Assessing the Urban Waterlogging Risk under Rainfall Condition in Shanghai

Lanjun Zou [1], Zhi Wang [1] and Yinming Yang [1]

[1] Shanghai Central Meteorological Observatory, Shanghai, China

Corresponding author's E-mail: lanjunzou@gmail.com

ABSTRACT

This paper focuses on the effect of weather and drainage conditions on urban waterlogging risk. The main objective is to examination whether or not weather rain condition impacts urban area and road in Shanghai. This general examination is a contribution that allows policymakers to assess the appropriateness of local traffic management strategies. To achieve this goal, the paper analyzes urban accumulated water and drainage data of over 260 different parts in shanghai with a historical series of ten years to find out the relationship between rainfall and ponding depth at the different traffic locations with the heterogeneity of the weather effects. Thus, six levels of urban waterlogging risk are set up with six different colours. With the statistical relationship between rainfall and ponding depth, AWS rain gauge data, radar QPE and NWP rainfall data are engaged in to predict urban waterlogging risk condition in Shanghai. The results indicate that rainfall increases the traffic intensity, and the perdition or warning information of urban waterlogging risk is useful to diminish traffic intensity. Further findings might be possibly achieved by studying rainfall impacts on local roads and by shifting the focus of research toward local human travel behaviour.

Keywords: urban waterlogging risk, Shanghai, traffic management

1 INTRODUCTION

With the extreme weather in the recent years, some cities in China were suffered by urban waterlogging because of short-time heavy rain. Shanghai is a city often suffered by urban waterlogging lying on the mouth of the Yangtze River with the altitude below sea level [1], [8]. Drainage network of Shanghai was greatly improved in the past 40 years, but pump drainage system is far behind actual waterlogging situation. There are still over 83 street blocks and 100 roads easily suffered by waterlogging. Some studies conclude that heavy rain will become more often and more serious during the background of global warming and rapid urbanization procedure [4], [6], thus traffic problem caused by urban waterlogging will be more serious [2].

Shanghai Weather Services highly concerns about urban meteorological disaster defence and reduction. With the rapid improvement of weather services, Shanghai Weather Services spread the weather monitor and forecast information more accuracy and timely for the public, but there are still some contradiction between weather services capability and disastrous weather prediction and warning, such as short-time heavy rain [5]. For example, on the morning of Aug. 25, 2008, with the short-time heavy rain above 110mm per-hour, waterlogging depth exceeds 20cm on more than 60 roads and hundreds of houses. Many sections of overpass, such as Wuzhong Road and Middle Ring, were temporally shut down for traffic safety [7].

Since urban waterlogging problems often trouble the people's daily life in Shanghai, especially for traffic, waterlogging risk assessing and prediction will be more urgent for municipal administration to take action. Rain pipe drainage management system is mainly controlled by pumps in Shanghai [3]. There are over 260 different drainage parts charged by these pumps in the whole city. Thus, waterlogging risk can be modelled according to drainage capability of different parts under different rainfall conditions. This will give a contribution that allows policymakers to assess the appropriateness of local traffic management strategies.

2 DATA

To find out the relationship between rainfall and ponding depth at the different traffic locations, urban accumulated water and drainage data of over 260 different parts in shanghai with a historical series of ten years are analyzed, and the AWS rain gauge data, radar QPE and NWP rainfall data are engaged in.
Otherwise, drainage facilities information is included. There are over 210 rain drainage facilities distributed over a considerable extent in Shanghai with different drainage mode in charge of a number of roads and street blocks (See Table 1).

Section name	*Area(km^2)*	*Rain drainage facilities number*	*Drainage mode*
Jia-bao-bei	691	15	Mainly area drainage, partly neighbourhood power and buffer drainage
Yun-nan	203	80	Mainly neighbourhood power drainage
Dian-bei	179	32	Mainly neighbourhood power drainage
Central city	50	23	Mainly neighbourhood power drainage
Dian-nan	187	16	Mainly area drainage, partly neighbourhood power drainage
Pu-dong	1977	45	Neighbourhood power drainage, area and buffer drainage

Table 1. Drainage information of different sections in Shanghai.

3 MODEL SETUP

3.1 Relationship between rainfall and ponding depth

To find the relationship between rainfall and ponding depth, one-hour-precipitation data of AWS and historical waterlogging data are applied. Statistics of waterlogging depth and one hour rainfall data shows their relationship can be expressed by some mathematical regression equation.

$$y = ax + b \quad (1)$$

where x is one hour rainfall (mm), y is waterlogging depth (cm). If y is negative, let it be zero.
For example, for the first zones (i.e. drainage capability is 27mm/hr), the relationship between rainfall and waterlogging depth is $y = 1.1659x - 30.377$.

3.2 Urban waterlogging risk levels

According to drainage capability (<27mm/h, 27mm/h for once half year, 36mm/h for once per year and 50mm/h for once per 3 years) of each parts, urban waterlogging risk calculating model was setup in different drainage parts based on urban waterlogging information during 2001-2010.
The road waterlogging risk standard in Shanghai is categorized to 6 levels from 0 to 5 according to ponding depth somewhere from statistics. The 6 levels of urban waterlogging risk is named as “none”, “slight”, “low”, “moderate”, “high” and “severe” in accordance with the colour of “none”, “light blue”, “blue”, “yellow”, “orange” and “red” (See Table 2). For example, if the ponding depth is greater than 30cm and no greater than 44cm, the waterlogging risk is determined 3 with the meaning of “moderate” impact and colour of “yellow”.

Risk	*Ponding Depth(h)*	*Impact levels*	*colour*
0	0	none	none
1	1cm≤h≤14cm	slight	light blue
2	15cm≤h≤29cm	low	blue
3	30cm≤h≤44cm	moderate	yellow
4	45cm≤h≤59cm	high	orange
5	60cm≤h	severe	red

Table 2. The waterlogging risk standard in Shanghai.

3.3 Waterlogging risk prediction

For the prediction of waterlogging risk, radar OHP, 0-72hr NWP forecast rainfall data were applied. Based on the grid forecast data, urban precipitation of drainage partition in downtown was provided. Then ponding depth can be obtained according to the relationship between rainfall and ponding depth. With the different drainage capability, different waterlogging risk of each partition can be achieved.

4 ASSESSING

4.1 Sites assessing

The ponding data during June to September of 2011 are used to evaluate waterlogging risk in Shanghai. After carefully selection of some heavy rain event, Table 3 shows that predicted waterlogging risk is almost close with observed ponding risk.

Date	*Sites*	*Obs. waterlogging risk*	*Predicted waterlogging risk*
2011-06-17	Wuzhong & Outer Ring Road	3	2
	Yishan Road	1	1
2011-07-31	The Orient Sports Center	1	0
2011-08-03	Puxi Road	3	2
	Yangpu	1	1
	Gaoqiao, Pudong	2	2
2011-08-04	Xinzhuang	3	4
	Wuzhong Road, Xianxia Road	3	4
	Middle Ring	2	2
2011-08-12	Changning, Putuo	3	3
	Yangpu, Huangpu	4	4
2011-08-13	Central city	1	1

Table 3. Comparison of predicted and observed waterlogging risk during Jun. to Sep. of 2011 in Shanghai.

4.2 Case study

On the ponding event on Aug. 4th of 2011, it gives that the ponding depth of Wuzhong Road, Xianxia Road (B) and Xinzhuang (A) exceeded 30cm, and that of Middle Ring (C) was near 25cm. So according to the road ponding risk standard in Shanghai, the observed waterlogging risk of Wuzhong Road, Xianxia Road and Xinzhuang was 3 and that of Middle Ring was 2. And from the prediction, the level of waterlogging risk in Wuzhong Road, Xianxia Road was 3, and that of Xinzhuang was 4 and that of Middle Ring was 2. The predicted results were close to observation.

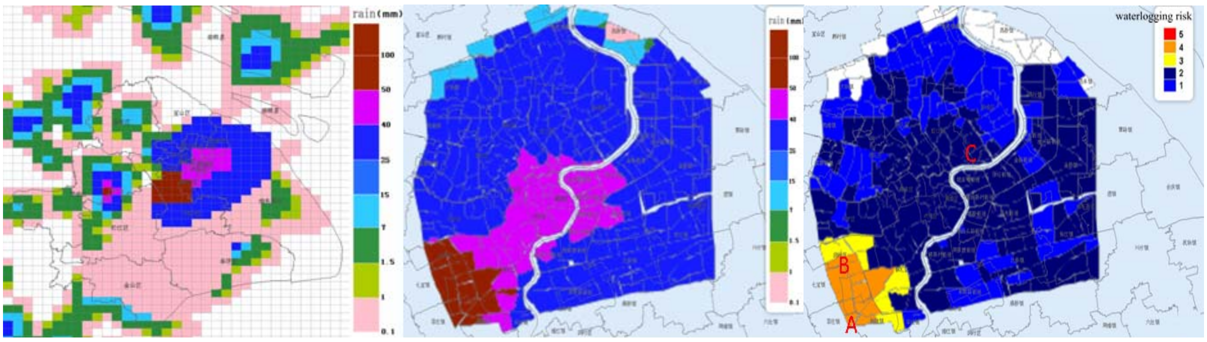

Figure 1.Rain and waterlogging risk evaluation on Aug. 4th of 2011.
(Left: NWP rainfall in shanghai; middle: rain in central city; right: waterlogging risk)

4.3 Suggestion for public and policymakers

Urban waterlogging risk information gives useful suggestions to drivers to be watch out the area or roads which will impact by extreme heavy rain and waterlogging. For example, if the waterlogging risk level is above 3 in some sites, drivers may take a devious route to avoid traffic jam. And for the road, subway management agency policymakers, it is a contribution that allows them to adjust the appropriateness of local traffic management strategies. After the waterlogging risk information is made full use of, it will be useful to diminish traffic intensity.

5 CONCLUSION

In this paper, urban waterlogging risk under rainfall condition is setup by finding out the relationship between rainfall and ponding depth and statistics of urban waterlogging risk levels in Shanghai. Predicted waterlogging risk is carried out by radar OHP, 0-72hr NWP forecast rainfall data. By assessing the waterlogging risk in the event of some heavy rain from June to September of 2011, predicted waterlogging risk is close to observation. Information with urban waterlogging risk gives the public and policymakers timely adjust their route and traffic management which is hoping to diminish traffic intensity.

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ACKNOWLEGEMENTS

The authors would like to thank Dr. Tang Xu for giving helpful suggestions for this paper, Mr. Chu Hai and Ms. Zhang Xin for data analysis.