THE ANALYSIS OF DRAINAGE PATHS IN CHAO PHRAYA RIVER BASIN BY GRAPH THEORY

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Abstract— **Flood is one of the natural hazards and it is critical to be controlled through proper management. Severe flood events in Thailand (2011) caused damage to both life and property. Moreover, heavy flood or drought affected life, existence and the country's economy. Therefore flood control is important. This study proposes methodology for analyzing drainage paths in Chao Phraya river basin by graph theory and simulation connection between floodgate and water gauging stations to find out capability of stations. After that capability and efficiency of station were compared to determine which stations can receive water more than maximum performance and to find out solutions for stations.**

Keywords—Drainage Paths; Flood; Graph Theory; Complex network

I. INTRODUCTION

Flood is common natural disasters that arise all over the world. It is considered as a severe natural hazard and the coverage of its damages is not measurable [1]. In 2011, Thailand suffered the severe flood all year round in history. It affected all regions across the country in particular the northern and the central part of Thailand which impacted longer time than the others. Moreover, Bangkok and suburban areas were heavily during in the past 70 years. This caused damage on agriculture, industrial, economic and social sector which also led effect on other sectors. For this reason, natural hazard management especially in flood control is one of the most important factors because heavy flood or drought affects life, existence and the country's economy. Many studies have been done in order to control flood. Among them is the optimal flood control that can give the best cost-effective schedule to minimize the risk of hazardous floodwaters. It also helps to find the best design of capacities and locations of flood control structures, such as floodgates, water detention basins [2, 3]. Meanwhile, optimal flood flow control methodologies can be utilized to practice best management of water resource, sediment transport [4], and water quality [5] to achieve sustainable development of economy and society that largely depend on limited water availability. According to the studies mentioned, we can assume that controlling open channel flow is a key issue to mitigate hazardous flooding in a river basin, or to deliver water in an irrigation system according to a specified demand pattern.

To optimize flood control for Chao Phraya river basin, this study analyzed a connection between floodgates and water gauging stations to find out the stations that receive huge water (capability) by Graph Theory [6] and Complex Network [7]. The study also aimed to find out a drainage efficiency of each station and compare with station' capability for adjusting flood control planning.

II. RELATED WORK

Flood control to mitigate hazardous flood water in rivers and watersheds is of vital importance for inundation prevention, flood risk management, and water resource management. In the recent years, many studies have been developed and applied flood control model to forecast flood with various methods such as trend analysis, regression analysis, prediction, genetic algorithm and artificial intelligence algorithms[8, 9]. Water flow forecasting and forecast modeling from water factors with hydrography tool

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development helps decide flood management on basins and reservoirs. In area of flood forecasting, many methods has been not only implemented the data mining for model but also improved algorithm to more efficiency, for example [10, 11]. In addition, a part of studies proposed factors analysis for forecasting water[12] which its objectives were to explore the relationship between factors that affected flood and find out the most important factor for flood prediction. Furthermore, some studies were also tried to propose methods for controlling water of reservoir to appropriately drain or retention water with current environment without data mining but used hydrological model such as [13] and [14].

At present, Graph theory was applied to solve problem. It was a set of nodes and edges, where nodes were the individual elements within the network and edges represented connectivity between nodes. Edges may be binary (connected or not) or contained additional information about the level of connectivity [15]. Networks surround us in both the natural and anthropogenic world. For example, societies are networks of people connected by family, friendship, and professional ties [16], and landscapes can be viewed as a network of habitat patches connected by dispersing individuals. Network topology is especially interesting because it is an emergent property that affects qualities such as spread of information and disease, vulnerability to disturbance, and stability [7, 17].

In this study used Graph theory to analyze of drainage paths for simulation connection between floodgate and water gauging stations. The result was associated of stations in Chao Phraya river basin and for flood planning in the feature.

III. METHODOLOGY

This study proposes methodology for analysis of drainage paths in Chao Phraya river basin by graph theory. Processes of the methodology are divided into two main parts. The first process is to find out capability of each floodgate and water gauging station for receiving water. The second process is to find out the drainage efficiency of each station. After that, capability and efficiency were compared to determine which stations were received water more than maximum performances. Fig. 1 shows workflow of this study.

A. Data Collection

A connection simulation between floodgates and water gauging stations used data of stations on rivers and canals in Chao Phraya river basin: 34 floodgates and 20 water gauging stations which were represented as nodes by Pajek program. Rivers and canals were represented as edges or arcs that are connected between nodes.

B. Analysis Features of node

The features of node were analyzed based on Betweenness centrality, Degree Centrality and Efficiency of node. Details of each feature are as follows:

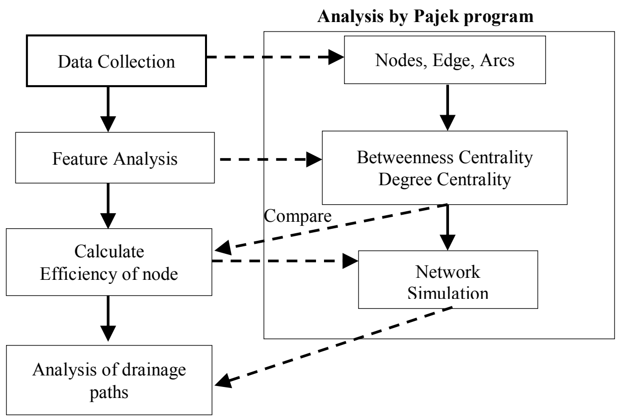

Fig.1. Workflow of this study.

- Betweenness centrality: to identify an entity's position within a network in terms of its ability to make connections to other pairs or groups in a network. A node with high betweenness centrality has a large influence on the transfer of items through the network, under the assumption that item transfer follows the shortest paths [18].

$$BC_v = \sum \frac{\sigma_{st}(v)}{\sigma_{st}} \quad (1)$$

Where σ_{st} is the total number of shortest paths from node s to node t.

$\sigma_{st}(v)$ is the number of those paths that pass through v.

- Degree Centrality : The simplest definition of point centrality is based on the idea that important points must be the most active, in the sense that they have the largest number of ties to other points in the graph [19].

$$DC_v = \frac{deg(v)}{n - 1} \quad (2)$$

Where deg(v) is degree of node v.

n is the number of node in network.

- Efficiency of node: The result would provide the risk of station to support water from multiple nodes if this study used only capability of node (Betweenness Centrality and Degree Centrality) to analyze drainage path. In addition, the result cannot be taken to adjust flood control planning because of insufficient data to improve capability of station such as optimize floodgates and rivers/canals dredging. Therefore, this study required efficiency of node in order to discuss and analyze.

Node's efficiency is considered by the highest water capacity of rivers/canals that can support the maximum quantity of water the station can be drained, equation is given as follows:

$$\text{Efficiency}(v) = \frac{\sum S(Q_{max})}{R(Q_{max})} \quad (2)$$

Where $\sum S(Q_{max})$ is the sum of the highest capacity of rivers/canals sent to station.

$R(Q_{max})$ is the maximum quantity of water that station can be drain

C. Simulation

A network connection between stations was simulated by Pajek program. The data were converted into Pajek program format after it had been collected in process A. Floodgates and water gauging stations were represented by nodes. Rivers and canals are set to link between nodes in both directional and unidirectional because sometimes water could flow back for some advantages.

D. Analysis of drainage paths

This process is to analysis the information gained from the mock-up of node capability and efficiency. Then the efficiency of node is compared in order to find out the association of capability and efficiency.

IV. Result

A Network simulation data for analysis of Chao Phraya river basin included 126 rivers/canals that connected between floodgates and water gauging stations. Each link had maximum capacity that could be accommodated the quantity of water flow which was measured in cubic meters per second. The second part was 54 floodgates and water gauging stations that were classified as 34 floodgates and 20 water gauging stations. After data of network were simulated, the next step was to assess the features analysis based on Betweenness Centrality, Degree Centrality and Efficiency of node. Finally, features were compared in order to find out their association.

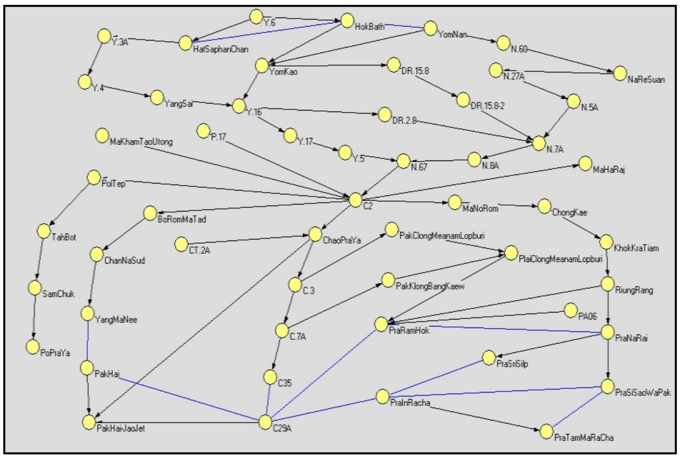

Fig.2. The result of drainage paths network simulation

A. The result of drainage paths network simulation in the Chao Phraya River basin.

Network modeling using Pajek can create network drainage paths in the Chao Phraya River basin based on the true path, as shown in Fig. 2.

B. Result of features analysis

Example, network simulation results were analyzed using the Betweenness centrality with drainage paths of Chao Phraya River basin network. If the Betweenness centrality is very valuable, then the circle is large. However, if value drops, the circle is small, as shown in Fig.3.

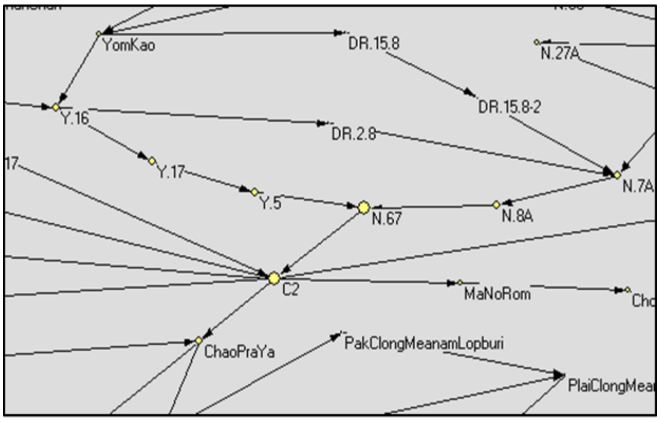

Fig.3. Betweenness centrality simulation

The average value of Betweenness centrality is equal to 0.240573 that can sort the Betweenness centrality descending to top 5, as shown in Table 1.

TABLE I. TOP 5 OF THE MOST BETWEENNESS CENTRALITY

No.	Station	Betweenness centrality
1	C2	0.240573
2	N.67	0.226244
3	Y.5	0.122738
4	Y.17	0.114819
5	Y.16	0.113688

Table I. shows the sort of Betweenness centrality that has great value representing a channel that supports the large water quantity flowing. The Betweenness centrality has a large influence on the transfer of items through the network. The maximum value is water gauging station C2, with a value of 0.240573

For example, network simulation results were analyzed by using the Degree centrality with the route network of the Chao Phraya River drainage basin. If the Degree centrality is very valuable, then the circle is large. However, if value drops, the circle is small, as displayed in Fig 4.

The average value of Degree centrality is equal to 0.049857that can sort the Degree centrality descending to top 3, as shown in Table 2.

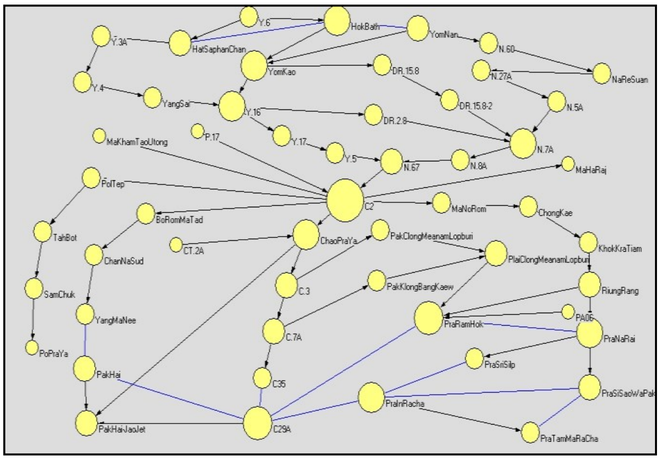

Fig.4. Degree centrality simulation

TABLE II. TOP 5 OF THE MOST DEGREE CENTRALITY

No.	Station	Degree centrality
1	C2	0.153846
2	C29A,PraRamHok	0.096154
3	HokBath, YomKao, Y.16, N.7A, ChaoPraYa, PraInRacha, PraNaRai	0.076923

Table 2 shows the sorting of Degree centrality of the station to accommodate the water from multiple paths. Because the station is the most influential position in the network, the maximum value is water gauging station C2, with a value of 0.153846.

Efficiency of node to receive water for each station in the Chao Phraya river basin can be sorted descending top 5, as shown in Table 3.

Table 3 shows the sequence of the Efficiency of node. If the Efficiency of node is high, it will be good because it illustrates the ability or capacity to drain water effectively. Nonetheless, the largest value includes YangSai, YomNan, N.60, DR.15.8, DR.15.8-2 and N.5A which is equal to 1.

TABLE III. TOP 5 OF THE MOST EFFICIENCY

No.	Station	Efficiency of node
1	YangSai, YomNan, N.60, DR.15.8, DR.15.8-2, N.5A	1
2	PraRamHok	0.98955
3	HokBath	0.85714
4	C3	0.82394
5	YomKao	0.8

C. Results of comparison value between Degree centrality, Betweenness centrality and Efficiency of node

In Fig.5, it can be concluded that the floodgates and water gauging stations have the high Degree centrality, Betweenness centrality and Efficiency of node, which will result in good drainage. If the floodgates and water gauging stations have the Degree centrality, Betweenness centrality at high value but Efficiency of node is low, this may cause flooding.

In addition, the node with high Degree centrality affects the point of support water from many paths. In fact, the node will be more important than another node that represents the dam itself. From Table 2, PraRamHok and Chao Phraya Dam is so precious high Degree centrality.

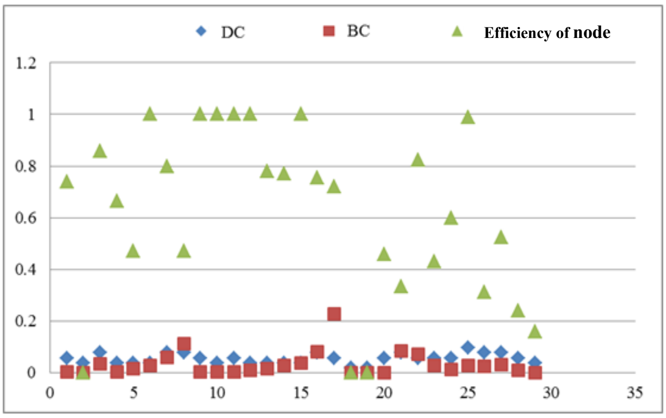

Fig.5 Comparison chart of Betweenness centrality, Degree centrality and Efficiency of node.

V. CONCLUSION

The analysis of drainage paths of the Chao Phraya River basin has embraced graph theory and complex networks were applied to create the network model and analyze features to inform the rate of floodgates and water gauging stations of the Chao Phraya river basin. We found that if the station drains the water, less effective drainage will cause flooding problems at that station and other stations.

REFERENCES

[1] S. Rozalis, E. Morin, Y. Yair, and C. Price, "Flash flood prediction using an uncalibrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions," Journal of hydrology, vol. 394, pp. 245-255, 2010.

[2] Y. Ding and S. S. Wang, "Optimal control of flood diversion in an open channel and a channel network," in Proceeding of the 7th international conference on hydroscience and engineering, Sept, 2006, pp. 10-13.

[3] Y. Ding and S. S. Wang, "Optimal control of open-channel flow using adjoint sensitivity analysis," Journal of Hydraulic Engineering, vol. 132, pp. 1215-1228, 2006.

[4] J. W. Nicklow and L. W. Mays, "Optimization of multiple reservoir networks for sedimentation control," Journal of hydraulic engineering, vol. 126, pp. 232-242, 2000.

[5] M. Piasecki and N. D. Katopodes, "Control of contaminant releases in rivers. I: Adjoint sensitivity analysis," Journal of hydraulic engineering, vol. 123, pp. 486-492, 1997.

[6] J. A. Bondy and U. S. R. Murty, Graph theory with applications vol. 290: Macmillan London, 1976.

[7] R. Albert and A.-L. Barabási, "Statistical mechanics of complex networks," Reviews of modern physics, vol. 74, p. 47, 2002.

[8] W. Wei, Z. Hai-bo, and W. Dao-xi, "Study of flood prediction based on multi-evidential fusion model," Water Power, vol. 12, p. 007, 2005.

[9] D. P. Solomatine and Y. Xue, "M5 model trees and neural networks: application to flood forecasting in the upper reach of the Huai River in China," Journal of Hydrologic Engineering, vol. 9, pp. 491-501, 2004.

[10] J.-C. Xie, T.-P. Wang, J.-L. Zhang, and Y. Shen, "A method of flood forecasting of chaotic radial basis function neural network," in Intelligent Systems and Applications (ISA), 2010 2nd International Workshop on, 2010, pp. 1-5.

[11] H. Ping, "Wavelet neural network based on BP algorithm and its application in flood forecasting," in Granular Computing, 2009, GRC'09. IEEE International Conference on, 2009, pp. 251-253.

[12] Q. Yang, J. Shao, M. Scholz, and C. Plant, "Feature selection methods for characterizing and classifying adaptive Sustainable Flood Retention Basins," Water research, vol. 45, pp. 993-1004, 2011.

[13] W. Zhou, H. M. Thoresen, and B. Glemmstad, "Application of Kalman filter based nonlinear MPC for flood gate control of hydropower plant," in Power and Energy Society General Meeting, 2012 IEEE, 2012, pp. 1-4.

[14] Y. Ding and S. S. Wang, "Optimal control of flood diversion in watershed using nonlinear optimization," Advances in Water Resources, vol. 44, pp. 30-48, 2012.

[15] E. S. Minor and D. L. Urban, "Graph theory as a proxy for spatially explicit population models in conservation planning," Ecological Applications, vol. 17, pp. 1771-1782, 2007.

[16] G. Kossinets and D. J. Watts, "Empirical analysis of an evolving social network," Science, vol. 311, pp. 88-90, 2006.

[17] C. J. Melián and J. Bascompte, "Complex networks: two ways to be robust?," Ecology Letters, vol. 5, pp. 705-708, 2002.

[18] U. Brandes, "A faster algorithm for betweenness centrality*," Journal of Mathematical Sociology, vol. 25, pp. 163-177, 2001.

[19] V. Latora and M. Marchiori, "A measure of centrality based on network efficiency," New Journal of Physics, vol. 9, p. 188, 2007.