A Research on the Applicable Modes of LID-based Slope Residence Planning

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Abstract. LID provides a new way of thinking to solve urban waterlogging and runoff pollution, and has attracted many scholars to try to integrate the LID concept into the planning and design of residences. After comprehensive analysis of LID’s application into residence planning, it is found that the existing results are not suitable for slope residences, resulting in problems such as difficulty for rainwater to gather into the center of the block, grid-type road patterns not conforming to the characteristics of mountain cities, and some LID facilities layout unsuitable for slope residences. Therefore, combining the characteristics of mountainous areas, this article designs the “hexagonal” road network on behalf of the general road structure of slope residences. Furthermore, we find LID facilities suitable for slope residences and propose the rainwater runoff organization scheme in slope residences corresponding to the LID facilities. Finally, we explore the implementation of LID applicable modes in slope residences via the four continuous levels of architecture, site, road and greenbelt. It is hoped that the current research can supply some ideas to slope residence planning oriented to rain and flood management.

1. Introduction
Low Impact Development (LID) means storm management and surface pollution treatment technology emerging in the United States in the late 1990s. It originally referred to the adoption of prevention measures at the source, and decentralized measures in the site development to maintain pre-development hydrological characteristics (Ministry of Housing and Urban-Rural Development, 2014). Since the year 2000, research on LID has been unfolding around the world. Abroad, the traditional green design begins to expand from the building to the site, community and street, forming a green community, green street and other design theory and methods. In China, Chen Xiong (2012), Miao Zhantang (2014), Xu Yuhui (2015), Liu Miaomiao (2016) and others have carried out relevant research and practice, trying to combine the LID concept with residential planning, and achieved certain results. But most of them take examples of plain cities, and there are few studies of mountain cities in related areas.

The author found that in the planning and design of the Zhongtian “Future Ark”, a green eco-city project in Guiyang City, the existing plain-based LID model is not well applied to the mountain area, because the mountain city is quite different from the plain city in terms of topography and so on. Mountain cities have a more superior natural background, but they are beset with the characteristics of strong vulnerability, fragility and low self-recovery ability. It is particularly important to implement low-impact development and research there. Combining the characteristics of mountain cities, this
article tries to apply the LID concept into the planning of slope residences, hoping to be beneficial for the management of rainstorms and the treatment of surface pollution in slope residences in the future.

2. An Overview of Existing Research for Residence Planning from the Perspective of LID

Traditional rainwater runoff tends to flow from the inside of the block to the surrounding roads. This means once problems appear like the pipe network blockage or its overload due to heavy rain, the city will face the risk of flooding. At the same time, the traditional rainwater management mode increases the runoff pollution of rainwater. It makes it more difficult for the rainwater to be recycled later.

The adjustment of rainwater runoff based on LID facilities is to guide rainwater to the center of the block. It should rely on greenbelt at all levels to organize rainwater runoff and arrange LID facilities. The function of the LID facilities in residence can be divided into five categories: penetration, transmission, purification, storage and regulation (Li Qiang, 2013). Various facilities reduce the rainwater runoff and control the total amount of runoff. Compared with the traditional rain and flood management mode, the new mode reduces the burden of urban rainwater pipe network, and effectively alleviates the problem of urban waterlogging and runoff pollution (Wang Jianlong, Che Wu, 2013) (Figure 1). At the same time, Residence planning under the LID concept is a composite and systematic planning. The combination of LID facilities and residence planning should focus on LID facilities that are configured for each spatial layout, and each facility’s spatial layout and convergence in residences.

![Figure 1. Traditional(left) and LID (right) Rain and Flood Management](image)

So the existing research for LID-based residence planning can be summarized into three aspects: (1) A shift of draining rainwater from the road around the block to the center of the block; (2) A shift from relying solely on the urban pipe network to a variety of LID facilities and urban pipe network; (3) Systematic planning and design based on four consecutive hierarchies of “site-building-road-greenbelt”.

3. Problems of Existing Slope Residence Planning

3.1. Great Differences between Road Patterns of Mountain Cities and Plain Cities

The terrain in the mountainous area rises and falls. We often use the way of small angle climb along the contours in mountain city roads. The plain residential form formed by the square network road obviously cannot be fully applied to the mountain residential. Thus, the exploration of the application mode of LID in the slope residence planning should first determine the general road form there.

3.2. Difficulty for Rainwater to Gather in the Center of the Block Resulting from Natural Terrain Slope

The terrain in mountainous areas is complex and changeable, some of which are single-oriented and gentle-sloped, others with large slope fluctuations, many ravines and steeps. Therefore, the slope residence simply can change the direction of rainwater runoff parallel to the contour, while the rainwater runoff in the direction of the vertical contour is single, always flowing from the high ground to the low ground. This makes it difficult for slope residences to bring rainwater to the centre of the
block, requiring a rational planning of rainwater runoff suitable for the mountains and the appropriate LID facilities according to the mountain pattern.

3.3. Difficulty for Part of the LID Facilities and Layout to Be Applied into Slope residences
With scarce urban land, many residences in mountain cities are built in the slope, valley and other areas in order to save land use. Therefore, when selecting low-impact development facilities suitable for mountain cities, we should take full account of the characteristics of land tension and large slope, and exclude some facilities that need to occupy too much space, are too affected by the terrain and have too high maintenance costs, so that they can be better applied in mountainous areas.

4. Basis of Slope Residence Planning Combined with Lid

4.1. General Road Pattern in Slope Residences
The road pattern in slope residences is very complicated and varies with the terrain. According to the differences of terrain conditions and site shape, their flat line types can be divided into four basic forms: linear type, S-type, Z-type and screw-type (Hu Fang, 2008) (Figure 2). Differences between the road line type of slope residences and plain residences lie in that the traffic in the vertical direction of the former can not be reached in a straight line, but by climbing with the contour stakes of a small angle. That in the horizontal direction is not much different. According to this characteristic, this study designs the “hexagonal” type road network to represent the general road structure of slope residences (Figure 3).

![Figure 2. Road alignment of Slope residence.](image)

![Figure 3. “Hexagon” type road network.](image)

4.2. LID Facilities Suitable for Slope Residences
With three types and four indicators of economic features (including construction and maintenance costs), spatial demand degree, the extent affected by the terrain, the authors evaluate the adaptation of low-impact development facilities to the mountain area (Table 1). Research findings demonstrate that the adaptation of 9 facilities like permeable paving is higher and can be applied directly, that of the two facilities of reservoir and regulation pond is low and not recommended, and that of rainwater garden, wet pond and constructed wetland is moderate, and their application depends on the current situation of the terrain.
Table 1. LID facilities’ adaptation level of the neighbourhood in mountainous cities.

| Stage          | Function         | Name                  | Economy               | Spatial Demand | Extent Affected By Terrain | Adaptation |
|----------------|------------------|-----------------------|-----------------------|----------------|---------------------------|------------|
| Emission (source) | Penetration      | Permeable pavement   | low                   | low            | low                       | high       |
|                |                  | Green roof           | middle                | middle         | low                       | high       |
|                |                  | Low elevation greenbelt| low                   | low            | middle                    | high       |
|                |                  | Rain garden          | middle                | middle         | high                      | middle     |
|                |                  | Seepage pond         | high                  | middle         | high                      | low        |
|                |                  | Seepage well         | low                   | low            | low                       | high       |
| Transmission (processes) | Transmissions | Grass swale          | low                   | low            | low                       | high       |
|                |                  | Seepage tube/canal   | middle                | middle         | low                       | low        |
|                |                  | Slope greenway       | low                   | low            | middle                    | high       |
|                |                  | Vegetation buffer zone| low                   | low            | middle                    | low        |
| Purification   |                  |                      |                       |                |                           |            |
| Regulation (end) | Storage          | Constructed wetlands | high                  | middle         | high                      | middle     |
|                |                  | Reservoirs           | high                  | middle         | high                      | low        |
|                |                  | Rainwater tank       | low                   | low            | low                       | high       |
|                |                  | Regulation pond      | high                  | middle         | high                      | low        |

4.3. Rainwater Runoff Adjustment in Slope Residences Based on LID

In cases of organizing LID-based rainwater runoff in slope residences, we should reasonably divide the catchment area according to the natural terrain characteristics of the site. In a hexagonal block, rain gardens are set up at the bottom of the block, diverting the rainwater on both sides into the middle of the block and finally to the rain garden. Grass swales and vegetation buffers are arranged on both sides of the road to guide the road rainwater to rain gardens. Rainwater retention facilities are set up at lower levels of the area, part of the rainwater stored in the rain gardens in each block fully evaporated and seeped, and the other part flowing into rainwater retention facilities such as constructed wetlands or wet ponds in the area through seepage tubes. In the event of heavy rain, the rainwater that overflows from the rainwater retention facility passes through the drainage facility and is discharged into the surrounding natural water bodies (Figure 4). In the planning and design of the green eco-city project, Zhongtian “Future Ark”, designers build a hilltop park and plan several ecological green corridors from the top of the mountain to the Nanming River, intersperse the residences between the green corridors, and set up several rain gardens at the intersection of the residences and the green corridors. All these designs make full use of the terrain, and solve the problem of rainwater in residences with the help of rain gardens, slope greenways, natural water bodies and other LID facilities.

![Figure 4. LID facilities layout and Rainwater runoff adjustment in slope residences.](image_url)

5. Lid-Based Implementation of Slope Residence Planning

Residence planning should first enjoy reasonable treatment and planning based on the site’s topography characteristics, reasonable layout of three types of carrying surface of the building, road and greenbelt, and then detailed design of them according to the relevant needs and the current conditions.
5.1. LID-Based Site Design of Slope Residence

In terms of site design, we should delineate the areas suitable and not suitable for construction of development according to the topography characteristics of the site. In the area suitable for construction and development, we should reduce the damage to the natural mountain slope, maximize the preservation of the original site, arrange building and road along the ridge line, and use sub-layer ingestion treatment. At the same time, we construct ecological transition zone between the building and the road, to ensure that rainwater from the building can be successfully diverted into the LID facilities. In the latter case, development should be severely restricted, the natural drainage system protected and utilized, appropriate amounts of vegetation planted for greening, and more rainwater retained and stored. (Figure 5)

Figure 5. LID-based site design of slope residence.

5.2. LID-Based Building Design of Slope Residence.

The architectural design should focus on the link between the building’s own rainwater dissipation capacity and the drainage route of the surrounding site. In terms of the building design, green roofs are used, and drain lines or catchment semens are established to divert the rainwater from the roof overflow into underground rainwater tanks. In turn, the rainwater is drained into the scattered LID facilities in the surrounding greenbelt through selongic ditches, seepage tubes and other transfer facilities. (Figure 6)

Figure 6. LID-based building design of slope residence.

5.3. LID-Based Street Design of Slope Residence.

Streets are one of the main areas that produce rainwater runoff, so the design of residential streets in conjunction with LID should increase the permeability of the street surface, trying to combine the different components of the street sections(road, parking belt, sidewalk paving,......)with suitable LID facilities, and directing rainwater to LID facilities, while focusing on the convergence of LID facilities and drainage networks when rainwater overflows. (Figure 7)
5.4. **LID-Based Greenbelt Design of Slope Residence.**

Greenbelt plays the most important part in carrying LID facilities of residences. Its proportion, continuity and coordination between the greenbelt determines the rainwater storage capacity. In terms of greenbelt design, small and dot-like greenbelt should be evenly scattered in the various locations of the residence. Further, corresponding LID facilities are equipped around the greenbelt, so that rainwater can infiltrate through the surrounding greenbelt after falling, thus effectively reducing rainwater runoff. Meanwhile, grass swales, seepage tubes, open canals and other transfer-type LID facilities are built to discharge the overflowing rainwater in the small greenbelt into the belt green corridor and large surfaces for adequate storage, thereby reducing the construction costs of drainage networks.

6. **Conclusion**

The application of LID in slope residences is an important part of residence planning under LID theory, and it is complement and improvement to the LID theory and methodology. Based on the existing related research, and the special terrain conditions of mountainous areas, this article summarizes the application of LID in the planning of slope residences of green eco-city, Zhongtian “Future Ark”, solves the problem that the original method system can not be well applied to slope residences, and achieves good results. It is hoped that it can provide some ideas for slope residence planning oriented to rain and flood management. These guidelines, written in the style of a submission to *Material Science and Engineering: Conf. Ser.*, show the best layout for your paper using Microsoft Word. If you don’t wish to use the Word template provided, please use the following page setup measurements. Some before their text citation. Figures should never appear within or after the reference list.

7. **References**

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