

PAPER • OPEN ACCESS

Evaluating the Sustainability Impact of Greening, Water Management, Ventilation and Interior Lighting on Car Parking in Taiwan

To cite this article: Shu-Hui Hsieh *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **291** 012042

View the [article online](#) for updates and enhancements.

Evaluating the Sustainability Impact of Greening, Water Management, Ventilation and Interior Lighting on Car Parking in Taiwan

Shu-Hui Hsieh. Yu-Chen Chien. Yi-Chien Lee

Chaoyang University of Technology, Taiwan

ericayichien@gmail.com

Abstract. Amid increasing rates of car ownership, serious issues around parking have emerged in Taiwan in recent years. However, most debates on the construction of urban parking infrastructure have focused on assessments of its economic benefits, rather than on a more comprehensive decision-making framework that takes energy use and other sustainability issues into account. Accordingly, this paper is a first step toward creating such a framework from a green-architectural perspective.

1. Introduction

Due to rising living standards in increasingly complex societies around the globe, ownership of personal motor vehicles has increased dramatically in recent years. As such, ensuring that parking structures meet vehicle users' demand while also preserving the quality of urban life has emerged as a critical challenge for government in Taiwan, where road-widening is at best difficult, and traffic jams and accidents are commonplace. Until recently, the main factors considered when building or rebuilding parking facilities were their economic impact and the convenience of their locations, rather than any more holistic evaluation of their influence on their surroundings. Yet, with governments and the general public increasingly interested in pursuing sustainable development, such a holistic approach would appear somewhat overdue. The present research therefore suggests that the design and construction of parking facilities in Taiwan should take account of their energy use, especially with regard to interior lighting; carbon footprints; water-management characteristics; and other environmental aspects. Specifically, it will conduct three case studies, to examine:

- (1) Key design differences between a traditional parking structure and a modern one, with regard to vegetation cover and water-management characteristics;
- (2) A traditional underground parking facility's ventilation issues, and how these might be improved upon in a sustainable way; and
- (3) The interior lighting in an above-ground parking structure and ways of reducing its lighting-related consumption of energy and other resources.

2. Literature review

2.1 Christiansen, P., Engebretsen, Ø., Fearnley, N., Usterud Hanssen, J. (2017) [1]. Parking facilities and the built environment: Impacts on travel behaviour. Transportation Research Part A: Policy and Practice, 95, 198-206.



This research analysis modern parking facilities' key features and the relevant regulations affecting them, and establishes a set of principles for designing such facilities. In the case of open-air car parks, these principles include close attention to rainwater infiltration, the percentage of the land that is excavated, the percentage of green area, and soil depth .

2.1.1 , Shiau, Tzay-An (2018) [2]. Evaluating the sustainability of constructing public off-street parking lots.

Sustainable evaluation index.

2.1.2 Sarachanga et al. (2016)[3]. Evaluation of existing sustainable infrastructure rating systems for their application in developing countries.

This study evaluated the sustainability of infrastructure in terms of four dimensions, as shown in Table 1.

Table 1. Main Criteria Considered by the Rating Systems Under Assessment

(Sarachanga et al.'s)

Economy	Environment	Society	Management
Minimising workforce travel	Principles on the use of land	Stakeholder- and community engagement	Project management (contracts, design, construction)
Increasing the community's connectivity	Flood-risk management	Assessment of impacts in neighbours	Implementing sustainable procurement
Employment growth	Maintenance, enhancement or restoration of biodiversity and habitats	Boosting local employment	Improving decision-making processes
Resource efficiency	Maintenance or enhancement of landscapes	Preserving historical, cultural and archaeological heritage	Managing risk and opportunity
Business development	Efficient water use	Increase public information	Dealing with conflicting regulations and policies
Procurement practices	Maintenance or enhancement of water quality	Promotion of community health, wellbeing and safety	
Workforce development	Reduction of greenhouse gas emissions	Promoting workforce safety	
Stimulation of sustainable growth and development	Noise management	Improving accessibility	
Improvement of the community's quality of life	Reduction of air pollutants	Enhancing public space	
	Lighting pollution management	Preservation of views and local character	
	Reduction of energy use		
	Promotion of renewable energy		
	Efficient resource management		
	Hazardous-materials management		

3. Research methods

The three cases mentioned in Section 1 will be analysed based on the three indices described in Section 2, with particular attention to vegetation cover, soil water content index, ventilation-rate index, and interior-lighting index. The results of such analysis will then be used to establish principles for sustainable parking-facility design (Figure 1).

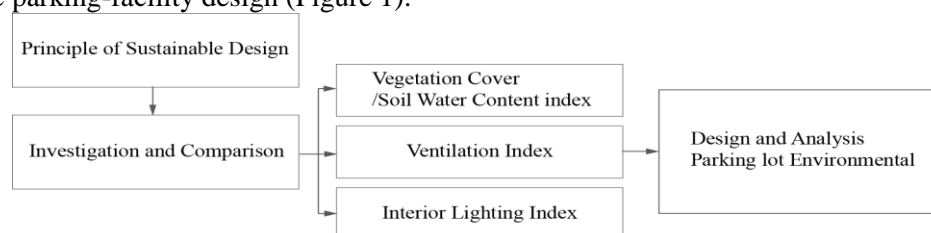


Figure1. Research Framework

4. Results and discussion

4.1 Building coverage ratio analysis

From the brown-shaded area of the left panel of Figure 2, it can be seen that the construction of Parking Facility “A” is typical from B1F to 4F, with the building taking up more than two-thirds of the site’s total area. Facility “B”, shown in the same figure’s middle panel, comprises underground parking arranged over two floors, raising questions related to the depth of the soil covering it. Lastly, the modern structure shown in the right panel from B2F to 4F includes a higher proportion of green space, in part as a means of achieving better soil water content.



Figure 2. Plan Views of the Three Studied Parking Facilities (Building Cover Shaded in Brown)

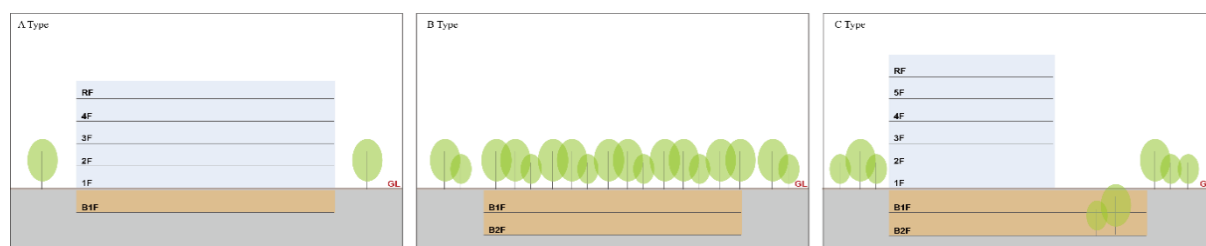


Figure 3. Sectional Views of the Three Studied Parking Facilities

4.2 Vegetation cover and soil water content indices

The soil water content index refers to natural and artificial soil layer’s ability to trap and store water inside construction base. Vegetation cover is computed as a percentage of the site area in which plants grow and statutory vacant space (Figure 4).

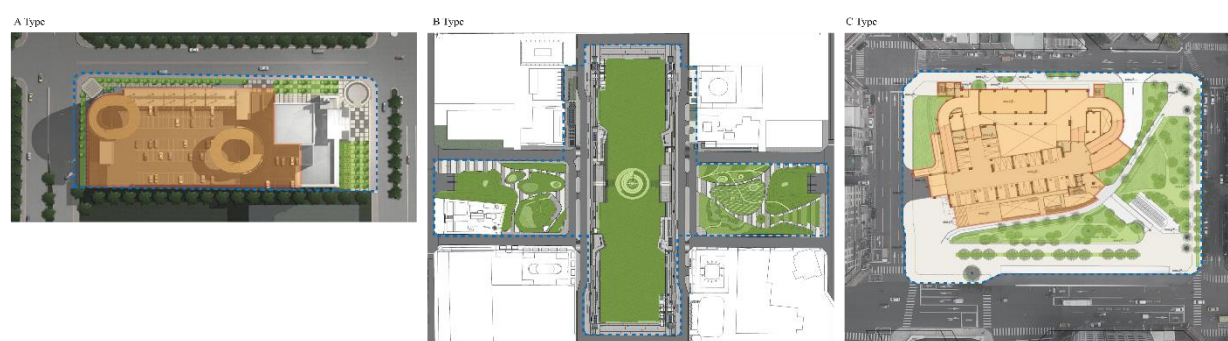


Figure 4. Area of Vegetation Cover and Soil Water Content Index

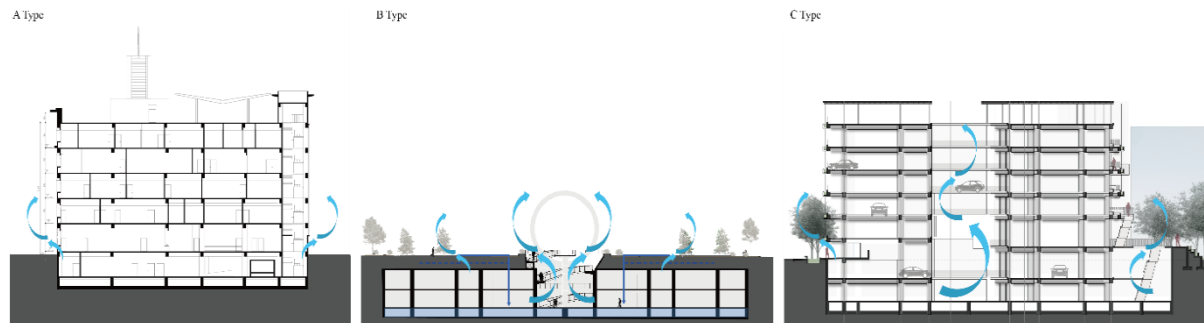
According to the statistics shown in Table 2, environmental re-design of sites “B” and “C” could reduce their building-coverage ratios, and thus raise vegetation cover to between 67% and 73%. It would also increase soil water content significantly, while providing new open space for public recreation.

Table 2. Percentage of Vegetation Cover and Soil Water Content Index

Dimensions	Traditional parking structure (Type “A”)	Underground parking facility (Type “B”)	Modern parking facility (Type “C”)
Building coverage ratio	62%	4%	33%
Vegetation cover and soil water content index	20%	73%	67%

4.3 Air quality of underground parking facilities

Building technical regulations in Taiwan specify that underground parking areas should have at least two vents or equivalent ventilation equipment. They should also incorporate opening windows, and the airflow in cubic metres per hour cannot be less than one-fifth of the floor area in square meters. Automatic ventilation equipment must be installed if natural air circulation is found to be insufficient.[4] As shown in Figure 5, facilities of type “A” tend to have traditional transom designs, while those of type “B” feature central patios, and type “C”, both patios and floor to ceiling windows in the centre and both sides.

**Figure 5.** Sectional Views of Ventilation

Given the inclusion of basement-level patios and floor-to-ceiling windows of sufficient size, CMH will increase to the point that auxiliary ventilation equipment is needed just one or the other of these things, thus achieving significant energy savings, as shown in Table 3.

Table 3. Comparison of Percentage of Ventilation

	Type “A”	Type “B”	Type “C”
Floor	B1	B1-B2	B1-B2
Basement Floor Area/m ²	1,113	43,000	6,393
5% Floor Area / m ²	56	2,150	320
Ventilation Rate / CMH	464	17,917	2,664
Size of Window / m ²	24	360	465
Patio Area / m ²	0	560	470
Ventilation Rate Area / m ²	34	920	935
	34 < 56	920 < 2,150	935 > 320
Percentage of Ventilation	7%	5%	35%

4.4 interior lighting

The interior lighting of parking facilities is often neglected, and underground structures in particular are stereotyped as dark and gloomy. This illumination problem can be addressed at the design stage, using solid angle project theory, and factoring in the angles of incidence of sunlight at various times of day and sizes, shapes, and precise placement of windows (Figure 6).

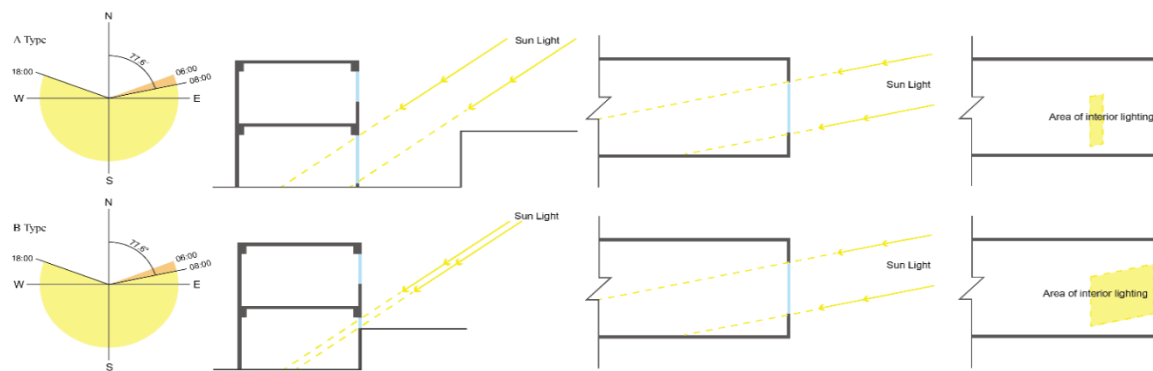


Figure 6. Analysis of Building Interior Lighting

Quantitative solid-angle analysis of type “A” and type “B” parking facilities shows that, when structures include patios and sufficiently large windows, interior lighting rates and illumination can be up to five times greater than in traditional designs with fanlight windows. And in general, increased access to natural light will decrease a given facility’s day-to-day need for artificial lighting (Table 4).

Table 4. Analysis of Window Size and Area of Interior Lighting

Dimensions	Type “A”	Type “B”
Window Size	H:60XW:300CM	H:280XW:300CM
Area of Interior Lighting / m ²	2	10

5. Conclusion

Most traditional parking facilities are dark, humid, expensive to maintain, and wasteful of energy, and are increasingly deemed undesirable and scheduled for demolition. The present research has pointed out a range of measures that could render parking facilities more suited to modern environmental needs, and provided preliminary analysis showing that all of these measures – comprising planting, water management, ventilation, and lighting – would have beneficial effects. As such, this research will be of considerable value to policymakers, construction-industry practitioners, and others responsible for the planning and implementation of parking-facility designs.

6. References

- [1] Riggs, William (EDT)(2017) Disruptive Transport: Driverless Cars, Transport Innovation and the Sustainable city of Tomorrow.
- [2] Shiau, Tzay-An (2018). Evaluating the sustainability of constructing public off-street parking lots.
- [3] Sarachanga et al. (2016). Evaluation of existing sustainable infrastructure rating systems for their application in developing countries.
- [4] Building Technical Regulations, Taiwan(2017).