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ALTERNATIVE VIEWS ON OPTIMAL URBAN PLANNING MODEL AND WATER ISSUES

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Abstract

Urban planning is one of the prolific research fields nowadays. Lots of interesting research work has been done related to this field. Previous studies were only concerned with the contentment of residents and did not indicate any environmental factors. Consecutive researchers study the optimal city structures but in other different factors and views. The numerous urban planning models have been widely investigated for their application in many fields. However, most of the model is lacking the environmental characteristics especially related with water issues. Commonly, water issues associated with urban areas are runoffs, landslides, soil settles, water security to name a few. These problems normally are due to the disturbance of water absorption processes in the affected area. This paper intends to provide a bigger picture used as preliminary for further studies in the problems related with urban planning and water security. This paper investigates past research and highlights the significance similarity and gaps for further research. The past models on urban planning and the impact of urban development to water issues will be reviewed and the significance of these problems will be discussed. The investigation in this direction highlights the importance of water issues in developing urban area.

Keywords: Urban planning models, water problem

Abstrak

Perancangan bandar merupakan salah satu kajian yang prolifik pada masakini. Terdapat banyak kajian yang menarik telah dijalankan berkaitan bidang ini. Kajian lalu hanya mementingkan kepuasan penduduk dan tidak menunjukkan sebarang faktor persekitaran. Kajian berkaitan struktur bandar yang optimum telah dijalankan berturut-turut oleh penyelidik daripada faktor dan pandangan berbeza. Pelbagai modal perancangan bandar telah dikaji dengan meluas dalam pelbagai bidang. Walau bagaimanapun, kebanyakan model tersebut kurang ciri-ciri persekitaran terutamanya berkaitan isu air. Biasanya, isu air yang berkaitan dengan kawasan bandar ialah banjir, tanah runtuh, mendapan tanah dan keselamatan air. Masalah ini biasanya disebabkan gangguan proses serapan air di kawasan tersebut. Kertas kerja ini bertujuan menyediakan pandangan yang lebih meluas untuk digunakan sebagai kajian awal berkaitan perancangan bandar dan keselamatan air. Kertas kerja ini mengkaji kajian lalu dan menekankan kepentingan persamaan dan jurang untuk kajian seterusnya. Model lepas tentang perancangan dan kesan pembangunan bandar terhadap isu air akan dikaji dan kepentingan masalah ini akan dibincangkan. Kajian ini bertujuan menekankan kepentingan isu air terhadap pembangunan kawasan bandar.

Kata kunci: Model perancangan bandar, masalah air

1.0 INTRODUCTION

Water security is an important element for the cities, especially nowadays when the number of population inhibiting towns are much higher, hence leading to higher water demand. Water security not only focuses on meeting the demand of water everyday but also includes the safety element involving water such as natural disaster, flooding including flash flood, landslide, soil settlement and much more.

Past studies have identified that poor water quality is mainly effected by the poor planning in the urban area. The rapid and poor developments of cities around the world are now have been seen as a major contributor to the misfortune and loss involving water disasters. The expansion of urban areas is a major

threat to the natural values of the area and can endanger not only the environment but also harm the future population.[1]

Nowadays, urban development has become an important area of study. The rapid growth of urban areas has brought serious problems such as overcrowding, poor development condition, insufficient urban and transport infrastructures, environmental disturbance, unemployment and poverty.[2] These problems are not new, yet the populations are still facing these problems. Urban development is referring to the relative concentration of people living in urban area when compared to the population.[3]

The urban development area is increasing due to the migration to escape the poverty, the lack of opportunities[3], natural increase of population, and geographical expansion of an urban area.[4] It is estimated that in 2015, there are around 560 cities around the world with more than a million people.[5] Thus, unplanned development which takes a shorter period to build may cause lots of problem as urban area is the main factor that contributes to the industrialization and economic growth of a country.

Residential land planning is the most important component of the physical development of land for residential use. The progress depends on the planning such as buildings, roads, houses and much more and not to forget the cost and population density.[5]

Hence, urban planners and researchers are facing the decision on how to achieve the best possible future. Many cities use a complete model to simulate the various aspect of urban structure with which they can predict the implication of the planning before the built. However, most of the model overlooked the possible natural disaster especially involving water, for example flood and flash flood. This problem usually occurs to developing countries. The lack of information on demographic and socioeconomic data complicates the planner to develop a comprehensive urban model to support planning decisions.

Regardless of the problem and disadvantages of urban development, it is still preferable as it is essential to both economic and environmental development perspectives. Clearly, planning is the only way to overcome these issues.

Therefore, this paper explores the prospects factors in urban area for future reference to enhance an urban planning model by providing supports from literatures toward being more water-friendly environmental. This paper can help urban planners, developers, government officials and researchers to understand the realistic of maintaining natural environment to preserve natural water storage for future development.

Firstly, this paper discusses the elements that influence the urban development. The main components of urban area are services and population. Later, this paper discusses the optimal model role in urban planning area of study. Consequently, next section points out the impact of urban development to water problem and the research gaps for this issue. Finally, conclusion and suggestions in this area of study for further research will be proposed.

2.0 ELEMENTS INFLUENCING URBAN DEVELOPMENTS

The study related with urban planning has been initiated for quite sometimes. Sasaki in year 1998, has done a study related to optimal urban growth.[6] Connection between land owner and residents is very high as the residents depend on the land owner to provide the settlement. Besides that, production activity, congestion externalities and public facilities also affect the growth of an urban area.[6]

Some of the reasons for people migrating to cities are to find job opportunities and better facilities. Jobs and residents locations are very important elements for the planners to consider. These two elements have to be connected and follow proper design. A better city would have multiple centers to focus on the distribution. For example, Shanghai is the main center in China with industry and housing located within the inner city area.[7]

For absorption capacity in a city, maintaining the land for the new settlement would be crucial.[8] Thus the problems faced by such cities, namely insufficient open space, uncoordinated utilities and facilities, resolving competition amongst land uses, undesirable densities, and so on, must be solved at when planning the city itself.

Thus, based on the relation of residential area and industrial area located, the production cost for the transportation between the areas is likely from the distribution of land uses for future years. The transportation cost which includes the average trip costs, trip length, travel time, network flows and congestion highly contributes to the wellbeing of city. Figure 1 shows that the simplest distribution in an urban area where we neglect the other factors such as geography surface, pricing, and others.

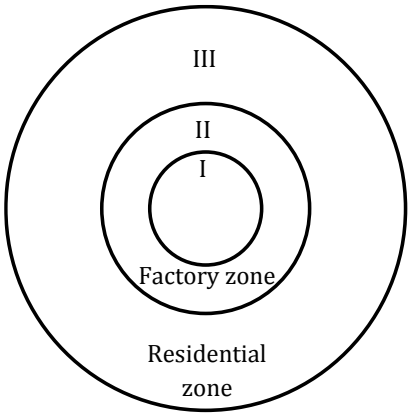

Figure 1 The distribution of industry and residents[2]

Figure 1 shows the residential area is located around the industrial zone which can minimize the transportation cost for residents (worker) to go for their works.

3.0 THE ROLE OF OPTIMAL MODEL IN STUDYING URBAN DEVELOPMENT

Mathematical models may act as valuable tools that are able to predict and optimize the usage of some systems. In recent decades, optimal control model has became popular amongst the academic and industrial research community to solve urban planning problems. The main objective of the model is to minimize the distance (or cost) for people to travel from the origin (residential area) to the destination (facilities). The optimal urban planning problem can be modeled in various ways and direction but still in the context of urban elements. Some study the transportation network in the urban area, distribution within the area, land use and zoning, optimal size of the city has been done and others.[9] Presented in Figure 2 is the summary on the directions and similarities of mathematical models in urban planning problem.

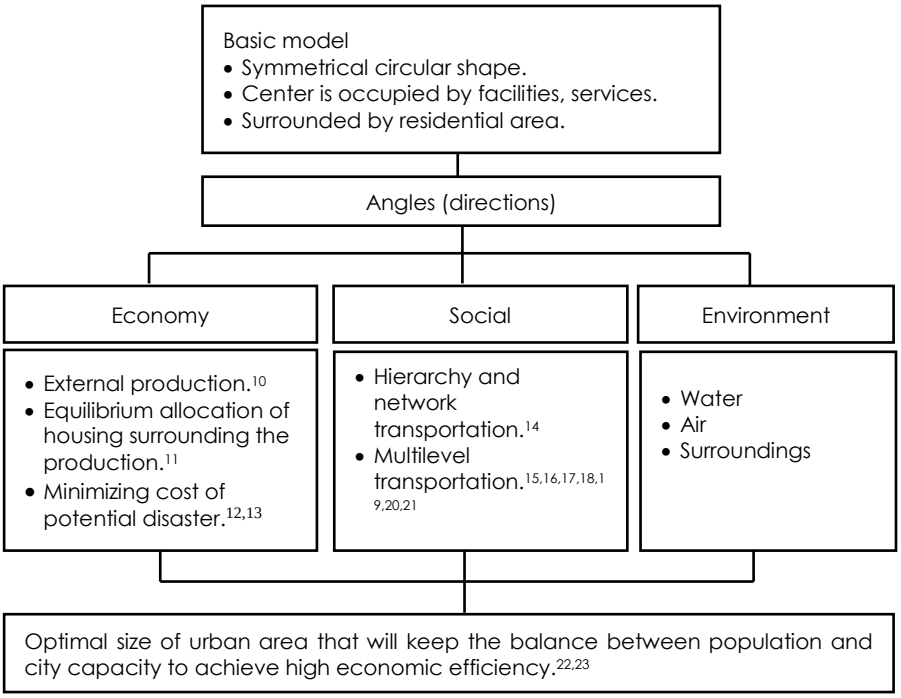

Figure 2 Summary of past urban planning problem area that has been explored

Optimal urban planning model also includes the efficiency of transportation either to study the distribution of people and services or the networks.

Optimal urban planning model studies the city structure and studies found that the optimal structure are in circular shape.[10,24,25,26] Business and housing are located close to each other in the area and the shapes of the city are symmetrical. Also, these studies implied the same result as described in the previous section in which the optimal distribution is where the business are at the center of the city and surrounded by housing area.

Eventough the result are the same, the model are proposed in different angles. Optimal size of urban area is needed as it will keep the balance between population and city capacity and at the same time achieves high economic efficiency.[22] More recent works study multiple optimal sizes for cities.[23] Most of the studies estimate the marginal benefit function defines on a particular size and the increasing rate[27,28,29,30] or applying the Henry George Theorem for an optimality purpose.[31]

3.1 Economical Aspects

External production as a major economic contributor to the city leads to the dispersion of housing surrounding the production[10] and equilibrium allocation that maximizes total production net of total consumption in a city.[11] The urban area is assumed as a firm where the firm balance the external benefit from locating near other production against the cost of longer commutes for workers. Carlier and Ekeland also modelled the urban problem based on the assumption between workers, firms and land owner relation give equilibrium in the land market.[11] Example of optimal urban model the transportation cost for workers where they live at x and work at y need to pay

$c(x-y)$, $C:R^2 \to R$ are convex and C^1. The product externalities is

$$z(x) := x\left(\int_{\Omega} \rho(x,y)v(y)\,dy\right)$$

where $v(x)\,dx$ is a number of workers per unit land, ρ are Kernal approximation Dirac mass and $x:R \to R$ is increasing. Further details on the model can be found in the paper.[11]

Also, city-specific equilibrium size of urban area is predicted using theoretical model on 56 Functional urban areas within EU27 used as suggestion for further urban planning.[9] The model is based on urban costs and its benefits.

Not only being the subject to the distribution within a city, an optimal urban model also has been used widely in minimizing the cost of potential disaster.[12,13] The developed multi-criteria optimization model consists of generating alternatives and establishing criteria, and application of the compromise ranking method (VIKOR).[12] Displayed in Table 1 are some general description of past literatures for mathematical model in economy aspects.

Table 1 Mathematical models in economic aspects

Reference	Main Elements	Assumptions	Models
Lucas and Rossi-Hansberg.[24]	• Production externalities. The production will be highest, *r = 0* in a uniform city which is the center and decline monotonically to a minimum at *r = S*.	People live where they work. Imply that employment and land rents decline from center outward.	Simulated as a firm balance the external benefit from locating near other production against the cost of longer travels for workers. - Spatial structure of cities. - The production externality is assume to be linear and decrease exponentially at a rate δ with distance between $(r,0)$ and (s,ϕ). Their model are, $z(r) = \delta\int_0^S \int_0^{2\pi} s\theta(s,\phi)n(s,\phi)e^{-\delta x(r,s,\phi)}d\phi ds$ where radius *S*, and location within the city (r,ϕ).
Opricovic and Tzeng.[26]	The results are to use as guideline for better global safety within area with potential natural hazard.	A maximum "group utility" of the "majority" and a minimum individual regret of the "opponent."	The fuzzy multi-criteria optimization (FUMCO) method for the criterion of represent public safety, sustainability, social environment, natural environment, economy, culture, and politics, as: $\underset{a\in A}{mco}(f_1(a), f_2(a), ..., f_n(a))$ where *A* is the set of feasible solutions, $a = (s_1, s_2, ...)$ is the alternative obtained from the system variables, s, f_i represents *i*-th criterion; *mco* denotes the multi-criteria optimization operator.
Carlier, and Ekeland.[11]	• Transportation costs. • Externalities of production.	The businesses and residences are mixed together.	There is a transportation cost for workers, $c(x-y)$ where x is the residence area and *y* where they work. The function $c:R^2 \to R$ is assumed to be strictly convex and C¹. There is a production externality is given by $z(x) := X\left(\int_{\Omega} \rho(x,y)\upsilon(y)\,dy\right)$ where $v(x)\,dx$ is a number of workers per unit land, ρ are Kernal approximation Dirac mass and $x:R \to R$ is increasing.
Adhvaryu.[3]	• Combinations of land use and transport	Can be used as preliminary models, due to the simplicity of the model	Using simplified urban models adapted to the data constraints. - The SIMPLAN (Simplified Planning) modeling

		structure and its limitations and data availability constraints.	has been developed for the case study in Ahmedabad, India to test alternative urban planning policies for the year 2021.
Camagni, Capello and Caragliu.[9]	• Urban costs • Urban benefits. Example: -Environmental quality -Urban form -Inter-urban cooperation networks.	Cities benefit from attracting educated professionals and hosting a rich and varied market, but also from facilities, which associate with a larger urban size.	The following total cost function is assumed where total location costs depend on the physical size of the city (size), and social costs (malaise), costs due to dispersed urban form (sprawl). In general, the costs of the city is assumed as urban land rent (rent): $C = f$ (*size, rent, malaise, sprawl*). In turn, total benefits are made depend on the physical size of the city (size), quality of life (amenities), creativity (diversity), urban atmosphere (density) and quality of economic (functions) and inter-urban networks (networks) as in the following function: $B = f$ (*size, amenities, diversity, density, functions, networks*). This theoretical model is then tested on 59 Functional urban Areas within the EU27.

3.2 Social Aspects

Optimal transportation network studies have been done broadly and the problems have been modeled in various shapes. The optimization models are either continuous or discrete.[32,33]

Relevant works throughout the decades described in the literature include multilevel transportation.[15,16,17,18,19,20,21]

Besides that, studies on urban planning models that are used to assist developers in their decision on urban distribution have been done and some are based on hierarchy and network transportation.[14]

Results show that the change in the urban hierarchy and the transportation network of the area will have influence on future distribution of population in the urban area.[14]

Also, the network in the sense of mass transportation theory studies the optimal distribution of transportation network between residents and services.[34] The optimal model is used to determine the facilities location and their network so that the total costs are minimized. The model includes simultaneous decisions about facility location and network is described in the paper.[14,35] Presented in Table 2 are some of related references for mathematical model in social aspect.

Table 2 Mathematical models in social aspects

Reference	Main Elements	Assumptions	Models
Awad and Aboul-El[36]	Residential land planning for low income groups	The cost function considered in the model: 1. Cost per unit length of street, which includes the cost of pavement, cost of water supply, sanitation, and electricity lines. 2. Cost of land. 3. Cost of service connection from the street to the lot.	The model is formulated as a non-linear programming problem. The solution came through a relatively simplified Focus Search and Monte-Carlo Simulation techniques.
Almandoz[37]	• Urban planning • Histography • Transportation network.	It is assumed that in the initial situation all at centers and all links belong to level 1. Other assumptions can refer to the reference.	Optimization model that simultaneously determines the urban centers and network links to promoted a new level of hierarchy.
Bigotte *et.al* [14]	• Urban hierarchy • Transportation network	Facilities are located in urban center. The numbers of lanes in a given road.	Mixed-integer model that simultaneously promotes urban centers to new levels of hierarchy and improves transportation network links. The objective is to minimize the travel time to the centers where the services are offered. The model is applied to case study in the Centro Region of Portugal.

3.3 Environmental Aspects

Urban development and natural environment are two elements which have different effects. To preserve the environment while developing the area is a very difficult task as urban development is directly related with expansion of an area, not to forget the pollution involved.

From the cost point of view, studies about cost related to general urban location with the natural environment and urban size has been done broadly.[9] It is known that simultaneous natural maintenance and space controlling leads to higher developing expenses and the loss of demand due to higher housing prices.

There are a lot of interesting problem arises, other than water issues, when these aspects are studied. Environmental issues generally have been studied in a large number of literatures particularly the studies from social sciences and environmental engineering. However, from mathematical modeling point of view, it occurred that limited literature available focusing on these aspects.

Relation of temperature with urban area is one of the common problems in environmental aspects. The effect of urbanization can be measured by urban planning indicator such as green cover ratio, lawn cover ratio, street cover ratio and others.[38] Petralli *et.al* found that forested areas has significantly reduced temperature compare to urban area.[38] Roughly, in comparison to the urban area, green areas are much cooler due to vegetation.[39,40,41,42,43]

Likewise, the effect of less flora and fauna due to urban development has led to disruption of animal habitat and ecosystem. Urban developments have significantly impact on animal population growth worldwide. Some interesting findings obtained by Polak *et.al* where they study the optimal planning for mitigating the impact of roads to wildlife.[44] Fences and wildlife crossing involve high expenses and an optimal decision is crucial to avoid unnecessary investment.

Also, considering the mathematical model point of view, study on the environmental issues particularly on water problem are still lacking. To preserve rather than to conserve the natural environment, can avoid water related problem such as shortage of water supply and availability, water pollution, disaster and others. This preservation involves a large number of parameters and constraints to consider in mathematical point of view.

These are some of the familiar issues arise in environmental aspect. It will be an interesting task to investigate these issues mathematically and these issues can be an area of study for further research.

4.0 IMPACT OF URBAN PLANNING TO WATER ISSUES

The investigation of the impact of urban development on the water security is not new and many literatures can be found in the past research. Poor planning not only destroys the environment but leads to the disturbance of the natural water storage.

Figure 3 summarizes the disturbance of urban development to the natural water infiltration rate. Developed area involve high impervious surface such as roads, parking lot and construction to meet the population demand. Thus, high impervious surface area will decrease water infiltration rate, which cause the area prone to flood.

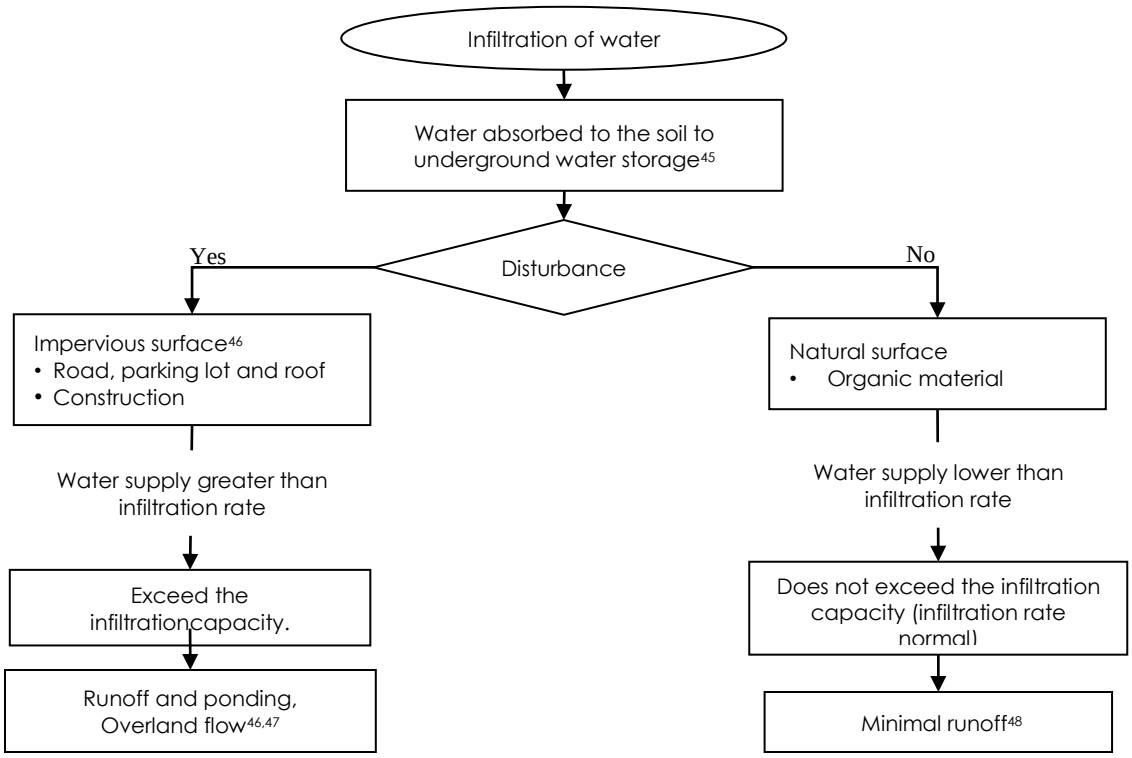

Figure 3 The effect of disturbance to the infiltration of water

So as to help prevent further loss, there is an urgent need for more strategic and planning approaches to avoid and conserve the high water absorption area from disturbance. The needs for understanding geographic pattern, water flow process and development pressure are essential before planning a town.

High soil compaction is unavoidable in an urban development to make the surface more stable to build a settlement leads to impervious land. Forest area have highest infiltration rate of any area types because of the natural absorption of the soil.[49] Most of the impervious areas are covered surfaces such as roads, parking lots and roofs.

The topsoil is removed during urban land developments used for construction, leaves the subsoil exposed to compaction.[50] As consequences, the effect of compaction may last for decades.[49] Compaction leads to loss of larger pore sizes and the number of pores causes a decrease in the absorption ability of air and water, thus lowering water-holding capacity.[51,52] Underestimation of the water absorption will cause the area to be prone to runoffs, greater flooding and reduction of groundwater recharge in the long-term.[52]

Mitigating the impact of the development of cities on water natural cycle and process is difficult by the demand on high land values, investor and developer.[53] Lack of research exposes concerning the threat of development to natural water process is also one of the problems.[54]

The conservation of natural water system not only benefits the water sector but can also conserve the biodiversity in the area. Furthermore, natural preservation close to people live and work gives

opportunities for education and awareness of environmental issues.[4]

5.0 RESEARCH GAPS

Even though, there are many mathematical models in the literature about urban planning, models related with the wellbeing of the environment are still lacking. Some of other environmental issues are pavement location, location of urban development to the water storage, high water infiltration area, and water flow area to name a few.

Other than issues explained in section 3.3, pavements allocation within a city are some of the example related with water issues. Pavements are supposed to absorb water into the soil and avoid runoffs from happening. However, studies to avoid runoffs and maintain the natural condition of high water absorption area are inadequate. Moreover, it is better and more cost effective to preserve the natural condition rather than disturbing the nature and rebuilding structures to represent the original process.

Urban planning problem is an area of study that can focus on various issues. Clearly, modelling water issues with an urban model is an interesting area of research, especially to help developers decide the best plan to avoid water disaster, such as flash flood. Therefore, a research in this area is one of the ways to explore the importance of this field to the sustainability of future environment and generations.

6.0 CONCLUSION

This article has presented a review of the relevant literatures to the investigation of urban planning problem and its impacts on water security in the area.

As a conclusion, based from the previous work, the main features of a city are business and residential area, where the center is concentrated by business and the business are surrounded by residential area. It is favorable for the residents living in the neighborhood around the facilities and provides guidelines for urban planners to decide for future benefit.

In order to avoid water issues in the area, several suggestions can be done for further study especially about types of soil as a constraint to place resident's settlement within the area, water infiltration rate in urban area which is higher water infiltration rate should be avoided and maintaining the forest area to preserve natural water absorption rate.

At the same time, it can solve the corresponding problem in various methods such as optimal control model, multi-objective optimization, mass transportation problem and others.

Since there are some aspects of research in urban planning problem still not explored, such as the study of the effect of combining various environmental factors to recognize the most significant factors. This paper provides a general review or guideline of urban model and the importance of preserving the natural water absorption. If possible, developments which contribute to the worsening of water quality should be avoided.

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