MDPI

Article

Economic Valuation of Green Infrastructure Investments in Urban Renewal: The Case of the Station District in Taichung, Taiwan

Kuo-Wei Hsu and Jen-Chih Chao *

Department of Landscape and Urban Design, Chaoyang University of Technology,
Taichung City 413310, Taiwan; kwhsu@cyut.edu.tw
* Correspondence: jenchihchao@gmail.com; Tel.: +886-4-2332-3000 (ext. 7668)

check for updates

Abstract: The extreme weather conditions that are increasingly affecting Taiwan require urgent solutions, especially as land-use pressures and intensive urban development are triggering new types of vulnerability to natural disasters. Green infrastructure is an especially promising means of enhancing the resilience of urban environments, as well as their residents' quality of life. However, due to the indirect nature of green investment, the economic value of green infrastructure is not adequately reflected in market prices, and novel methods of economic valuation are needed to ascertain their value. To fulfill that need, this study conducts a cost–benefit analysis of investment in green infrastructure related to urban renewal and identifies economic factors that could directly and indirectly increase environmental quality and promote sustainable development. The main finding of this work is that the increased cost of a green approach for a particular urban-renewal infrastructure project in Taiwan could be recouped in approximately eight years. Specifically, version of the plan based on green infrastructure would cost an additional US $9.2 million up front, but its positive impact would be greater than the non-green version by US $1.2 million per year.

Keywords: green infrastructure; urban renewal; economic value; urban disaster prevention

1. Introduction

Taiwan's older urban areas, defined as those that were built between 1980 and 1990, have been the subject of urban-renewal initiatives since the late 1990s and are especially vulnerable to extreme events, including earthquakes and floods [1]. The goals of urban renewal are many and varied and, in the Taiwanese case, these include alleviating poverty, improving the quality of urban life, enhancing public interest in residential security, fostering sustainable economic development within and beyond the cities, and mitigating or preventing disasters [2]. Through both laws and regulations, the government has promoted the sustainable development of cities, while various incentives such as green buildings and open spaces have aimed at the promotion of private participation in planning, design, and implementation.

Development histories and legal issues have led Taiwan's older urban areas to have—by present-day standards—insufficient open spaces and other public amenities. Therefore, in the face of multi-faceted urban-development problems, cross-disciplinary work involving diverse government agencies and other stakeholders would seem to be fundamental to the success of urban-renewal initiatives. At present, however, the foci of urban-renewal projects in Taiwan have mostly been individual buildings rather than whole streetscapes or districts. This could lead to various problems, especially as government planning and design goals are shifting focus to the promotion of green-building volume incentives aimed at reducing carbon emissions and energy use, and away from urban disaster

prevention and urban sustainability strategies. The selection of these kinds of buildings tends to be based on their state of decay and the benefits that will be reaped after renewal, among other factors. This approach often leads to opportunities for regional development being missed, further driving regional disparities in terms of development.

Matthews et al. (2015) and Norton et al. (2015) have studied how green infrastructure can mitigate the impact of climate change and reduce risks and uncertainties. The same studies have shown that the cost of investing in the construction of this kind of infrastructure is lower than the cost of post-disaster recovery and that its economic, societal, and ecological impacts are also positive and important [3,4]. Groot (2006) proposed that, to coordinate landscape protection with land use and the changing needs of natural resources, the ecological, social, cultural, and economic value of the landscape must be fully considered in planning and decision-making [5].

In the process of green-infrastructure development in Taiwan, the planning and design of buildings mainly involves conforming to green-building codes aimed at reducing carbon emissions and energy use, increasing groundwater retention, and expanding green-coverage rates [6]. However, under the pressure of extreme climatic events, urban-disaster prevention also needs to be taken into consideration; to this end, some designers have begun to incorporate ecological flood-detention ponds, greenbelt systems, larger water-permeable areas (including permeable pavements) and more robust rain and sewerage systems into their designs. Benedict et al. (2006) and Brown (2008) have shown that Taiwan's urban development and natural environment face a range of threats driven by climate change, notably, heat-island effects, and flooding. These authors therefore emphasize the importance of connecting the concept of landscape ecology with the life and space utilization of cities and communities and of integrating these seemingly disparate disciplines into a framework for sustainable urban land-use planning [7,8]. Gabrielsen (2008) proposed that the city is like an organism whose ecological development is composed of social, economic, cultural, and other activities. Inevitably, after a long period of development, the city will suffer gradual losses of functionality and amenities, a decline of its public facilities, emigration, and socio-economic decline. If the city is allowed to continue along such a path without countermeasures being applied, its sustainable development will be difficult at best [9].

Taiwan's traditional water-capture and water-treatment methods have proved unable to cope with the extreme flooding associated with climate change. The balanced and effective implementation of urban green infrastructure, aimed specifically at reducing the impact of such natural disasters, will involve coordination among investors/developers, maintenance and management professionals, and individual users of urban spaces, among others, as well as meticulous construction and arrangement. Thus, in addition to focusing on cost–benefit considerations, rejuvenating urban functions and improving living environments, this paper argues that urban-renewal efforts should conform to the concept of an ecological city (Chan et al., 2007; Gill et al., 2007; Mell et al., 2013) [10–12], not least in order to address the challenges of climate change and the associated increased incidence of extreme weather events. From this perspective, green infrastructure can play a key role in urban renewal while promoting sustainable development, and such urban renewal should occur within the framework of a green urban economy, incorporating both large and small-scale countermeasures from the economic, social, environmental, and development-suitability perspectives.

Current urban-renewal processes are often governed by the consideration of rates of return on financial investment and the economic benefits of business development; however, the goal of a green urban economy should not be seen as antithetical to such concerns. It is true that the fundamental characteristic of green infrastructure is not the socio-economic benefits it provides but its greater ability to preserve the functions and values of natural ecosystems, as compared to its non-green counterparts (Benedict and MacMahon, 2002) [13]. Nevertheless, green infrastructure such as open spaces and green networks contributes indirectly but positively to real-estate values and plays a role in maintaining and protecting nature, which in turn generates economic growth not only at the city level but nationally (Nazir et al., 2015) [14].

Nazir et al. (2015) confirmed prior researchers' findings that green infrastructure, defined as a network of green open space and green elements, contributes indirectly towards housing and other property prices [14]. McPherson (1992) proposed that the value of green infrastructure lies in its combination of internal cost-effectiveness and multiplier effects. However, many economic-assessment methods only indirectly reflect the flow of infrastructure's multiple benefits and costs, and are thus of limited utility to policymakers and other stakeholders [15]. Similarly, Vandermeulen et al. (2011) showed that, as well as enhancing the environment, investment in green infrastructure has indirect positive effects on the regions where it occurs [16]. Three-quarters of Mell et al.'s (2013) respondents to a survey about the value and attractiveness urban street-tree investment in Manchester, UK, said they would be willing to contribute between £1.46 and £2.33, and pay higher taxes, if the increase would be spent on green-infrastructure investments. The same survey showed that residents had a significant preference for larger and more environmentally friendly projects [17].

Although there is an extensive literature on green infrastructure in other countries, the number of empirical studies on its economic value in Taiwan remains limited. Therefore, this study conducts a cost-benefit analysis (CBA) of green-infrastructure development in the context of Taiwanese urban renewal. Specifically, its purpose is to empirically assess and compare the economic value and cost-effectiveness of urban renewal with and without green infrastructure in the specific case of the Taichung Station District, as a means of establishing the impact of green infrastructure on the economic value of urban renewal. This is important to understand, in light of expectations that Taiwan's public and private sectors will increasingly incorporate green infrastructure into future urban-renewal projects, to enhance both urban natural-disaster resilience and sustainable urban development.

2. Literature Review

2.1. Definitions of Green Infrastructure

In 1999, the US Department of Agriculture's Forest Service and the non-governmental American Conservation Foundation jointly developed a plan for the localization of sustainable-development goals. They defined a green foundation as any system that supports the country's natural life, e.g., boulevards, woodlands, parks, rivers, wetlands, woodlands, protected areas, and wildlife habitats. Green infrastructure can be used as a network to connect such areas to one another; thus, providing better-quality air and water, promoting biodiversity and wildlife mobility, and generally serving as a framework for the healthy operation of the natural environment within a city (Benedict et al., 2006) [7]. The UK government's Guide to Green Infrastructure Planning, published in 2009, defines green infrastructure as the physical environment of green spaces between cities, towns and rural hinterlands—including parks, gardens and woodlands, green passages, water bodies, street trees and open villages—considered as a multi-functional open network, whose design and management must respect land type and ecology.

In 1999, the US President's Council on Sustainable Development declared the green base to be one of five comprehensive strategies for sustainable community development. In principle, the green base is different from the green channel on at least three levels: (1) the green base emphasizes ecology over entertainment/leisure; (2) unlike a green channel, a green base includes large-scale, important ecological centers and major landscape connections; and (3) a green base, by shaping whole urban environments, can provide a framework for urban growth (Benedict and MacMahon, 2002) [13].

According to Jane Heaton Associates (2005), green infrastructure is a network of multi-functional green spaces that contributes to the high quality of natural and built environments that existing and new sustainable communities will require in the future. Because sustainable communities balance and integrate their social, economic, and environmental components, green infrastructure in this view consists of both public and private assets, with and without public access, and in both urban and rural locations [18]. Cambridge shire Horizons Endurance House (2006) defines green infrastructure as a sub-regional network of protected sites, nature reserves, manmade green spaces and greenway

linkages, which collectively should provide multi-functional uses, i.e., wildlife, recreational and cultural experiences as well as environmental services such as flood protection and microclimate control. Within the constraints of its sub-regional scale; however, it should operate at all spatial scales, from urban center through to open countryside [19]. Moreover, according to Matthews et al. (2015), green infrastructure—defined as the biological resources in urban areas that are human-modified and primarily serve an overt ecological function, and which are intentionally designed and deployed primarily for widespread public use and benefit—can play a potentially important role in human adaptation to some of the expected impacts of climate change [3].

2.2. Economic Valuation of Green Infrastructure

The theory of economic value holds that total economic value comprises "use value" and "non-use value" (Turner et al., 1994) [20]. The present study explores the impact of green infrastructure development through that theoretical lens, as explained below.

2.2.1. Green Infrastructure Directly Affects Economic Value

The Council of Tree and Landscape Appraisers (2003) proposed that trees can increase the total value of property by 15% to 25%, depending on their species, size, condition, and location [21]. The positive impact of proximity to Mesnes Park in Newton-le-Willows, Merseyside on the value of real estate, was subsequently computed as 19% (Commission for Architecture and the Built Environment, CABE, 2004) [22], echoing earlier findings that residents of Scotland and Ireland were willing to pay £269 per household per year for the visual comfort of woodland views from housing on the edge of the city (Garrod, 2002) [23]. The average premium for real estate near a local park is 11.3%, while the average premium for real estate near a park is 7.3% (9.4% standard deviation) (CABE, 2005) [24].

A high-quality public environment can also attract more residents and tourists to an area, thus improving retail sales and employment opportunities as well as property values (Natural Economy Northwest, NEW, 2008; Venn and Niemela, 2004) [25,26]. For example, carefully planned improvements to the public space in a town center can increase commercial transactions by up to 40%, and generate substantial private sector investment (NENW, 2008) [25]. Thus, the environment is a direct consideration for those seeking sustainable economic prosperity, as it contributes to growth and economic security, as well as healthy ecosystems. In short, relevant research has shown that green infrastructure has an impact on land's use value.

2.2.2. Green Infrastructure Indirectly Affects Economic Value

Su (2012) reported that the air temperature of the area in adjacent to the river and with tree shade is 0.2~0.7 °C lower than that of in the urban street away from the river side and dense tree shade and permeable pavement can further improve such outcomes [27]. In the immediate surroundings of parks, meanwhile, every 10% increase in green coverage can effectively reduce summer nighttime temperatures by 0.17 °C to 0.22 °C (Kuo, 2000) [28]. The British government (2009) also linked higher urban green coverage rates to lower temperatures and less atmospheric carbon dioxide (HM Government, 2009) [29]. Enhancement of environmental quality encourages more people to connect through green spaces, while urban trees intercept and store rainfall, filter pollutants, and provide comfort (Stovin et al., 2008) [30].

According to NENW (2008), green infrastructure can mitigate the effects of climate change, pollution, and flooding while improving public health, civic pride, and educational opportunities. In the specific case of flooding, through penetration and interception, trees reduce the speed at which water flows into the ground, and the implementation of a sustainable urban drainage system in the right place plays a vital role in preventing floods (Department of Energy and Climate Change, 2009; Lin, 1998; Lin et al., 2009) [29,31,32]. The tree canopy also reduces soil erosion by reducing the impact of raindrops on barren surfaces and improving soil strength and stability by promoting the accumulation of soil organic matter and the action of tree roots (Nisbet et al., 2004) [33]. In the Brussels area as of 2006, only 10% of buildings had undergone large-scale greening, but this process nevertheless

reduced runoff by 2.7%, and individual buildings' runoff by 54% (Mentens et al., 2006) [34]. CBA has provided further evidence in support of sustainable urban drainage systems, by pointing out that, if well-designed and well-maintained, such systems are more cost-effective than traditional ones, because their construction and maintenance costs are both lower (Duffy et al., 2008) [35]. Gill et al. (2007) computed that increasing green space by 10 per cent would reduce runoff by 4.9%, while increasing tree coverage by 10 per cent would reduce it by 5.7%, and the use of green roofs, by between 11.8 and 14.1% [11]. Any community susceptible to flooding can use a model based on geographic information systems (GIS) to estimate the benefits of green infrastructure for reducing flood damage, compare it with costs, and design a cost-effective target investment for unstructured flood-disaster mitigation policies (Kousky et al., 2013) [36]. The urban green coverage rate can be improved by building new structures in line with green design principles, adding new public facilities, and adding new open spaces such as parks. Bicycle lanes, in particular, reduce urban carbon-dioxide emissions, especially when connected in networks; and energy-saving appliances can reduce urban carbon emissions as well as energy costs.

In sum, the relevant prior research has reported that the economic value of green infrastructure consists mainly of indirect benefits, e.g., to the environment, human health, climate adaptation, and pollution reduction. We expect that through CBA, clearer understanding of the direct economic value of green infrastructure will be useful in the promotion of such infrastructure by both the public and private sectors.

3. Methods

3.1. Description of the Case

Taichung City Central District is an old urban area with no comprehensive plan for green open space. However, Taichung Railway Station—which has approximately 52,000 daily visitors—serves an elevated railway, the space under which serves as a green corridor, connecting the transfer center and the transfer station both to urban bus services and to the national highway network [37]. Current plans for this urban area include the building of new green infrastructure, improving the green transportation network, and enhancement of the pedestrian environment. Physically, as shown in Figure 1, the scope of this study is Taichung Railway Station and its surrounding area of planned green river environment construction; the Green Sky Railway axis; the Taitang Ecological Lake; and the Railway Culture Museum.

After the Jianguo Market was relocated, it management cooperated with the surrounding landowners to handle land-use changes. The physical scope of the resulting empty site was the 3.53 hectares bounded by Nanjing Road, Jianguo Road, Bade Street, Wude Street, and Xinmin Street. The original single site has now been subdivided into a 1.86-hectare northern commercial area, 0.77 hectares of market land, and roads covering 0.90 hectares. The vision for Taichung Grand Station is shown in Figure 2.

3.2. Data

Data on rents for commercial space in that area were obtained from the Taichung Grand Station Project. Green-building costs and other parameters were obtained from the Taiwan Architecture & Building Center, and the costs associated with earthquakes, typhoons, and floods, from the Fubon Insurance Company.
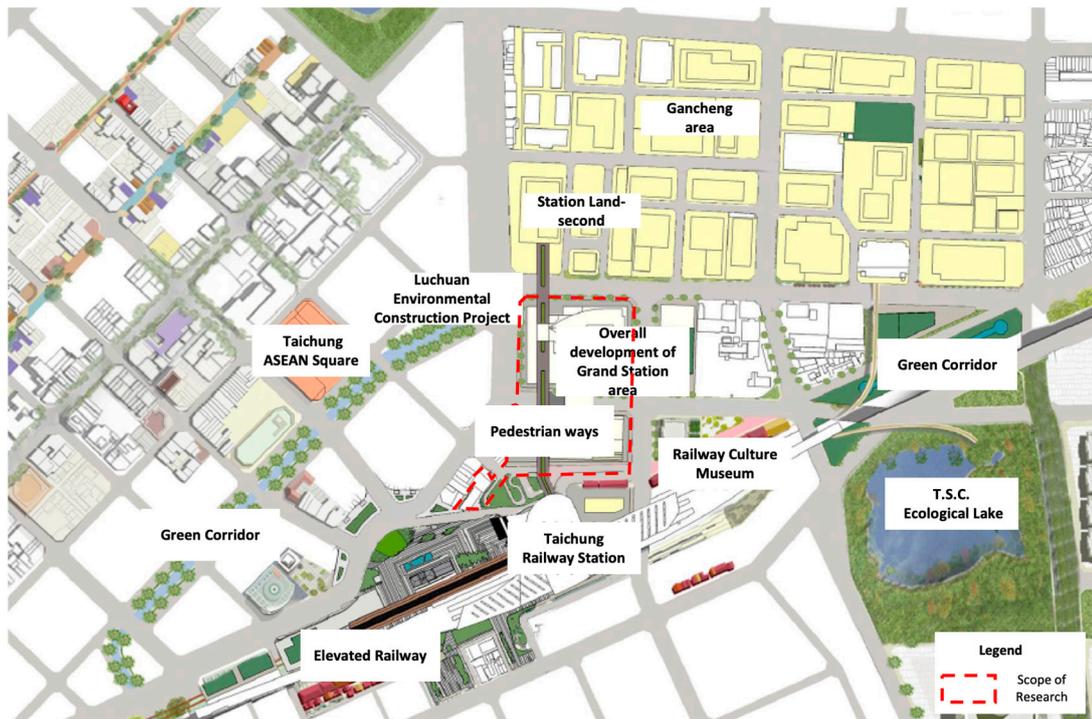
Figure 1. Vision of Taichung Grand Station. Source: Urban Development Bureau, Taichung City Government, Project Report on the Grand Station Project (2017) [38].
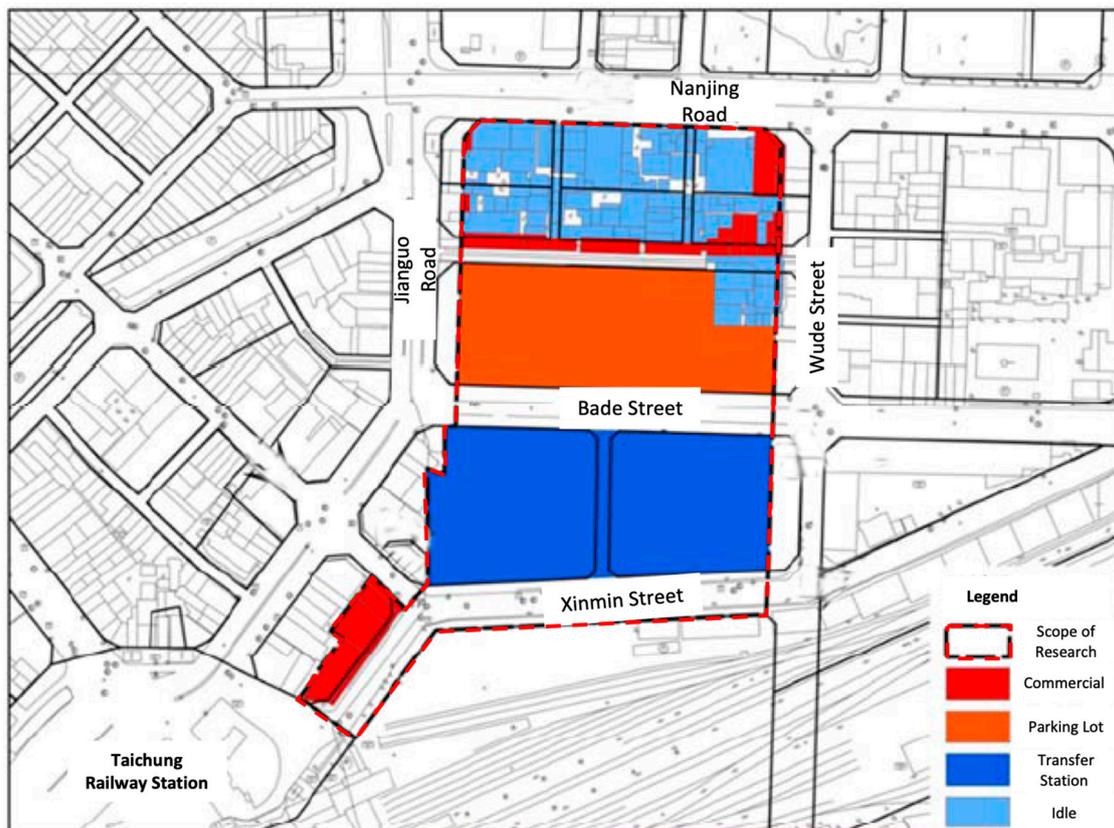
Figure 2. Scope of research. Source: Urban Development Bureau, Taichung City Government, 2018 change to the master planning document of Taichung City (fourth overall review, 35th case) [39].

3.3. Cost Benefit Analysis

Discussions of the economic value of green infrastructure involve a wide range of factors (Nesticò and Sica, 2017; Noelwah et al., 2014; Oranje and Voges, 2014) [40–42]. The present study will discuss the economic costs and benefits of incorporating green infrastructure into an urban renewal project, utilizing the same factors adopted in relevant previous studies.

This study's CBA of investment includes both direct and indirect costs and benefits, with the aim at arriving at net present values that reflect future opportunity value and risk. The net present value (NPV) can be given as follows,

$$NPV = \sum_{t=0}^{t} \frac{(B_t - C_t)}{(1+i)^t}$$

with *B* being the benefits; *C* the costs (including the investment costs); *t* the total period considered; *t* the year in which a cost or benefit occurs; and *i* the discount rate, reflecting opportunity values and risk.

4. Results and Discussion

4.1. Selection of Costs and Benefits

The urban renewal area associated with standard building is 35,299.2 m^2, and the relevant regulations for volume reward are 20% for planning and design, and 15% for renewal unit size. The floor area of the building is 38,122.4 m^2, with a construction price is US $822.81 per m^2; and the external space, 21,180.2 m^2, costing US $30.85 per m^2, yielding a total price of US $942 million. The commercial area is 24,776.9 m^2 (65%) and the parking lot and service facilities, 13,342.2 m^2 (35%).

The urban renewal of green infrastructure building is coordinated with the plan for Taichung Station, connected by corridors and green infrastructure, with the aim of achieving the Green Building Gold Mark (For further details, see Appendix A). The urban-renewal area earmarked for this type of building is the same as above, i.e., 35,299.2 m^2, though the relevant regulations for volume reward differ: i.e., 30% for planning and design, 8% for green building design, and 15% for renewal unit size, to a maximum of 50% in the aggregate). The buildings' floor area is somewhat larger, at 42,357.2 m^2, and the construction price is also higher, at US $925.65 per m^2. The external space is the same, 21,180.26 m^2, at the same cost as before. Therefore, the total price is US $1.22 billion. Further details are presented in Table 1.

Table 1. Comparison table. Cost of urban renewal, standard building vs. green infrastructure building.

Type		Cost (US$)
Standard	Land cost	35,299.2 m^2 × US $8.63 thousand = US $299.76 million
	Building cost	(38122.4 m^2 × US $822.81) + (21,180.2 m^2 × US $30.85) = US $31.48 million
Green	Land cost	35,299.2 m^2 × US $8.63 thousand = US $299.76 million
	Building cost	(42,357.2 m^2 × US $925.65) +(21,180.2 m^2 × US $334.21) = US $40.68 million

4.2. Calculating the Total Economic Value of the Green Infrastructure Investment

The value of land in the focal area next to the Taichung Railway Station after the integration of commercial, parking lot with transfer station was US $8.63 thousand per m^2, and rent of commercial space in standard buildings there, totaling 24,776.9 m^2, is US $102.85 per m^2 per year. Despite car-parking revenue collected from railway passengers who drive themselves to the station, and lease payments from the railway company itself, a single-building mass transportation system combined with a commercial development model was found to be have less connectivity with surrounding public facilities than its green-infrastructure equivalent. The latter's commercial space rents would be higher, at US $131.14 per m^2 per year (For further details, see Appendix A), and its rentable space 27,530.7 m^2.

Through joint development, it would connect the public transportation systems and thereby increase the flows of people and commerce. The cost of urban renewal and construction of green infrastructure building is higher than its non-green counterpart by US $9.2 million, and the annual economic value difference of space rental is estimated at US $1.08 million higher.

According to the statistics on energy efficiency compiled by the Taiwan Architecture & Building Center, green building is associated with average savings of 23.64 KWh of electricity per m^2 per year, which in financial terms breaks down as US $2.77 for electricity, 1.12 m^3 for water source, and US $0.37 for water per se. Since the statistics for energy-saving benefits are based on area, however, they do not facilitate comparison of such benefits across different grades of green buildings. The floor area of the standard of building for urban renewal is 38,122.48 m^2, meaning that—as compared to an un-restored building of the same size—it can be expected to reduce electricity use to 903,300 KWh per year, and thus electricity costs to US $105.11 thousand per year; and reduce water usage to 42,700 m^3 per year, at a cost savings of US $14.28 thousand. Thus, it can reduce total energy expenditures to US $119.39 thousand per year. The green-infrastructure of building for urban renewal, on the other hand, which has a floor area of 42,357.21 m^2, can reduce electricity consumption by 1,001,400 KWh per year, and thus decrease electricity costs to US $118.61 thousand, water usage to 47,400 m^3, and water costs to US $15.87 thousand. Thus, such a building, as compared to an unrestored building, would reduce energy expenditure by US $134.48 thousand per year. In other words, the annual economic value of the green infrastructure urban-renewal building is US $15.09 thousand higher than that of the standard equivalent.

According to Taiwan's National Center for Research Earthquake Engineering, buildings' exposure to wind, sunlight, and rain gradually causes their materials to deteriorate, and alongside such deterioration, their seismic resistance also declines. The normal service life of ordinary buildings is about 50 years. The Taiwan Earthquake Research Center's hazard potential distribution map and seismic probability map show that, over the next 30 years, the probabilities that earthquakes with magnitudes of more than seven occurring on Taiwan Island are highest in East Taiwan, at 20%, followed by Southwest, Central and North Taiwan at 13%, 7% and 4%, respectively. Over the 50-year horizon, on the other hand, these chances will rise to 31% for East Taiwan and 21% for the Southwest. In the shorter of these two timeframes, during such an earthquake, buildings less than three stories tall are the most likely to be severely damaged or destroyed. The newly built building is at least meeting the design earthquake code under the earthquake-resistant laws and regulations.

The return period of an earthquake of this magnitude is 475 years, and its 50-year surpassing probability is about 10%. At this size of earthquake, a building must not be severely damaged if serious loss of life and property is to be avoided. Although the standard building for urban renewal is generally more earthquake resistant than the older buildings it replaces, it does not contain any structural reinforcement specifically intended for seismic resilience. However, upgrading buildings' structures and planning their surrounding environments in a green manner requires higher engineering costs, but reduces the earthquakes' on buildings and outdoor refuge spaces alike, reducing the probability of loss of life.

Turning now to the possibility of extreme climatological events, it should first be noted that the underbuilding of standard urban-renewal buildings is marked by low water retention and low connectivity to the surrounding environmental network, making it difficult to assess such buildings' relationship to flood prevention in their wider surroundings. Urban renewal utilizing green infrastructure, on the other hand, is known to reduce surface runoff during heavy rain; slow down urban drainage; and retain water in outdoor environmental bases—all of which reduce the likelihood of severe flooding.

The indirect economic value of the above-mentioned differences between green and non-green urban-renewal projects can be evaluated by reference to the costs of earthquakes, typhoons, and floods to the insurance industry. Here, data from Fubon Insurance Company has been used for this purpose, and reveals that the annual earthquake insurance of the standard building is 5.22%, and for insuring it against typhoons and floods 3.27%. Thus, choosing green building techniques for a project

of this size would tend to result in an annual insurance-cost of US $267.99 thousand. Similarly, if purchased separately, the earthquake insurance rate for green infrastructure is 2.28%, and for insuring it against typhoons and floods 1.51%, meaning that its annual insurance cost for these policies purchased separately would be reduced to US $162.35 thousand, as compared to those of an equivalent building constructed using standard techniques.

Thus, the total economic value of a green infrastructure building in this case is US $105.64 thousand per month higher than for its standard counterpart, while its construction cost is US $9.2 million higher. The economic value benefit can create a difference of approximately US $1.2 million in economic value every year. The new cost can be recovered in about eight years. Further details are presented in Table 2.

Table 2. Comparison table, urban renewal, standard building vs. green infrastructure building.

Type		Economic Value (US$)
Standard	Direct economic value	24,776.9 m^2 × US $102.85 per m^2 per year = US $2.54 million
	Indirect economic value	Reduced use of electricity by 901,300 KWh, saving US $105.11 thousand; reduced use of water by 42,700 m^3, saving US $14.28 thousand; total savings, US $119.39 thousand
		Insurance rates: earthquake 5.22%, typhoon and flood insurance: 3.27%; total, US $267.99 thousand per year
Green	Direct economic value	27,530.7 m^2 × US $131.14 per m^2 per year = US $3.62 million
	Indirect economic value	Reduced use of electricity by 1,001,400 KWh, saving US $118.61 thousand; reduced use of water by 47,400 m^3, saving US $15.87 thousand; total savings US $134.48 thousand
		Insurance rates: earthquake 2.28%, typhoon and flood insurance: 1.51%; total, US $162.35 thousand per year

4.3. Appraisal of Green Infrastructure Investment

As we have seen, the construction cost of the green-infrastructure building is projected to be higher by US $9.2 million. However, the direct value of its rents, at US $2.54 million, is higher than that of the standard building's rents by US $1.08 million. Likewise, the standard building's indirect economic value, in terms of reduced electricity and water costs relative to the status-quo old building, would be US $105,110 and US $14,280 per year, respectively, or US $119,390 in all—but these savings are still lower by US $15,090 per year than the savings that could be achieved by the green-infrastructure building, i.e., electricity US $118,610 and water US $15,870, totaling US $134,480. Similarly, in terms of insurance cost, the standard replacement building comes to US $267,990 per year, which–while lower than that of its predecessor building—is still higher than the insurance cost of its green-infrastructure counterpart by US $105,640 per year. Thus, the higher cost of the green version of the new building, US $9.2 million, could be recouped in seven years and seven months, due to its greater annual direct and indirect economic value of US $1.2 million.

4.4. Implications to Future Green Infrastructure Investments

In short, if a green-infrastructure version of the Taichung Grand Station renewal project were implemented, including green buildings and human-oriented environments, it would reduce energy use and carbon emissions and create a more comfortable and user-friendly urban environment. This in turn would tend to increase the value of land use, attracting commercial activity and investment, and thus open further opportunities for urban redevelopment. It would also help to adapt the area to extreme climatic events and other natural disasters, thereby mitigating the rates of losses from such disasters. Moreover, by enabling the public to understand the positive impact of green infrastructure on the economy, living environments, and sustainable urban development, the private sector can promote the development of green infrastructure in urban renewal, thus reshaping and driving regional development, along with the important opportunities that such development implies.

5. Conclusions

Under Taiwan's prevailing volatile climatic conditions, the island is frequently struck by sudden heavy rains, which can overload its urban drainage systems and cause disastrous floods. Given that such extreme weather events are increasing in frequency and severity, improving the quality of the urban environment via more holistic urban-renewal plans encompassing multiple buildings, land use, and transportation links can aid disaster prevention and mitigation. Through the evaluation of an actual case, we have computed the economic value of green infrastructure in urban renewal, and the results present a compelling case that stakeholders should choose a landscape planning approach to future urban-renewal projects. This study identified three major areas of economic contribution from green infrastructure in Taichung Station, with combined added value of US $1.2 million per year. The additional annual value of the commercial rents of green buildings would be US $1.07 million, while such buildings' design would reduce electricity and water costs by an estimated US $13,500 per year, and their insurance costs by US $107,280 per year. This suggests that, driven by public-sector investment in construction, in conjunction with the promotion of urban renewal and the establishment of green urban-infrastructure networks, the resilience of urban areas to disasters can be enhanced alongside their general quality-of-life aspects.

It is also expected that the private sector will participate not only in continued piecemeal implementations of urban renewal, but also in the development of green cities. The development of green infrastructure in the context of urban renewal positively influences economic value, not only of the target buildings themselves, but also of their wider contexts of open spaces, housing, and public facilities. It is hoped that the present research will highlight some ways in which the total economic value of urban renewal results not only from direct financial benefits, but can also be indirect, not least through important positive impacts on citywide sustainability.

Because green infrastructure is intimately connected with surrounding public facilities, it tends to increase the flow of people, which has knock-on effects on maintenance and management costs; and these inherently higher ongoing costs should be a topic of scholarly discussion. Future research should therefore explore green infrastructure's possible negative economic impacts on urban renewal's economic value, and/or on the value of the wider economy, since direct and indirect benefits are interrelated, but the indirect ones are arguably more valuable. It is therefore recommended that future studies explore how the indirect benefits of green infrastructure for urban renewal can be modeled, and how such models can incorporate urban-disaster prevention and mitigation.

Appendix A. Data Generated by Costs and Benefits

1. According to Hsu (2016), in cases where a building attains a "qualified level" rating except for the two threshold indicators "daily energy saving" and "water resources", are required. Most of designer use "greening amount", "base water retention" and "sewage and garbage improvement" as the priority application indicators. If between eight and nine indicators are obtained, the overall green-building grade trend will be better, almost reaching the "gold level" standard [43].

2. Specific figures regarding the standard of urban-renewal building have been estimated with reference to 2019 rental prices for stores near the railway station. Those for the green infrastructure building have been calculated with reference to the 2019 Taiwan Railway Leasing Taichung Railway Station 2F commercial space standard rent. At present, each day, about 20,000 people enter and leave the Taichung Transit Station, and about 60,000 enter and leave the Taichung Railway Station.

References

1. Urban Regeneration Portal Site. Available online: https://twur.cpami.gov.tw/zh/theme/main/1 (accessed on 1 May 2019).
2. Urban Renewal Act. Available online: http://uract.cpami.gov.tw/module.php?i=rule&type=A10 (accessed on 1 May 2019).
3. Matthews, T.; Lo, A.Y.; Byrne, J.A. Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landsc. Urban Plan.* **2015**, *138*, 155–163. [CrossRef]
4. Norton, B.A.; Coutts, A.M.; Livesley, S.J.; Harris, R.J.; Hunter, A.M.; Williams, N.S.G. Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landsc. Urban Plan.* **2015**, *134*, 127–138. [CrossRef]
5. De Groot, R. Function-Analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. *Landsc. Urban Plan.* **2006**, *75*, 175–186. [CrossRef]
6. Taiwan Architecture & Building Center. Available online: http://gb.tabc.org.tw/modules/pages/target (accessed on 1 May 2019).
7. Benedict, M.A.; MacMahon, E.T. *Green Infrastructure: Linking Landscapes and Communities*; Island Press: Washington, DC, USA, 2006.
8. Brown, P.R. The Role of Citizen Activists in Urban Infrastructure Development. In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century*; Birch, E.L., Wachter, S.M., Eds.; University of Pennsylvania Press: Philadelphia, PA, USA, 2008; pp. 152–169.
9. Gabrielsen, G.V. *Area-Based Strategies and Urban Regeneration*; AHO The School of Architecture and Design: Oslo, Norway, 2008.
10. Chan, E.; Lee, G.K.L. Critical factors for improving social sustainability of urban renewal projects. *Soc. Indic. Res.* **2007**, *85*, 243–256. [CrossRef]
11. Gill, S.E.; Handley, J.F.; Ennos, A.R.; Pauleit, S. Adapting cities for climate change: The role of green infrastructure. *Built Environ.* **2007**, *33*, 115–133. [CrossRef]
12. Mell, I.C.; Henneberry, J.; Hehl-Lange, S.; Keskin, B. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Urban For. Urban Green.* **2013**, *45*, 96–306.
13. Benedict, M.A. Green Infrastructure: Smart Conservation for the 21st Century. *Renew. Resour. J.* **2002**, *20*, 12–17.
14. Nazir, N.N.M.; Othman, N.; Nawawi, A.H. Role of Green Infrastructure in Determining House Value in Labuan Using Hedonic Pricing Model. *Procedia Soc. Behav. Sci.* **2015**, *170*, 484–493. [CrossRef]
15. McPherson, E.G. Accounting for benefits and costs of urban greenspace. *Landsc. Urban Plan.* **1992**, *22*, 41–51. [CrossRef]
16. Valerie, V.; Ann, V.; Bert, V.; Van Huylenbroeck, G.; Xavier, G. The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landsc. Urban Plan.* **2011**, *103*, 198–206.
17. Mell, I.C.; Henneberry, J.; Hehl-Lange, S.; Keskin, B. Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. *Urban For. Urban Green.* **2013**, *12*, 296–306. [CrossRef]
18. Jane Heaton Associates. *Green Infrastructure for Sustainable Communities. Environment Agency*; Trentside Offices: West Bridgford, Nottingham, UK, 2005.
19. *Green Infrastructure Strategy—Quality of Life Programme*; Cambridgeshire Horizons Endurance House: Cambridge, UK, 2006.
20. Turner, R.K.; Pearce, D.; Bateman, I. *Environmental Economics: An Elementary Introduction*; Harvester Wheatsheaf: London, UK, 1994.
21. Council of Tree and Landscape Appraisers (CTLA). *Summary of Tree Valuation Based on CTLA Approach*; International Society of Arboriculture: Savoy, IL, USA, 2003.
22. Commission for Architecture and the Built Environment. *The Value of Public Space*; Commission for Architecture and the Built Environment: London, UK, 2004; Available online: http://www.cabe.org.uk/publications/the-value-of-public-space (accessed on 1 May 2019).

23. Garrod, G.D. *Social and Environmental Benefits of Forestry Phase 2: Landscape Benefits, Report to the Forestry Commission*; Centre for Research in Environmental Appraisal and Management, University of Newcastle upon Tyne: Newcastle, UK, 2002.

24. Commission for Architecture and the Built Environment. Does Money Grow on Trees? *Commission for Architecture and the Built Environment: London, UK,* 2005. Available online: http://www.cabe.org.uk/publications/does-money-grow-on-trees (accessed on 1 May 2019).

25. Natural Economy Northwest. The Economic Value of Green Infrastructure. Available online: http://www.naturaleconomynorthwest.co.uk/resources+reports.php (accessed on 1 May 2019).

26. Venn, S.J.; Niemela, J.K. Ecology in a multidisciplinary study of urban green space: The URGE project. *Boreal Environ. Res.* **2004**, *9*, 479–489.

27. Su, Y.-S. The Strategy to Mitigate the UHI Intensity for an Eco-City by Using Natural Water Areas in the Hot Humid Zone: A Case of the Tamshui River in Taipei City. Master's Thesis, Department of Architecture, China University of Technology, Taipei, Taiwan, 2012.

28. Kuo, P.-Y. A Study on the Micro-Climate of Urban Parks in Tainan. Master's Thesis, Department of Architecture, National Cheng Kung University, Tainan, Taiwan, 2000.

29. Department of Energy and Climate Change. *The UK Low Carbon Transition Plan: National Strategy for Climate and Energy*; HM Government: London, UK, 2009. Available online: http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx (accessed on 1 May 2019).

30. Stovin, V.R.; Jorgensen, A.; Clayden, A. Street trees and stormwater management. *Arboric. J.* **2008**, *30*, 1–4. [CrossRef]

31. Lin, T.-P. The Research on the Performance of Raining Storage in Building Site. Master's Thesis, Department of Architecture, National Cheng Kung University, Tainan, Taiwan, 1998.

32. Lin, C.Y.; Chung, C.P.; Lin, C.R. A Study of Vegetation Coverage and Water Storage Capacity at Taichung Metropolitan Park Before and After development. *J. Soil Water Conserv.* **2009**, *41*, 31–44.

33. Nisbet, T.R.; Orr, H. *Broadmeadow, S. A Guide to Using Woodland for Sediment Control*; Forest Research: Farnham, UK, 2004.

34. Mentens, J.; Raes, D.; Hermy, M. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? *Lands Urban Plan* **2006**, *77*, 217–226. [CrossRef]

35. Duffy, A.; Jefferies, C.; Waddell, G.; Shanks, G.; Blackwood, D.; Watkins, A. A cost comparison of traditional drainage and SUDS in Scotland. *Water Sci. Technol.* **2008**, *57*, 1451–1459. [CrossRef] [PubMed]

36. Carolyn, K.; Sheila, M.O.; Margaret, A.W.; Molly, M. Strategically Placing Green Infrastructure: Cost-Effective Land Conservation in the Floodplain. *Environ. Sci. Technol.* **2013**, *47*, 3563–3570.

37. Number of Passengers Entering and Leaving the Taichung Railway Station. Available online: https://data.gov.tw/dataset/8792 (accessed on 1 May 2019).

38. *Project Report on the Grand Station Project*; Urban Development Bureau, Taichung City Government: Taichung, Taiwan, 2017.

39. *Change to the Master Planning Document of Taichung City (fourth overall review, 35th case)*; Urban Development Bureau, Taichung City Government: Taichung, Taiwan, 2018.

40. Antonio, N.; Francesco, S. The sustainability of urban renewal projects: A model for economic multi-criteria analysis. *J. Prop. Invest. Financ.* **2017**, *35*, 397–409.

41. Mark, O.; Pierre, V.P. A successful local economic development-urban renewal initiative: A case study of the Mandela Bay Development Agency. *Stads-En Streeksbeplan.* **2014**, *65*, 35–47.

42. Noelwah, R.; Netusil, Z.L.; Vivek, S.; Ted, H. Valuing green infrastructure in Portland, Oregon. *Landsc. Urban Plan.* **2014**, *124*, 14–21.

43. Hsu, H.H. *A Study on the Relationships between the Green Building Rating System and the Green Building Evaluation Indicators*; Ministry of The Interior Research Project Report; Architecture and Building Research Institute: Taipei, Taiwan, 2016.