

INTERACTION BETWEEN URBAN SPATIAL ORGANIZATION AND FLOOD RISK. TAIPEI CASE STUDY (1895-1945)

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ABSTRACT: Using a systems approach, a city can be considered as a complex system divided into several subsystems. Each of these systems require numerous regulations which enable the actors, at all times, to maintain or reestablish desirable urban functions during/after disruption from external events such as natural hazards. In this sense, flood risk could be considered as one of elements which can trigger urban regeneration. Among urban subsystems, our research focuses on the urban spatial morphology (USMS) which is made of geographical, physical and societal components. Surrounded by steep hills on three sides, Taipei is located on the floodplain of the Danshuei River. According to historical records, typhoons sweep through Taiwan around 3 times per year. With these geographical characteristics, the city has endured several floods and become more resistant to flood risks by adopting various adaptive regulations and measures. In this paper, a description firstly is given to show how floods caused by typhoons promoted interactions between components of the USM during 1895-1945. Secondly, a demonstration exposes that adapted architectural and urban planning regulations protected the city from flood risks. Finally, an analysis of the City's Master Plan displays that flood risk became one of key components of urban structure.

Key Words: Flood risk; resilience; Taipei; urban spatial morphology

1. INTRODUCTION

Over last few years natural disasters, especially flood-related, seem to be getting more and more frequent and destructive. Also, they are widely broadcast by the media. Certain research demonstrated that these disasters were related to the location of buildings and to the way they were built, especially in cities (Adikari et al. 2010) where numerous constructions were situated along the river front or along the coastline, and in some cases both. The construction of dikes and of high walls (which corresponds to the concept of resistance) is nowadays commonly applied as flood protection measures. Moreover, non-structural measures, such as warning systems based on real-time flood forecasting techniques, are used together with floodplain zoning and local flood proofing and flood insurance programs (White, 1974; Rossi et al., 1994). However, it is feared that rapid and dense urbanization as well as climate change may increase in frequency and intensity of flooding despite such measures.

The question then arises as to how to reverse the trend of increasing urban flood vulnerability. Recent research in flood risk management suggests using the concept of resilience so as to help cities to better deal with unexpected events. (Resilience Alliance, 2007) First introduced as a descriptive ecological term (Holling, 1973) the theory of resilience offers insights into complex systems that take into account criteria such as memory, self-organization and diversity. Since the 1970s the concept of resilience has been interpreted with multiple levels of meaning. In relation to flood risk management, it inspired the basic principle reflecting the idea of "living with floods". An urban flood resilient system is not only concerned

with resisting/withstanding a flood, but also active with coping with and recovering from impacts of a flood as well as adapting itself to the next flood (Folke et al., 2002; Bruijn, 2004; Provitolo, 2009). The latter puts the flood risk management strategy into a long-term perspective. Regarding to flood risk management, recently the concept of resilience is visible in few urban planning literature, especially in urban spatial morphology (Gersonius et al., 2008).

Using a systems approach, a city can be considered as a complex system, which may be divided into several subsystems, such as urban spatial morphology system (USMS) (Alain, 2004). In the process of urbanization, components of these subsystems may be re-organized in order to achieve a goal or to relieve an urban problem by adopting regulations and launching urban renewal projects. For example, in the history of numerous cities, urban crises in different periods (such as sanitary, economic or environmental crises) have stimulated thoughts on architectural and urban forms (Choay, 1965; Sitte, 1980). From this perspective, our research questions the relation or the interaction between flood risk and urban spatial organization. Special attention is given to the components of the USMS which are reconfigured in the process of urbanization in order to withstand, cope with, recover from and adapt themselves to floods. This paper aims to demonstrate the interaction between components of the USM and floods which trigger urban regeneration.

2. METHODOLOGY

2.1 Case study: the city of Taipei

Aware of the hazardous geographical and climate situation, together with dense and rapid urbanization, varied structural and non-structural flood mitigation measures were built progressively since 1884 to protect the city from flooding. The Nari typhoon which swept Taipei between 16-19 September in 2001, was the heaviest precipitation the city suffered in the last 100 years (according to the National Meteorological Office) and it revealed problems linked to heavy precipitation. Despite of such flood risk mitigation measures, an area of about 1900 hectares was flooded in Taipei because of failure of structural flood mitigation measures. The total economic loss of Taiwan was evaluated at around 40 billion NT dollars (around €0.95B) (Water Resources Agency, 2001).

After 2001, the city's government became aware of limitation of the existing flood protection system and established Comprehensive Flood Measures Plans (CFMP) in 2005 which managed flood risk mitigation strategy at the watershed scale (Committee of CFMP, 2005). Also, in combination with the launched CFMP, the Taipei City Master Plan (CMP) 2009-2040 took flood risk into account by reconfiguring urban spatial organization. (Taipei City Government, 2009) This latest CMP referred to the one approved in 1932, the first and the only historical CMP integrating flood risk in urban spatial reconfiguration. In this paper, a demonstration was carried out to show how flood risk in Taipei progressively became one of the key urban structure components during the period of 1895-1945, when the country was under Japanese occupation.

2.2 Method

Historical maps of Taipei drawn in 1895, 1905 and 1932 and published by the Japanese colonial government of Taiwan (JCGT) were served as reference maps for a space transformation and structural analysis. Also, the city's official archives and related research materials were the main data sources of this study. Based on the mentioned documents, all iconographies of the USMS analysis were produced by this study with GIS tools.

The urban spatial morphology system was divided into three dimensions: geographical, physical and societal. (Boire et al., 1981; Alain, 2004) The term "geographical dimension" was chosen but not "natural dimension" because little portions of urban areas remain "natural" without man-made transformation. The geographical dimension of the USMS consists of four components: topography, hydrology, green space and geology (Boire et al., 1981). In this study, geology was not taken into account because of a lack of

relevant data. The analysis of geographical dimension and climate firstly provides us with information of physical environment and characteristics of natural hazard.

Along with three components proposed by Alain (2004): buildings, street pattern and open space, "structural measure" was also comprised into the physical dimension of the USMS. Secondly, taking the arrival of JCGT in 1895 as the baseline, ten significant floods, which engendered severe damage in the city, were chosen for this study in order to show reconfiguration of components of physical dimension after the floods. Furthermore, analysis of societal dimension of the USMS, including approved regulation, urban planning documents and stakeholders involvement, can provide us with an overall comprehension of the reactions of a society facing floods (the ability of adapt and cope capacities) (Turber et al., 2003; Leurs, 2005). Finally, according to applied urban flood risk management strategies, we divided the study period (1895-1945) into three phases in order to demonstrate how flood risk interacted with the other components of the USMS by analyzing the historical maps of Taipei, the one laid out in 1895 and the City's Master Plan of 1905 and 1932.

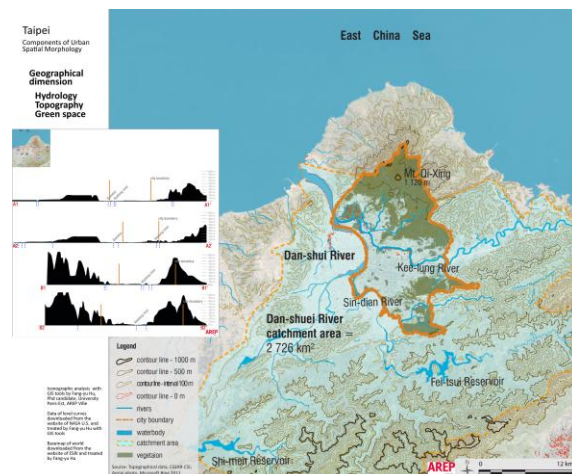
3. RESULT AND DISCUSSION

3.1 Geographical dimension of the USMS

3.1.1 Hydrology

The current extent of Taipei is mainly located in a relatively narrow valley of the Keelung and Xindian rivers, which fall into the Danshuei River along its urban western border. (Figure 1.) The Danshui river channel is 592 kilometers long with a catchment area of 2726 square kilometers. The short river length and the steep bed slope result in short concentration time from the upstream watersheds to the downstream floodplains as quick as 3 to 6 hours (Taiwan Water Resource Agency, 2013), which is the main characteristic of flash flood.

Figure 1. Geographical dimension of Taipei

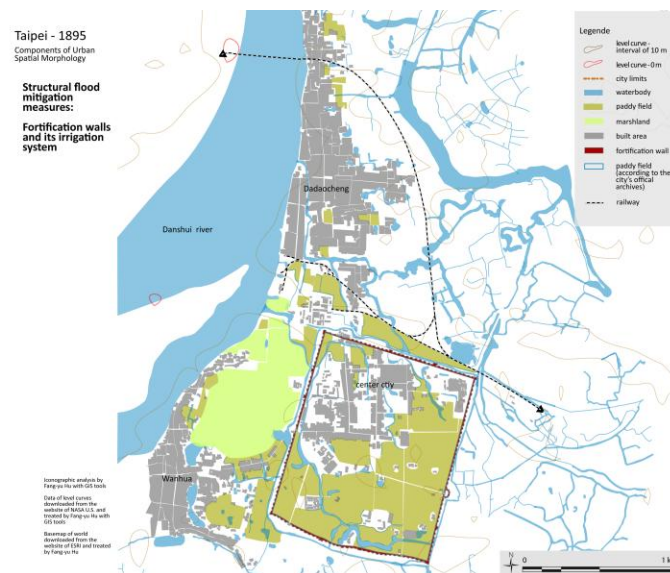


In addition, a 22-kilometer irrigation canal system named Liugongjun for flooded paddy field farming was achieved by a Chinese immigrant in 1763. These canals ranged from wide navigable waterways for transportation use to narrow ditches for irrigation and drainage purposes (Taipei Liugong Irrigation Association, 1993). However, they spread out on the floodplain of the Danshui River which aggravated flood risk, in particular during heavy rainfall.

3.1.2 Topography and green space

The northeastern region of the city is mountainous, where it reaches 1120 meters at the Qixing Mount. (Figure 1.) The southeastern and southern areas have few hills, and the northwestern part is an alluvial floodplain with elevation below 5 meters. Taipei city's first dwellers started to settle at the junction of the three rivers, on the right bank of the Danshui River, called Wanhua. (Figure2.) The northern port of Dadaocheng replaced it and became the commercial centre because of the shift of the confluence of the 3 rivers in 1860. The port area is flat and low-lying (about 6 meters ASL). Moreover, an approximately 40-hectare marshland with an elevation of 2.5-meter, which was situated between these port areas, was a natural barrier to urban expansion before 1905. Besides the human settlement in the port area, the major land use was paddy fields in current urban areas during 1895-1945.

Figure 2. Taipei 1895



3.1.3 Climate

Taipei has a humid sub-tropical climate with an annual average precipitation of about 2500 mm. Most precipitation concentrates from May to September. According to historical records, typhoons sweep through the island around 3 times per year and lead to precipitation which can reach a total of over 100 mm in an hour.

From the geographical dimension analysis of the USM, the city of Taipei is prone to fluvial and pluvial floods. Moreover, due to steep bed slope of Danshui river's tributaries and to heavy rainfall often caused by a typhoon, flash flood is a threat to the city of Taipei located on the floodplain of the Danshui River.

3.2 Interaction between the components of the USMS and the ten floods

After analyzing related urban regulations approved after ten floods, one in 1895, three in 1898, five between 1910 and 1912 and one in 1920 (Table 1.), the analysis result showed that after each event certain components of the USM were rearranged according to adapted urban regulations. However, depending on priority setting of JCGT in the face of flood risk, the components of the USMS were reorganized differently in order to relieve the most urgent urban issues. In this sense, taking the arrival of JCGT in 1895 as a baseline, the study period was divided into three phases: urban drinking water and sanitation improvement, implementation of structural flood mitigation measures and river watershed management and combination of urban planning and urban flood risk management. Because of serious

damage caused by floods, we expose that flood risk progressively became one of key components of urban regeneration by analyzing urban planning plans approved by the JCGT in 1905 and in 1932, which corresponded to the beginning of the second and the third phase of this study.

Table 1. Damage caused by the 10 floods during 1895-1945, source: Taipei City Archives

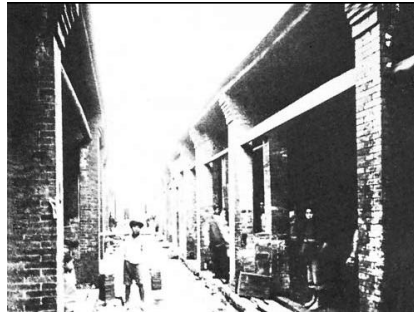
Phase	Date of event	Examined Affected areas	Total rainfall (mm)	Buildings' condition			Human losses (per.)	Injures (per.)
				Flooded	Ruined	Partial ruined		
Sanitation improvement	4 th Sep. 1895	Northern region of Taiwan (including the city of Taipei)	-	880	25	86	-	-
	6 th -9 th Aug. 1898		363	-	2203	3386	105	85
	28 th Aug. 1898		734	-	31	20	0	0
	29 th Sep. 1898		196	-	163	231	0	3
Implementation of structural flood mitigation measures &	2 nd Sep. 1910		433	353	104	122	13	1
	26 th Aug. 1911		302	36873	5122	5454	99	250
	31 st Aug. 1911							
	28 th Aug. 1912		325	37419	4090	4219	65	20
	16 th Sep. 1912		216	13011	2064	2115	9	24
	4 th Sep. 1920		375	-	-	-	-	-

1. Urban drinking water and sanitation improvement phase (1895-1904):

Fortifications walls, built under the governance of Chinese Qing dynasty since 1884, with a height of 4.8 meters, with a system of water control installed on each side of the walls protected the fortified area against military attack and flooding. Also, flood-proof architectural adaptations were realized in some commercial zones of the Dadaocheng district at the end of the Qing Dynasty (1887-1891), such as street broadening with tarmac pavement, roadside ditches and embankment implementing as well as elevation of building structures. Nevertheless, the installation of drinking water and sanitation networks was not yet built under the governance of the Qing dynasty in Taipei. The inhabitants of the city still drew drinking water from wells or rivers. Diseases spread due to stagnant waters, such as cholera and plague, represented a high rate of mortality during this period. During military attacks on the northern towns of Taiwan in the first Sino-Japanese War of 1894-1895, poor hygiene condition caused a significant loss of lives of Japanese soldiers. Following this experience and under hot humid weather in summer, improving hygiene condition was the priority task at arrival of the Japanese governor in June 1895 in order to maintain the military forces.

In the first phase of the study period, four floods caused by typhoons, one in 1895 and successive three in 1898 resulted in serious damage. According to JCGT published documents, two ports areas with narrow traditional-style of 2-m streets (Figure 3.) and few roadside ditches were the most affected areas during these floods. Even if the fortification walls protected the central area of the city from fluvial flood, water logging occurred in this area because of the lack of proper drainage equipment to evacuate rainwater. During hot humid summer, the problem of water logging became an urgent and essential challenge for the JCGT after the 1895 flood in order to prevent the spread of soil and water-borne diseases.

Figure 3. Taipei 1896: Tudihoujie in Wanhua, narrow traditional-style of 2-m street (source: Taipei City Archives)



Two sanitary engineering experts, William Kinninmond Burton and Yashiro Hamano, hired from Tokyo after the 1895 flood, played a crucial role in improving the urban sanitary conditions to the city. Their proposals had an impact on flood risk management as well as urban spatial organization in many Taiwanese cities. Based on European sanitary engineering theories and practices at that time and on hydrological analysis after a series of fields visits in Taiwanese cities, Burton submitted several reports regarding improvement of urban sanitation and drainage system to the JCGT from 1896 to 1899. Taking street pattern as an example, according to experiences of European cities at that time, Burton suggested adopting rectangular grid street pattern rather than a ring and radial one, which the JCGT had planned to install in Taiwanese cities due to military concern (Official archives of Japanese Colonial Government of Taiwan, 1896). Moreover, based on cultural and geographical condition of Taiwanese cities, varied dimensions and materials of open and closed channels were proposed. In a bid to install roadside ditches and underground rainwater drainage system, he proposed street widths shall range from 27 m to 36 m which would become a reference for future urban spatial reconfiguration. However, before the JCGT could decide to apply or not these suggestions which were still in their preliminary concept stages until three floods occurred in 1898.

Sever damage was caused by the three successive floods in 1898 (Table 1.). This drew the attention of the JCGT on a temporal circle of flood risk management by implementing some suggestions of Burton and approving related urban regulations. Among these approved regulations, two of them deserved a special attention: "Building and housing code in Taiwan" and "Regulation of land preemption for public works". The former defined different rules preferring Japanese stilt-style and Taiwanese clay constructions in order to minimize flood and wind damage. The latter gave the city government power and responsibility to legally preserve and purchase lands for public works, such as roads and structural flood mitigation measures.

Compared to the 1895 historical map of Taipei, the urban spatial configuration of the 1905 map shows that most actions taken by JCGT after major floods concentrated on improving urban sanitation in the city centre where government institutions were located and Japanese immigrants lived. Adaptations to flood risk in the first phase include removal of paddy fields and watercourses, street broadening, adapted building codes and installation of roadside ditches. (Table 2. and Figure 6.)

2. Implementation of structural flood mitigation measures and river watershed management phase (1905-1931): After the urban development plan of 1905 the official urban area expanded from 0.6 km² to 7.2 km², including the Wanhua and Dadaocheng districts, with a hosting capacity of 150 thousand inhabitants in 1929. Installation of a combined storm sanitary sewage system was the priority task, especially in these two port districts. However, few concerns were paid to flood risk mitigation, such as creation of floodwater retention area at the riverbank and implementation of open and closed channels. Structural fluvial flood protection measures were barely planned. Moreover, destruction of the old fortification walls in 1905 meant nearly no flood defense against fluvial flood, except a 818-m stone embankment along the Danshui river near the railway station. The location of the old fortification walls was converted into three-lane boulevards with closed channel which drained water into the Danshui river. Furthermore, the

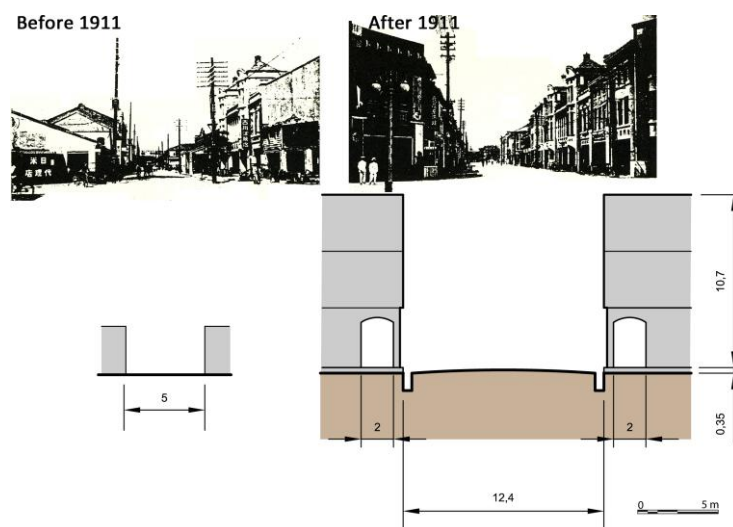
possibility of intense rainfall during a typhoon was not taken into account in the combined storm sanitary sewage system.

The most serious damages caused by the five floods during 1910-1912 (Table 1.) since the arrival of JCG pointed out the errors of fluvial flood risk ignorance. Taking Japanese style buildings as an example, according to the "Building and housing code in Taiwan" approved in 1900, structures of this kind of constructions were elevated nearly 105 cm above the street level in order to protect the constructions from floodwater. In spite of the precautionary principal, these constructions were mostly inundated to a depth of 60 cm floodwater during the 1911 floods. According to official review report of these floods, the water level of the Danshui River during the flood was much higher (6.9 m) than outlets of closed channels (4.2 m). In this case, the closed channels were unable to drain rainwater toward the river. Moreover, without installation of floodgates, floodwater of the river flowed to urban areas by closed channels and resulted in water logging in urban areas.

After the 1911 floods, the JCGT was aware that adapted buildings and implemented urban drainage system was insufficient to protect the city against flooding without structural fluvial flood mitigation measures. Three enhancement projects were approbated by the JCG as follows: enlargement of river bed of the Danshui River, implementation of a floodway to diverge river flow of the Dahan River and reinforcement of flood protection in urban area. However, river hydraulic engineering works were stopped in 1916 because of a lack of financial support from the JCGT. The third project named "the Lunzhong project" planned to improve urban flood protection, including raising of an enclosed levee along the Danshui and Dahan rivers and land filling low-lying areas in two port areas in combination with creating green spaces and floodwater retention pond. These projects engendered dynamic reconfiguration of the USMS. Moreover, the application of latest construction material and techniques of levee reinforced the defense capacity against fluvial flood.

Moreover, in cooperation with "Architectural Association of Taiwan", the dwellers of affected area initiated reconstruction work after the 1911 floods. According to the standards of this work, the JCG of Taipei approved in September 1911 the "Standards of reconstruction after a flood" including the width of streets and the height of arcade architecture for Taiwanese cities. These regulations aimed to enlarge the width of roads and to upgrade underground drainage work as well as to modify the building code in order to reduce flood impacts. (Figure 4.)

Figure 4. Before (left, 5-m street) and after (right, 12.4-m) the reconstruction after the 1911 flood (source of old photos: Huang, 1998; road sections drawn by this study)



Sever damage caused by the flood of 1920 was reported in Taipei during this flood as follows: Taipei bridge across the Danshui river was destroyed by floodwater; some closed channels were paralyzed

because of heavy discharge of floodwater. According to the official review report of this flood, a floodplain was a flat area which did not drain naturally via closed channels toward the river, especially when a levee blocked the flow to the river. However, this problem could be solved if pumping stations were installed which might efficiently remove rainwater from urban area (Huang, 2008). Also, this flood revealed that flood containment control could not reduce flood risk without associating the other flood mitigation measures, such as rainfall counting of drainage system, channel configuration design, and river watershed management.

Devastating damage caused by flooding in 1920 showed that the implemented urban flood containment control could not protect the city from a flood and it should be combined with river watershed management. From this perspective, the JCG was determined to continue the river watershed management works and approved several related regulations and projects in order to minimize fluvial flood risk, such as "the Forest preservation for flood control" project in 1925, "the River management act" in 1928, "Standards of fluvial flood risk assessment" and "Standards for river survey" in 1929, and "Standards for flood emergency readiness" in 1933 (Huang, 2008).

3. Combination of urban planning and urban flood risk management (1932-1945):

With rapid demographic growth, the UMP of 1932 expanded the official urban area from 7.2 km² to 66.8 km² with a hosting capacity of 600 thousand inhabitants in 1955. Learning from previous floods experiences, the UMP of 1932 took both fluvial and pluvial floods into account and proposed a series of flood risk mitigation measures which triggered urban reconfiguration. The design of multi-use public spaces activated the intense interaction of the components of the USMS, such as a combination of urban green spaces and a boulevard, of urban green spaces and hydrological networks as well as of a boulevard and hydrological networks.

A total of 5 green axis-corridors, a combination of urban green spaces and a boulevard, was designed for mixed purposes such as urban emergency management. These corridors linked 16 low-lying urban public parks which were configured for emergency shelters during an earthquake and potential floodwater retention zones. Among these five green corridors, 2 of them were also defined as "special boulevards", which combined the boulevards with hydrological networks. The width of these "special boulevards" I (Figure 5.) and II were respectively 47 m and 40 m with respectively a 13-m and 10-m open channel arranged in the middle. According to the pathway of Liugongjun, both of them were the major channels of irrigation networks and would be served as open channel to drain floodwater toward the Keelung River. In contrast to the watercourse removal applied previously in urban areas, the method of dredging and stream channel restoration was intended to drain floodwater as soon as possible into the river. Beside these five corridors, a road situated besides the levee along the Danshui and Xindian Rivers would serve as an emergency exit road during a flood. Only the axis-corridors and the "special boulevard I" of the UMP were realized because of the Second World War followed by the end of Japanese occupation.

However, after the 2001 flood, it is believed that alternative flood risk mitigation measures other than flood control ones shall be implemented in high-density urban areas in order to store extensive rainfall. In reference to the CMP approved in 1932, flood risks are one of key essential components of urban structure in the latest CMP. For example, a total of seven low-lying urban parks and several public spaces are planned for excessive floodwater storage during heavy precipitation events. Also, there are hopes of reopening "Special boulevard I" which was buried since the 1970s for floodwater evacuation and a planning of waterfront revitalization.

Figure 5. 47-m "Special boulevard I" with a 13-m open channel arranged in the middle (source: Shou, 2010; road section drawn by this study)

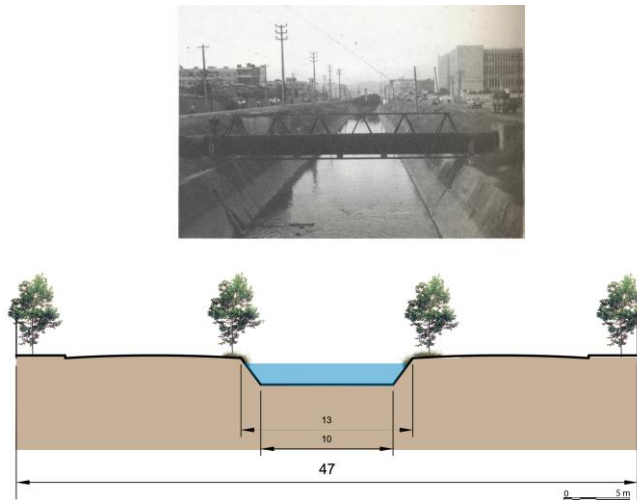
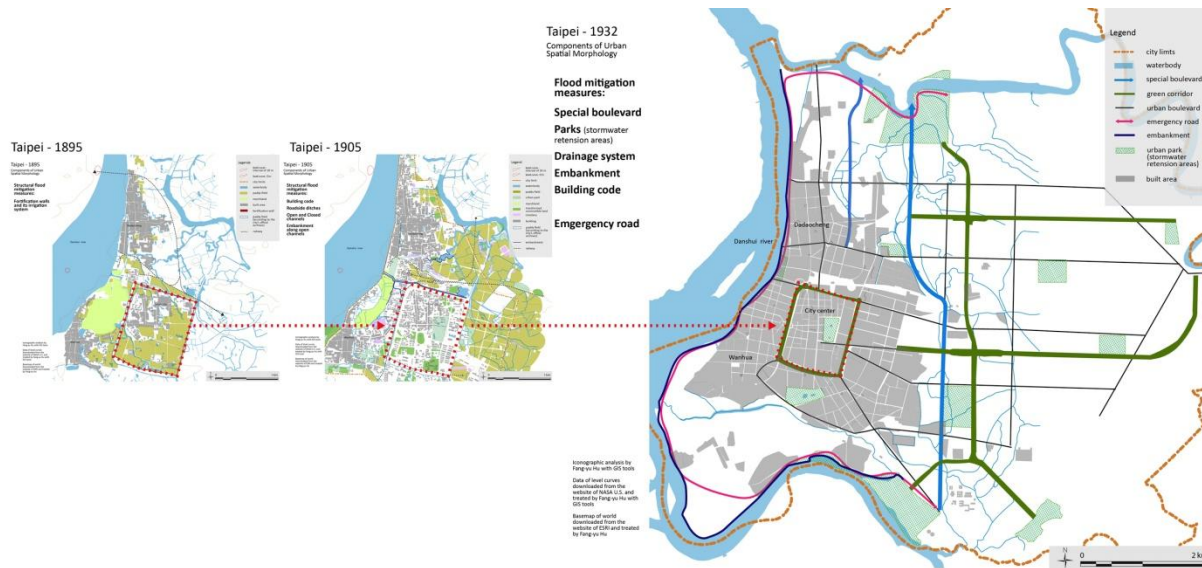


Table 2. Comparison of the USMS based on the historical maps 1895, 1905 and 1932

Year / Components		1895	1905	1932
Urban area (km ²)		0.6	7.2	66.7
Geographical	Topography	-	Retention area (riverbank)	Reclaimed marshland (6.3 m)
	Hydrology	Irrigation water system (city centre)	Diversion and fill-up of watercourses (city centre)	Diversion and fill-up of watercourses (3 districts)
	Green space	Flooded paddy fields (city centre)	Transformation of paddy fields into constructive areas	Few green space (3 districts)
		Marshland between 2 port areas	Decreasing extent of marshland	No more marshland
	Building	Elevating structures (in Dadaocheng district)	Adapted Japanese- & Taiwanese-style buildings (for 3 districts)	(for whole urban areas)
Physical	Street pattern	Irregular and narrow	Broadened streets Urban boulevard	Rectangular Special boulevard Green corridors Emergency road
	Open space	-	Riverfront (water retention)	16 Parks (water retention)
	Structural measure	Fortification walls	No fortification walls Urban drainage network	RC Levee with floodgates Urban drainage system

Figure 6. Comparison of the USM based on the historical maps of 1895, 1905 and 1932



4. CONCLUSION

Based on the above demonstration of the interaction between urban spatial organization and flood risk in Taipei during the period of 1895-1945, it is thought that flood risk was not only a danger to the city and its inhabitants but it also became, little by little, one of the essential components of urban structure and the evolution of the city's urbanization. As noted November (2008), urban risk which is here related to flood risk possesses its own consistency of urban interactions and should be reckoned with urban planning and with urban risk management. According to November, urban risk, especially natural or environmental such as floods, is not only a threat to the city and its dwellers but is also one of the essential components of urban structure and the evolution of its urbanization. From this perspective, flood risks could be considered as one of elements which can trigger urban regeneration.

The components of the urban spatial morphology system were configured/reconfigured in the processes of urbanization in order to withstand, cope with, recover as soon as possible from and adapt themselves to floods. Moreover, the current Taipei City Master Plan of 2009-2040 shows the potential of reorganization of components of urban spatial morphology which could improve flood risk management in face of urban future uncertainty, such as climate change.

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