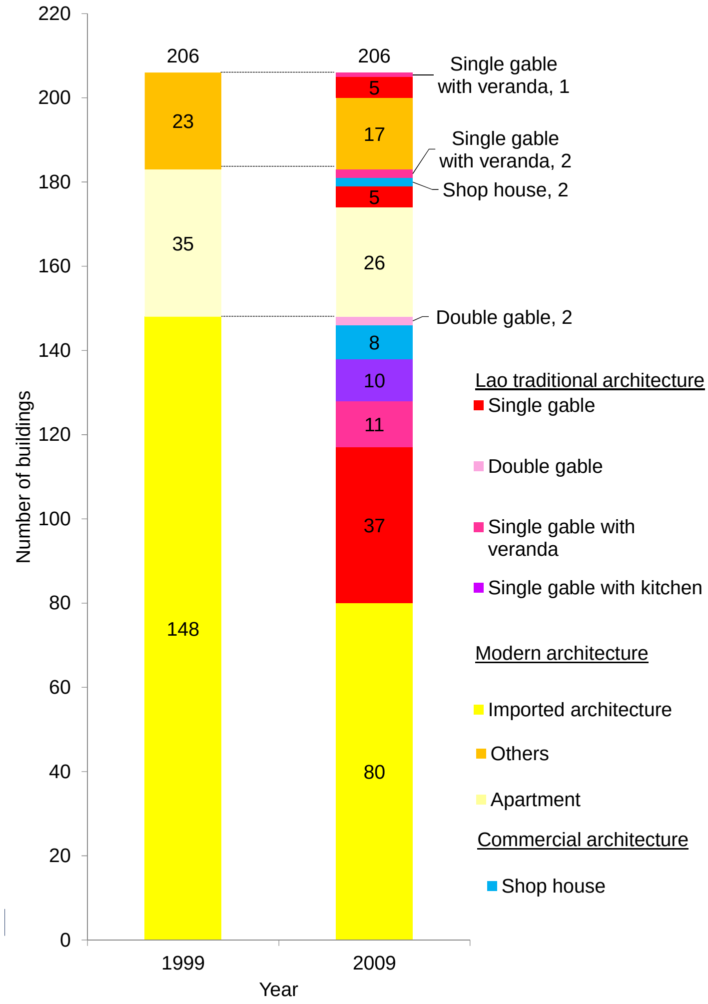
Source: Department of World Heritage, 2009

Appendix 7: Building Architecture



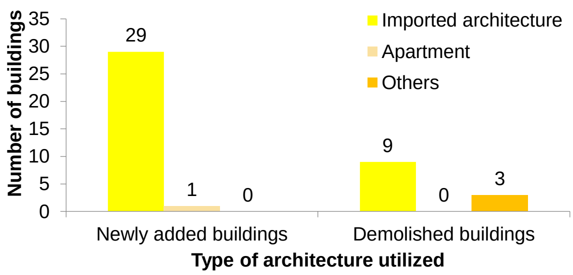
Comparison of spatial distribution of different types of Lao traditional, commercial, and modern architecture

Source: Department of World Heritage, 2009



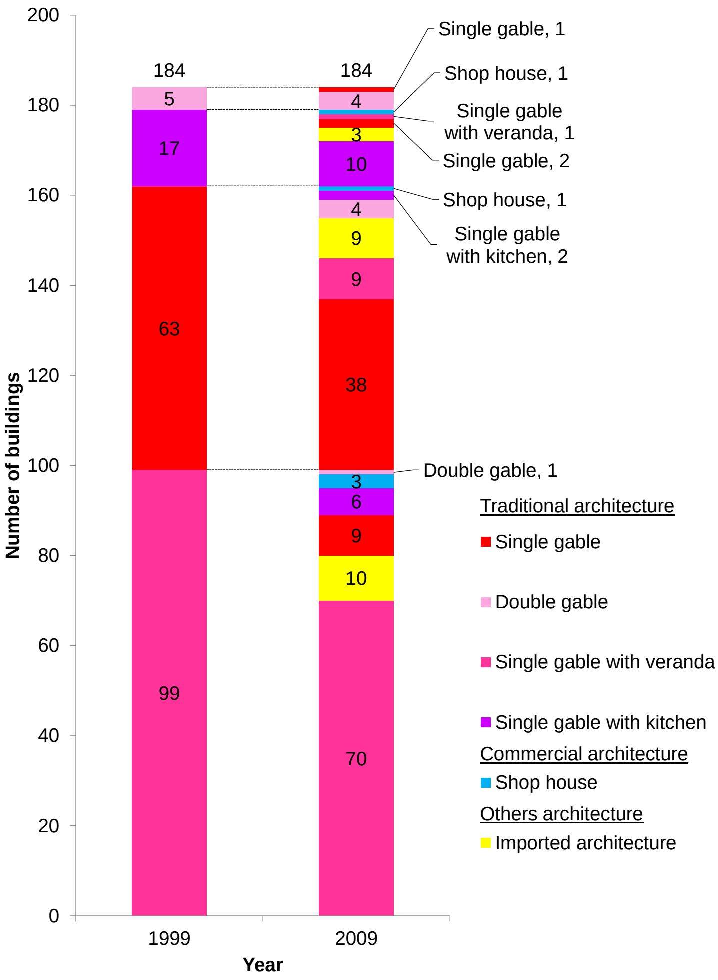
Change in modern arhictecture (N=206)

Source: Department of World Heritage, 2009



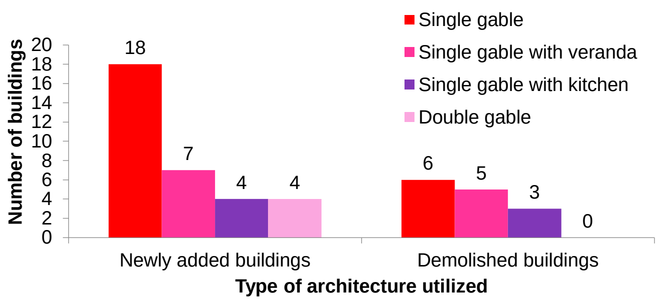
New buildings built using modern architecture (N=30) and demolished modern architecture (N=12)

Source: Department of World Heritage, 2009



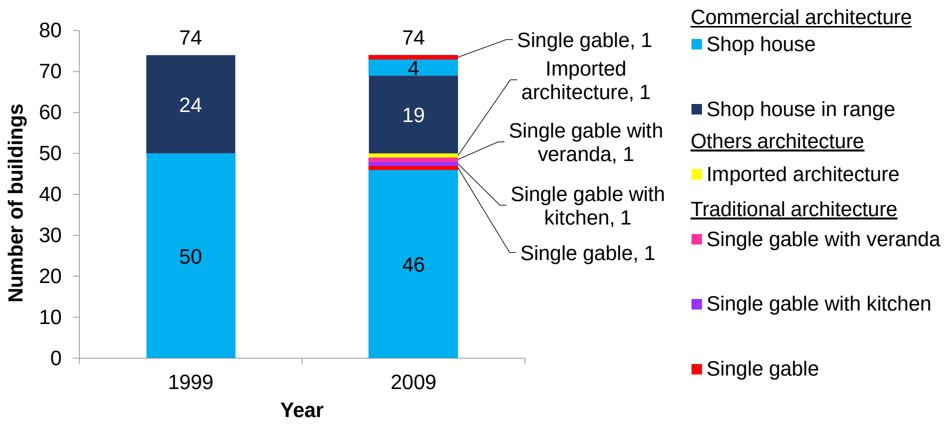
Change in Lao traditional architecture (N=184)

Source: Department of World Heritage, 2009



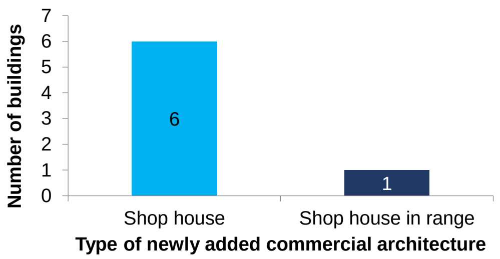
New buildings built using Lao traditional architecture (N=33) and demolished Lao traditional architecture (N=14)

Source: Department of World Heritage, 2009



Change in commercial architecture (N=74)

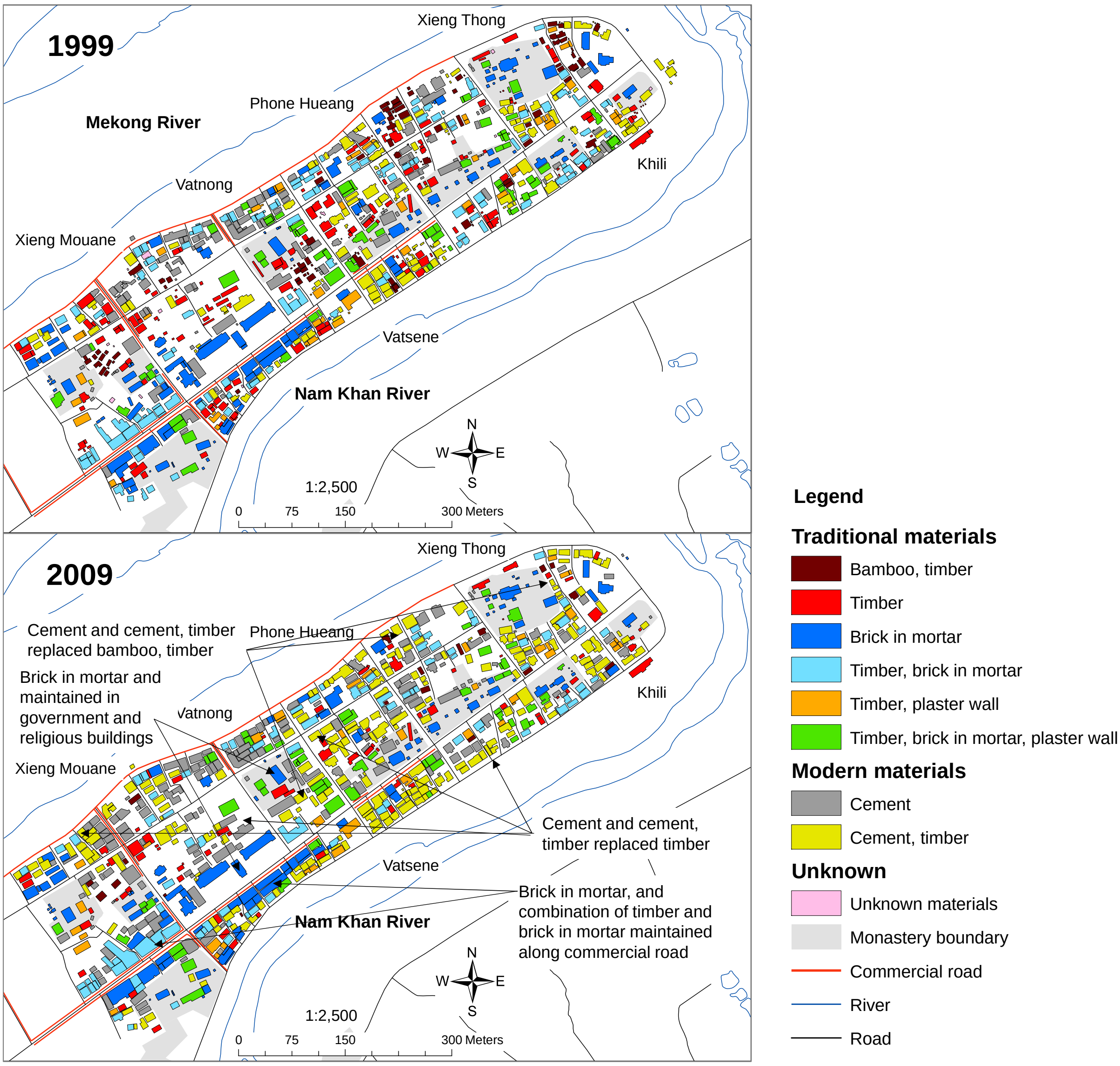
Source: Department of World Heritage, 2009



New buildings built using commercial architecture (N=6) and demolished commercial architecture (N=1)

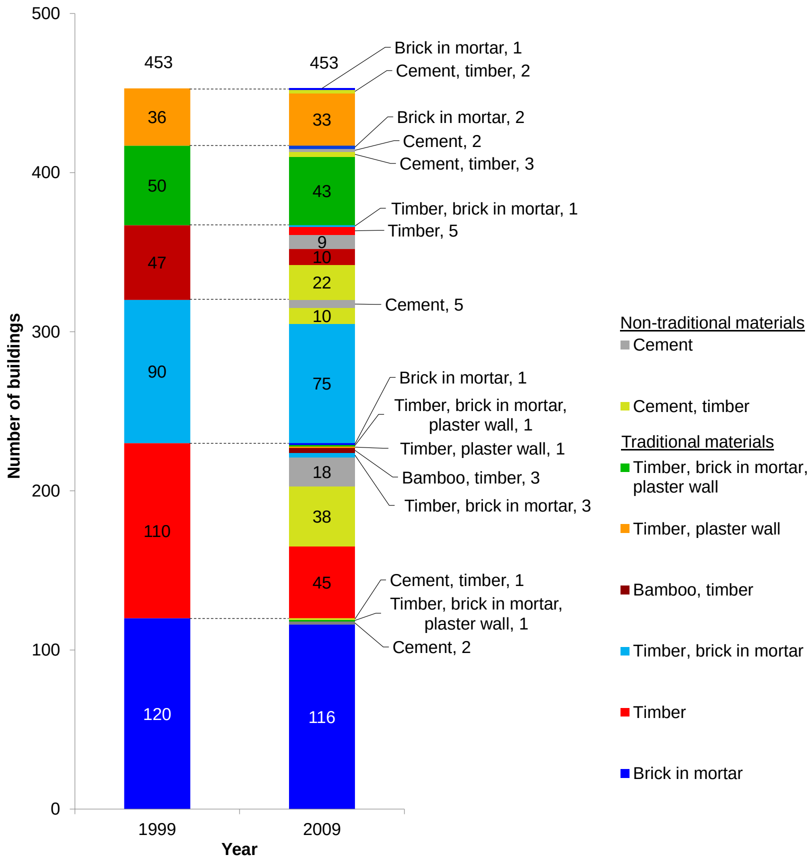
Source: Department of World Heritage, 2009

Appendix 8: Building Materials



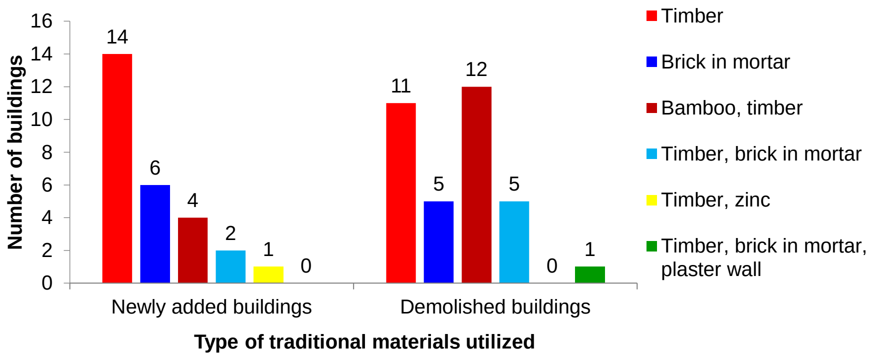
Comparison of spatial distribution of different types of traditional and modern materials

Source: Department of World Heritage, 2009



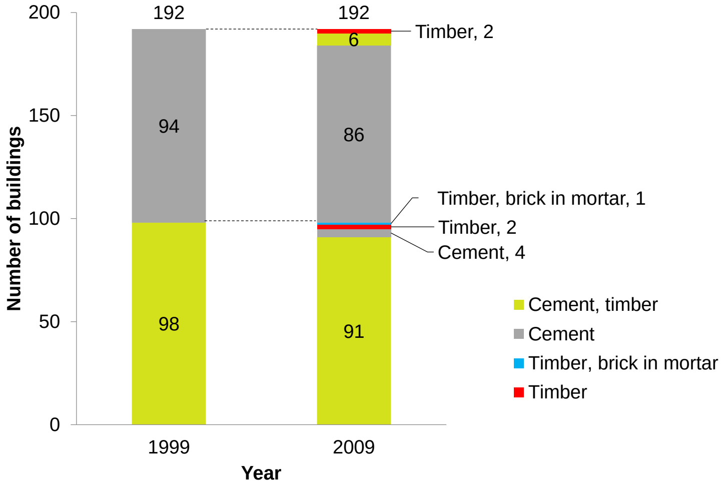
Change in traditional materials (N=453)

Source: Department of World Heritage, 2009



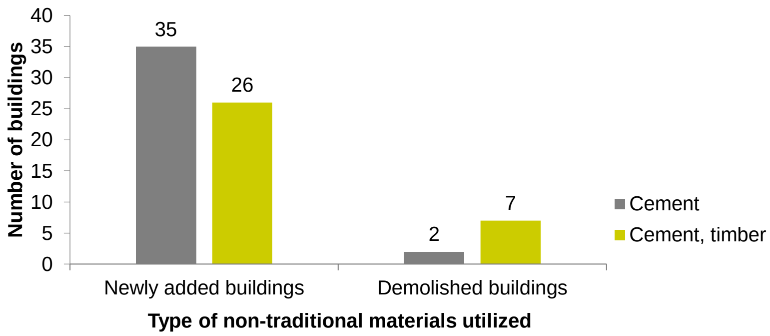
New buildings constructed using traditional materials (N=27) and type of traditional materials in demolished buildings (N=34)

Source: Department of World Heritage, 2009



Change in modern materials (N=192)

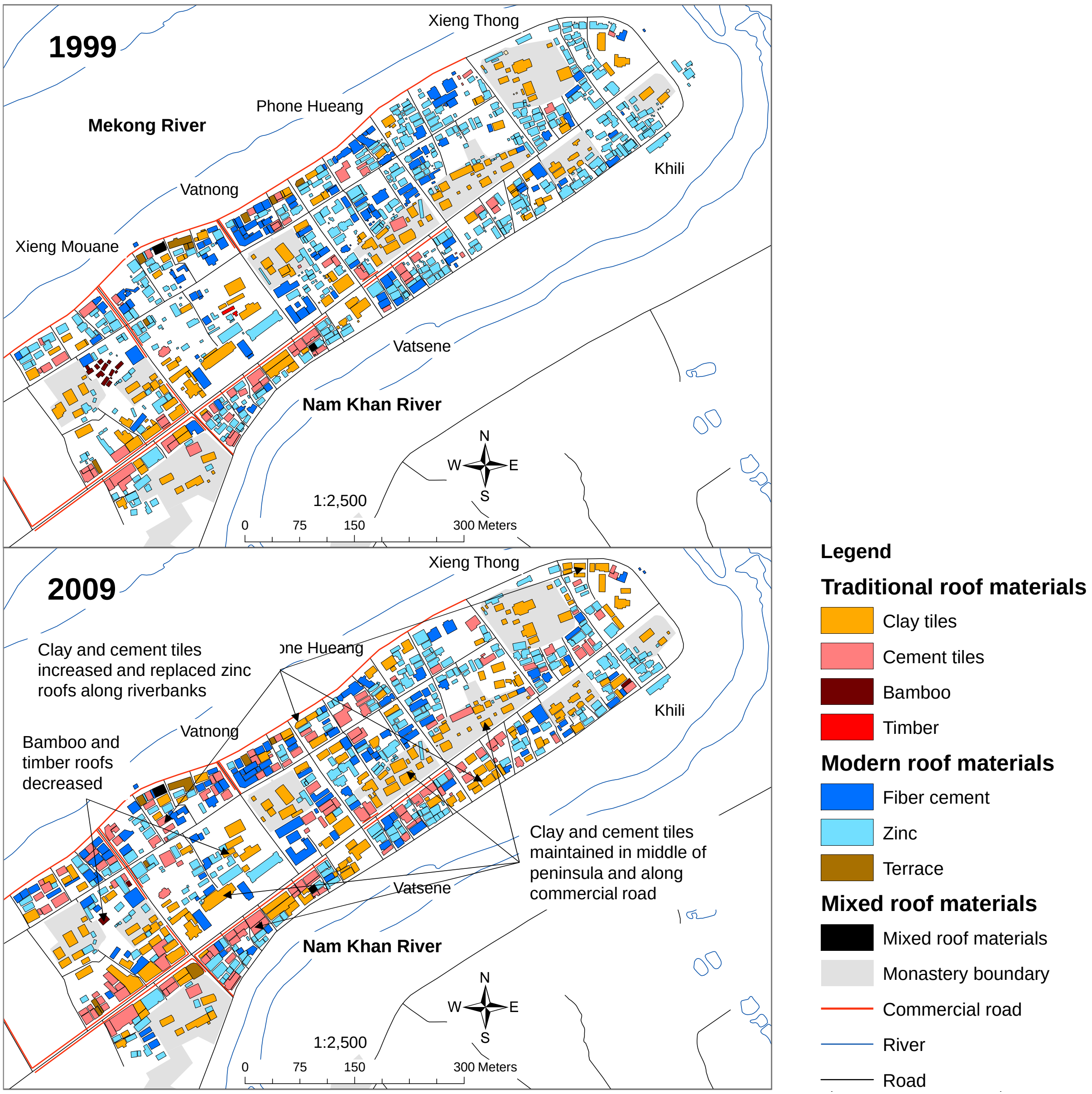
Source: Department of World Heritage, 2009



New buildings built using modern materials (N=62) and type of modern materials in demolished buildings (N=9)

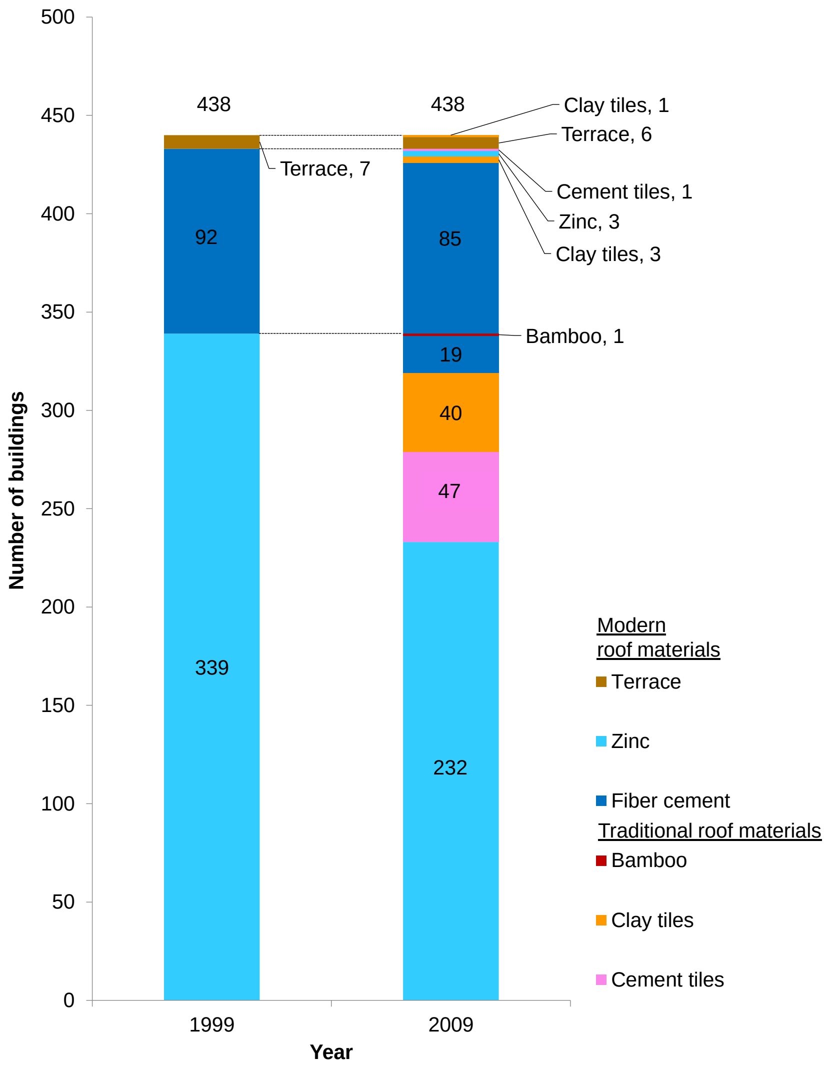
Source: Department of World Heritage, 2009

Appendix 9: Roof Materials



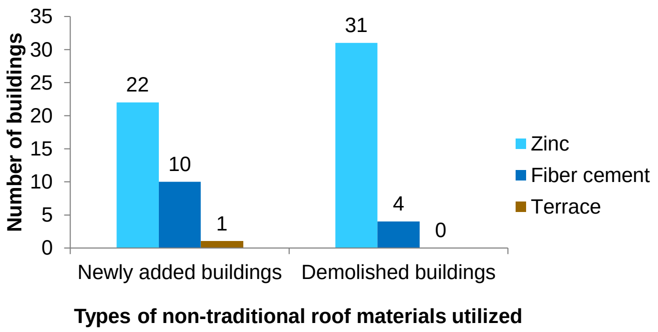
Comparison of spatial distribution of different types of traditional and modern roof materials

Source: Department of World Heritage, 2009



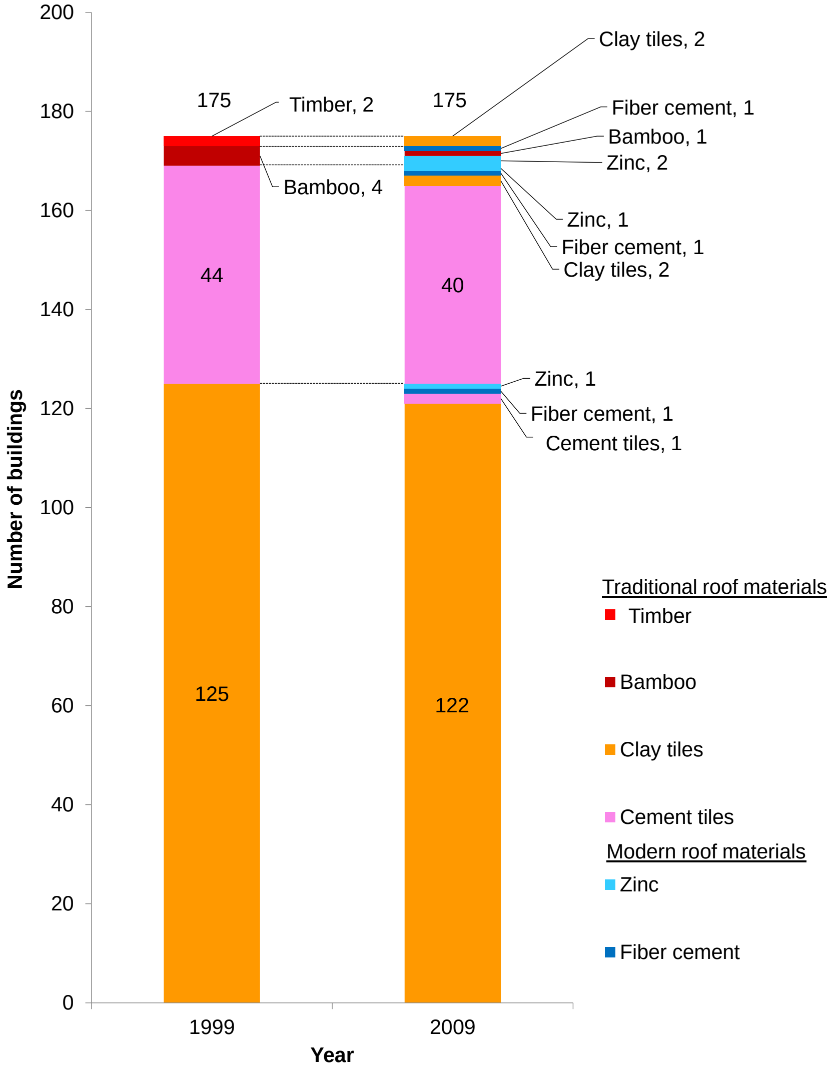
Change in modern roof materials (N=438)

Source: Department of World Heritage, 2009



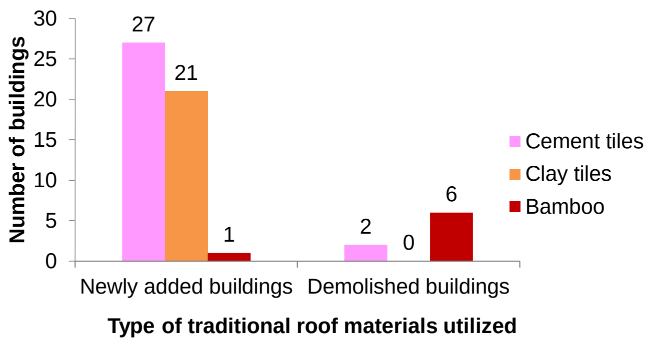
Types of modern roof materials utilized in new buildings (N=33) and demolished buildings (N=35)

Source: Department of World Heritage, 2009



Change in traditional roof materials (N=175)

Source: Department of World Heritage, 2009



Types of traditional roof materials utilized in new buildings (N=49)

and demolished buildings (N=8)

Source: Department of World Heritage, 2009