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Feasibility assessment of LID concept for stormwater management in China through SWOT analysis

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Abstract: The strengths, weaknesses, opportunities and threats (SWOT) analysis method is applied to assess the feasibility of traditional stormwater management and low impact development (LID) in China. The results show that traditional stormwater management has many disadvantages, e. g. only stormwater collection and discharge or flooding peak-flow regulation is taken into consideration but lack of many important functions such as on-site infiltration, non-point pollution control, ecological treatment, etc. Meanwhile, as a new stormwater management concept, the LID system has many advantages, e. g. LID can not only control rainwater quantity but also effectively prevent non-point pollution. Moreover, LID is easy for implementation and cost effective, and operation and management can also be done easily. LID has attracted more and more attention from governmental authorities at different levels and the majority of practitioners. Therefore, LID has bright prospects for wide applications in China.

Key words: stormwater management; low impact development (LID) concept; strengths, weaknesses, opportunities and threats (SWOT) analysis
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Water management has become a critical issue in China due to rapid urbanization, especially the adverse impact of the traditional runoff drainage system on the urban environment and its inhabitants. Development negatively impacts water quality in two ways. First, many of the new materials and components used in land development contribute higher pollutant loads during rainfall and subsequent stormwater runoff. Secondly, the natural filtering action of wild vegetation is replaced by concrete, asphalt, and rooftops, which offer little means for water-quality improvement[1]. The concept of the conventional stormwater system is that stormwater runoff is undesirable and must be removed from the site as quickly as possible to achieve good drainage, which can hardly meet the current situation in China. Therefore, new technologies have to be developed and applied for urban runoff quantity and quality control. Low impact development (LID) was introduced into China ten years ago and developed rapidly.

LID was initially piloted in Maryland as a way to mitigate the negative effects of increasing urbanization and impervious surfaces[2-3]. It was then applied in many places in America, Sweden, New Zealand and Canada[4]. LID seeks to mitigate the impacts of increased runoff and stormwater pollution, which comprises a set of site design approaches and small scale stormwater management practices that promote the use of natural systems for infiltration, evapotranspiration, and reuse of stormwater. These practices can effectively remove nutrients, pathogens, and metals from stormwater, and they can also reduce the volume and intensity of stormwater flows. Some projects in the USA, Australia and New Zealand, etc. demonstrate the water service efficiencies and ecological advantages of this LID[5-6]. Therefore, LID can enhance the ability to protect surface and ground water quality, maintain the integrity of aquatic living resources and ecosystems, and preserve the physical integrity of receiving streams.

The increase of sealed surfaces leads to an increase in peak flows and runoff flooding, which causes flooding disasters and serious non-point pollution. Large amounts of stormwater discharge into water bodies or are conveyed to wastewater treatment plants, which can lead to serious non-point pollution of water bodies and increase the pollution loads of the wastewater treatment plants. The performance of the traditional stormwater system has shown its weakness. There have been frequent flooding problems in the urban areas of China in recent years due to the increasing volume and low design standard of the stormwater sewer system in many cities, such as Beijing, Tianjin, Guangzhou, Wuhan, etc.

To effectively solve the problems caused by urban stormwater, more and more cities paid attention to this and began to act for flooding control, including the introduction of advanced concepts for the integrated manage-

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ment of stormwater. The LID is becoming more and more attractive for acceptance and recognition by technical personnel and governments. A number of stormwater utilization demonstration projects integrated with low impact development concept have been built so far in China. Guangming New Development District in Shenzhen City was positioned as the national LID demonstration area in China in 2011. The area of this district is about 155 km^2 and several LID-designed demonstration projects in this new development zone have been built. In Beijing, the system with porous pavements, green roofs and rainwater cisterns has been applied in the Beijing Olympic Village (BOV) residential area[7] as well. A stormwater management system plan which includes the filtration-storage system, the detention basin, the vegetated swale collection system, etc. was designed and taken into practice in Jinan City[8]. Besides, Changdao island in Shandong province, Zhangzidao island in Dalian, and so on have also designed some decentralized urban stormwater utilities for practical applications[9]. However, the applications of LID technology in China are still at the initial phase and they are immature and need localization.

This study successfully applies strengths, weaknesses, opportunities, and threats (SWOT) analysis as a tool to assess the feasibility of LID applications. Through the identification of the LID technologies strengths (elements to leverage and build on) and weaknesses (areas to seek assistance and support) in addition to community opportunities (areas to leverage for program advantages) and threats (elements that can hinder the scheme), the positive aspects for the LID concept are observed. The results will be useful for promoting the LID concept.

1 Methods

A SWOT analysis method is a research tool that is widely used in business management applications, which is applied in this study to assist in identifying strategic direction for an organization or practice. SWOT analyses have been successfully applied in the fields of regional energy planning and municipal solid waste management[10-11]. It is preferred for the present work as it yields useful information about the future viability of the considered system. The predictive capabilities of the technique come about from the consideration of system's strengths and weaknesses in the context of the environment, which may present opportunities and threats. The intention is to determine how the system will fare in the light of changes taking place around it. The strengths and weaknesses of a system are determined by internal elements, whereas external forces dictate opportunities and threats. Strengths can be defined as any available resource that can be used to improve its performance. Weaknesses are flaws/shortcomings of any system that may cause it to lose a competitive advantage, efficiency or financial resource. Sometimes it is recommended to identify opportunities and threats first in order to more quickly bring to light the systems strengths or weaknesses. Many of the threats are based on weaknesses[12-15].

2 Results

2.1 SWOT analysis

According to the current situation of stormwater management in China, SWOT analysis is applied for both a conventional stormwater management system and LID, respectively. The results are presented in Tab. 1 and Tab. 2.

2.2 Strength and opportunity

Conventional stormwater management systems have been constructed and used for decades, during which period a system has been already established. Generally, there is no obstacle of public acceptance for conventional systems. Every feature of a conventionally developed site is carefully planned to quickly convey runoff to a centrally located management device, usually at the end of a pipe system. However, LID can be used to minimize the impacts of urbanization on hydrology and water quality. LID aims to mimic natural hydrology and processes by using small-scale, decentralized practices that infiltrate, evaporate, and transpire rainwater to help protect and restore water quality. Especially, it aims to minimize impervious surfaces, disconnect hydrologic elements (roofs, downspouts, parking areas), maintain/increase flow paths and times, and utilize decentralized treatment practices.

Tab. 1 SWOT analysis of conventional storm-water management

Strength	Weakness	Opportunity	Threat
Complete planning, design, construction and maintenance system has been established. No problem for acceptance.	It is a purely structural approach which may not consider environment and sustainability. It is mitigation-based and flood control focused only. Increasingly high investment and operation cost. Lack of flexibility for climate changes. Limited capacity for heavy rain drainage. None/lack of community participation. Rainwater harvesting is limited or impossible. Non-point pollution is difficult to control. Limitation to protect aquatic resources from adverse effects of development.	Training and education of conventional management methods. Creation of employment opportunities.	Flooding challenges. Unfavorable climate changes (extreme weather). Increasingly sealed surface percentage. Limited underground water recharge. Non-point source pollution.

Tab. 2 SWOT analysis of LID

Strength	Weakness	Opportunity	Threat
Protect environment. Develop the full potential of environmentally sensitive site planning and design. Encourage public education and participation in environmental protection. Help build communities based on environmental stewardship. Reduce construction and maintenance costs of the stormwater infrastructure. Introduce new concepts, technologies, and objectives for stormwater management. Encourage flexibility in regulations that allows innovative engineering and site planning to promote "smart growth" principles. Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches. Mitigate the negative impact of urbanization and impervious surface. It advocates for more careful site design in the planning phases. Central government's willingness and support for this approach. An integrated approach to manage stormwater at its sources.	Limitation of suitability for all areas. Lack of people's interests and awareness. Lack of user's involvement in maintenance. Lack of infrastructural development. Lack of technical guideline and standards. Lack of proper operation and maintenance.	Sustainable city or eco-city development in China. New industry and employment creation. Frequently urban flooding can be tackled. New rules and policy formulation. Research and development opportunities.	Migration towards urbanization. Changes of land utilization purposes

This goal is accomplished by creatively designing hydrologic functions into the site design with the intent of replicating the predevelopment hydrology and thus having a significant positive effect on stream stability, habitat structure, base flows, and water quality. Ahiablame et al.[16] studied the performance of rain barrel/cistern and porous pavement as retrofitting technologies in two urbanized watersheds in India, finding that LID practices could be effective in managing urban stormwater. In addition to runoff reduction and environmental protection[17] benefits, research models set up by Montalto et al.[18] indicated that LID technologies facilitated the use of harvested stormwater, reducing the demand for and O& M costs of municipal drinking water supply systems.

The LID system encourages public education and participation in environmental protection. Meanwhile, LID introduces new concepts, technologies, and objectives for stormwater management, which has micro-management and multifunctional landscape features (bioretention areas, swales, and conservation areas), can mimic or replicate hydrologic functions, and maintain the ecological/biological integrity of receiving streams. Shenzhen is a city that plays a leading role in sustainable stormwater management. Such kinds of techniques like infiltration filters and vegetation grass ditches have been constructed in municipal roads and Niushan Science and Technology Park. The stormwater from filters or ditches can be recycled as irrigation water for municipal greenery[19]. The LID concept has more opportunity than conventional stormwater management as there is a call for sustainable city or eco-city development in China. Though conventional stormwater management provides training, education and opportunities for employment, the LID can open up new research areas and development opportunities.

2.3 Weakness and threat

Conventional stormwater management is mainly a collection and quick treatment process, which needs a complex sewage system. Obviously, limitations to protect aquatic resource from adverse effects of development, high investment and operation cost, lack of community participation are major weaknesses. Typical conventional site design results in developments devoid of natural features that can detain or infiltrate runoff, which leads to a decrease in travel times. Lack of these features often adversely affects the ecosystem. Roadways, roofs, gutters, downspouts, driveways, curbs, pipes, drainage swales, parking, and grading are all typically designed to dispose of the runoff in a rapid fashion. The magnitude of hydrologic changes (increases in volume, frequency, and rate of discharge) is amplified because of loss of natural storage, increasing the amount of impervious surfaces and the degree of hydraulic connection, as well as decreasing the time of concentration and runoff travel times. This kind of management only focuses on the mitigation of flooding but cannot sustain the current flood control, so many flood disasters have occurred in China in recent years, causing a huge economic loss and environmental destruction. It is time to introduce new sustainable management methods of stormwater; however, we still have to face the current situation due to the lack of involvement in maintenance, infrastructural development as well as limitation of suitability for all areas. There is a noticeable lack of technical guidelines and standards in defining and establishing the appropriate application of LID. Prior to introducing any new concepts or methods, it is very important to make an evaluation whether or not the expectations, desires, interests and awareness of delivered concepts or methods for a particular use are acceptable and well understood for public. Green roof has been applied and investigated for many years abroad such as in Germany, USA, etc.[20–22]; however, it still needs to be promoted in China[23]. It is urgently needed to address all the major concerns of LID to the public through detailed researches.

It seems that the governmental authorities demonstrate

their willingness to accept the application of the LID concept, but the threatens of migration towards urbanization and changes of land utilization purpose should be recognized. Conventional stormwater management has a bit more threatens to the complete environment such as underground water and climate changes. The relevant factors can affect stormwater management including geophysical factors, law and social factors, technical and economic factors as well[24]. However, the strategies are also needed at different decision levels like political, regional, or local scale for the promotion of the LID concept.

3 Conclusion

It is crucial to understand that both time and a fair overview of the techniques are important for a new concept transmission. This paper gives a brief view on both the conventional stormwater management system and the LID system, and the results show that the LID system has potential long-term effects in properly designing and implementing stormwater managing strategies.

For promoting the LID technology, there are still some problems like lacking of people's interests and awareness, user's involvement in maintenance, infrastructural development, technical guideline and standards, proper operation and maintenance, which still need to be solved currently. Besides, there are no complete laws and regulations in China to support such stormwater management strategies. However, the General Office of the State Council in China has addressed the development and construction of LID mode recently; this is the great governmental strength to promote such kind of concept and will provide more favorable conditions of LID implementation in China.

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采用 SWOT 分析法评价低影响开发模式在中国应用的可行性

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摘要:采用 SWOT 分析方法对传统雨洪管理模式和低影响开发模式在我国应用的优势、劣势、机会和威胁进行评价. 结果表明,传统雨洪管理模式存在诸多缺点,例如只针对雨水收集排放或只用于调蓄洪峰,未考虑雨水的原位入渗、面源污染控制、生态处理等;作为新型的雨洪综合管理模式,低影响开发模式存在诸多优势,例如在进行雨水水量控制的同时,可有效控制面源污染,且便于实施、建设费用低、管理维护方便等. 同时,低影响开发模式已受到中国各级政府部门和广大从业者的广泛关注和重视,其在中国拥有广阔的应用前景.

关键词:雨洪管理;低影响开发概念;SWOT 分析
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