

Article

Assessing the Validity of a Green Infrastructure Conceptual Framework for Urban Transport Planning: Insights for Building Resilient Cities

Frances Ifeoma Ukonze ^{1,*} , Antoni Moore ¹ , Greg Leonard ¹ and Ben Daniel ² 

¹ School of Surveying, University of Otago, Dunedin 9054, New Zealand

² Centre for Teaching, Learning and Technology (CTLT), University of Northern British Columbia, Prince George, BC V2N 4Z9, Canada

* Correspondence: ifeoma.ukonze@postgrad.otago.ac.nz

Abstract

Green Infrastructure (GI) has increasingly been recognised as a crucial strategy for enhancing urban resilience, particularly in urban transportation systems facing the challenges of climate change. Although several conceptual frameworks for GI planning have been proposed, empirical studies examining their application in urban transport planning contexts remain limited. This study aims to validate a recently developed GI conceptual framework by evaluating its applicability in urban transportation systems. A structured questionnaire was administered to 94 participants in Aotearoa New Zealand comprising urban planners, engineers, architects, policymakers, and academics involved in transportation and sustainability planning with special focus on GI. The framework was assessed across key dimensions including the perceived benefits of GI in transportation, stakeholder and collaborative practices barriers to implementation, and indicators of perceived effectiveness. The results confirm that the stakeholders' perceptions of GI are significantly aligned with the dimensions of the conceptual framework, reinforcing its validity in assessing GI effectiveness. Key findings highlight a disconnect between stakeholders' general familiarity with GI and their understanding of its multifunctional benefits beyond stormwater management. Also, the prevalence of multidisciplinary collaboration suggests that additional interdisciplinary and transdisciplinary approaches are required for more holistic GI planning. This study recommends that the conceptual framework be considered for city adaptation to GI integration, and to do so effectively, these knowledge and cooperation gaps must be addressed

Keywords: green infrastructure; conceptual framework; urban resilience; urban transport planning; validity



Academic Editor: Harry Coccossis

Received: 15 May 2025

Revised: 11 June 2025

Accepted: 16 June 2025

Published: 20 June 2025

Citation: Ukonze, F.I.; Moore, A.; Leonard, G.; Daniel, B. Assessing the Validity of a Green Infrastructure Conceptual Framework for Urban Transport Planning: Insights for Building Resilient Cities. *Sustainability* **2025**, *17*, 5697. <https://doi.org/10.3390/su17135697>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Globally, urban transportation networks are becoming more susceptible to the many effects of climate change, such as increased temperatures, more frequent and severe flooding, and other severe weather occurrences [1]. As cities try to address these issues, GI integration has become a key approach for improving urban resilience [2–4]. GI describes a well-designed system that integrates built environments, natural, and semi-natural features to lessen the environmental effect of fundamental infrastructure, promote resilience, and provide a range of benefits for society and economy [5–8]. For urban transport, GI offers multiple benefits, which include air quality improvement, lessening the effects of urban

heat islands, minimising stormwater runoff, enhancing the streetscape, and making urban areas more liveable [9]. Among these benefits, GI aims to promote resilient cities [10]. Several major cities are adopting different strategies that will promote resilience, like GI, to plan for and manage the many risks not only to the environment [11] but also the economy [12], society [13], and food security among others [14]. Despite the increasing awareness of GI potential, its integration into urban transportation planning is still inconsistent and under-explored. Some studies attribute the challenges of its development to stakeholders' collaboration [2,15,16], financial constraints [16], institutional and administrative [17,18], and technical and design [17,19] factors. These challenges influence GI development in different ways—stakeholders' collaboration influences consensus-building and co-creation; fiscal constraints limit implementation and long-term viability. Other challenges, institutional and administrative, influence policy alignment and coordination, along with co-creation, while technical and design complexities shape the feasibility, functional and integration of GI solutions into current urban systems. However, a recent study showed that, although these issues exist, they could be managed with the right stakeholder collaboration tool [2].

Several studies have proposed conceptual frameworks to guide various GI discussions. These frameworks address a wide range of themes, including managing the multifunctionality of GI, evaluating the effectiveness of different components of GI, and its application across diverse social, economic, and environmental sectors [13,16,20–23]. Other frameworks support the integration of GI into policies [24,25] or identifying the barriers and drivers for a systemic approach to its regulation [26]. Whilst these frameworks focus on specific components or thematic areas of GI, Ukonze et al. [2] framework is different in its emphasis on the planning and implementation processes with a particular focus on multi-stakeholder collaboration and transdisciplinary approaches as critical enablers for effective GI integration in urban planning. However, the practical applicability of this framework, especially Ukonze et al. [2] in transport planning contexts, is yet to be systematically evaluated. This gap is especially significant in urban transportation systems, which are usually complex with many stakeholders involved, different governance structures, and varied environmental conditions. The conceptual GI framework suggests that achieving effective GI integration into cities is key to building urban resilience. Hence, by integrating stakeholder engagement, policy support, economic considerations, technical sustainability, governance, and time allocation, the framework aims to enhance the effectiveness of GI initiatives.

To fill the gap in systematic evaluation, this study tests the conceptual framework (see Figure 1) in urban transportation planning, evaluating its components from the viewpoints of actual stakeholders. This framework provides a systematic way of integrating GI into urban transportation systems, identifying the right stakeholder approach, weighing the positive indicators and confounding factors, and considering best practices to enhance resilience. The conceptual framework is structured into four stages. The first stage addresses the conditions necessary for starting a GI project, which include 'government maturity, increasing strength and time availability' [2]. Once the project begins, stage two evaluates stakeholders' collaboration approaches: multidisciplinary, interdisciplinary, and transdisciplinary. Given GI's boundary nature [27], the framework proposes the most effective transdisciplinary approach [2]. However, elements of other approaches may be used until the project matures sufficiently for full transdisciplinary implementation. The problems of GI are addressed in stage three, when confounding factors are evaluated against positive indicators to determine the next steps, which involves the integration of best practices. Stage four involves reassessing positive indicators against confounding factors after imple-

mentation. If confounding factors prevail, a different stakeholder collaboration approach is applied during the project review.

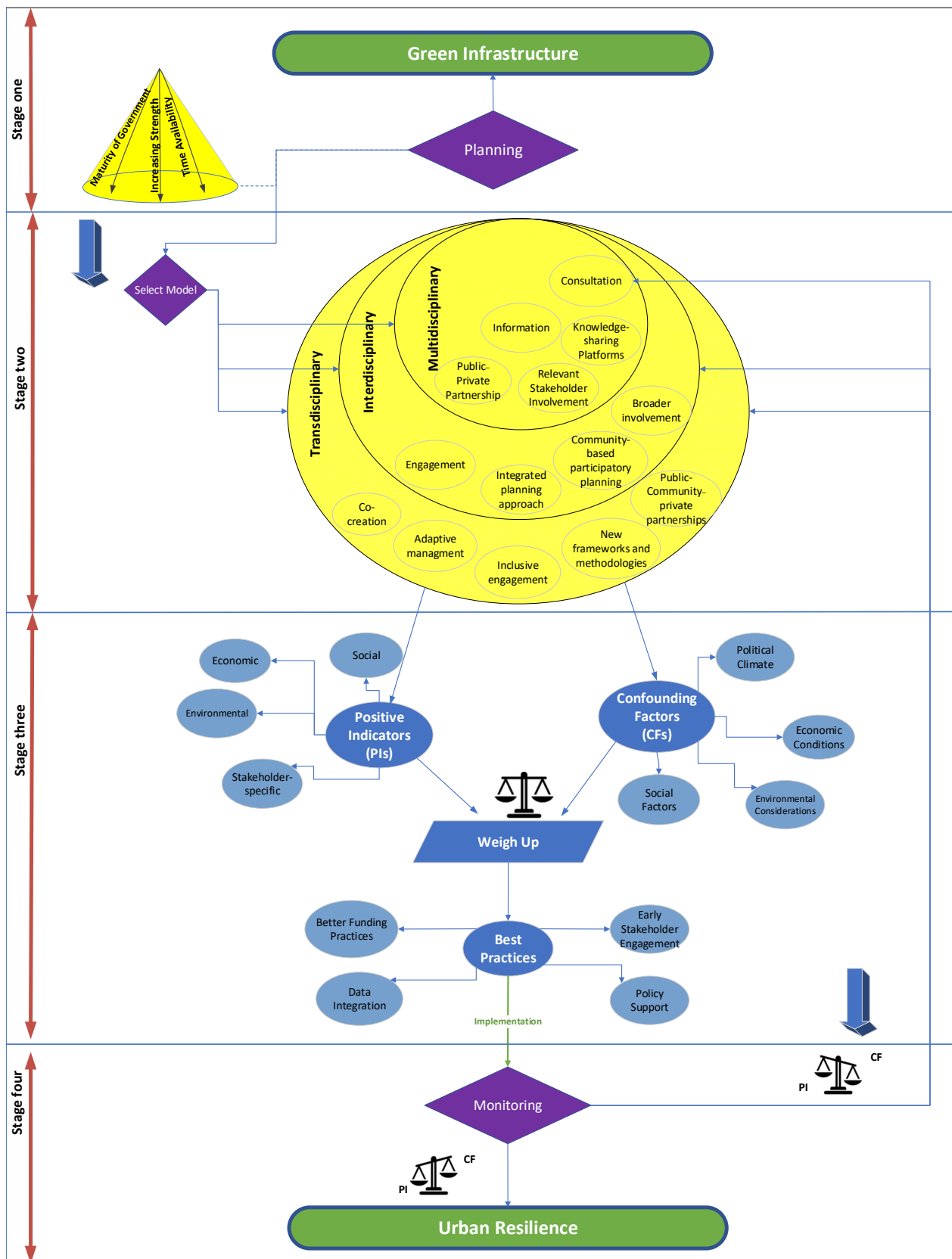


Figure 1. Conceptual framework of stakeholder engagement in Green Infrastructure development. Source: Extracted from the study of [20].

The framework suggests that extensive stakeholder involvement in GI planning and implementation is critical for ensuring context-specific, resilient, and widely supported interventions. This research employs a stakeholder-driven approach via an online survey, using Aotearoa New Zealand as a case study. This case study was selected because of its specific environmental challenges coupled with progressive urban planning initiatives [28]. Aotearoa New Zealand is exposed to several climate-related hazards that include flooding, storm surges, and sea-level rise [29,30], impacting its urban transport systems. Meanwhile, this country has proved to be one of the committed countries in sustainability and resilience planning, as most of its cities, like Tāmaki Makaurau Auckland, Ōtautahi Christchurch, and Ōtepoti Dunedin, are well into implementing GI strategies within the urban development processes due to the hazards they have previously faced [31,32]. In this respect, the diversity of Aotearoa New Zealand's stakeholder engagements with local governments, indigenous Māori communities, and environmental organisations provides a great context to evaluate the framework across different governance and cultural landscapes. This combination of environmental urgency and innovative GI integration efforts makes this country an appropriate setting to test the framework's relevance and adaptability.

This paper is organised as follows: Section 2 discusses the principles surrounding sustainable urban transportation and policy, with a summary of the theory of Green Infrastructure and the knowledge practices. Evaluating how these elements align with urban transportation systems and policy is crucial for advancing sustainable and resilient cities, as explored in the next section. In Section 3, we focus on validating the Ukonze, et al. [2] conceptual framework using a quantitative analysis. The survey data are first analysed, which will be presented in Section 4, highlighting how respondents' perceptions align with the dimension of the GI conceptual framework. Section 5 contains a short discussion on the usefulness of the framework and presents various outstanding research issues and the need to validate the model for city planning. The authors' concluding remarks and recommendations for future studies are given in Section 6.

2. Literature Review

2.1. Sustainable Urban Transportation and Policy

Urbanisation has increasingly contributed to the challenges of urban transportation, including the congestion of roads, infrastructure strain, and environmental impact. Transportation is a critical aspect of city functionality in that it facilitates the movement of people, goods, and services. It is also among the biggest emitters of greenhouse gases [33]. However, the environmental impacts of the urban transport sector have been largely overlooked, even though its technologies significantly contribute to climate change [34]. This instigated a change globally towards embracing sustainable transportation strategies such as smart mobility, clean and inclusive transportation, Green Infrastructure, and the compact city concept [35,36].

Initiatives such as the United Nations' 2030 Agenda for Sustainable Development and SDGs, especially SDGs 9 and 11, and a similar design known as the New Urban Agenda, formulated during the Habitat III summit [37], focus attention at a global scale on the subject of sustainable transport in cities. These agendas highlight sustainability, transport safety, efficiency, and environmental performance. Many cities worldwide have been adapting to climate change through strategies for meeting their emission targets by incorporating GI into city transport systems. Green Infrastructure, more commonly referred to as green transport infrastructure [38], incorporates the use of sustainable materials and designs that reduce environmental stressors. A typical example includes those associated with stormwater management, pollution, and urban heat islands. GI has now become an imperative in building sustainable and resilient cities with its multifunctional benefits.

Global policy for green transport infrastructure is ultimately implemented at landscape and local scales. However, adapting GI to local scales through the acceptance of different stakeholders, including within communities, is the challenge that cities continue to face. The United Nations 2030 Agenda highlights, in at least four key agreements, the need to engage local stakeholders as key partners for the implementation of global policy objectives [39]. These policy objectives address each city's emission requirements that must be adapted to the city's agenda. The United Nations Framework Convention on Climate Change Conference of the Parties (COP 21–26) has been progressing these discussions on employing new approaches that will bridge the divide between cities and local communities in the search for resilience [40]. However, even as an international consensus was achieved at COP21 to keep warming to 1.5 °C, present trends indicate that we are already at the verge of a +1.5 °C world, with most countries behind on their emission reduction commitments. This makes the need for localised, adaptive solutions, particularly in cities, to mitigate and respond to amplifying climate impacts. Many towns have relied on site-specific projects for cities and nature-based tools for rural areas. GI has been one of those discussions due to the principles that govern it, which depend heavily on governance, bottom-up, and top-down approaches. However, some cities in Singapore, the Netherlands, amongst others, have developed techniques to bridge that divide between cities and local communities using strategies like GI and other related strategies [41–43], hence providing cities that are nearing the concept of resilience.

2.2. Green Infrastructure: Current Knowledge Practices

Green Infrastructure (GI) supports ecological, cultural, and economic functions in urban environments [44] from its early applications in parks and green spaces. GI refers to the interconnectivity of natural and engineered elements within the urban environment to achieve specific resilience goals such as reducing flood risk, mitigating urban heat island effects, improving water management, enhancing biodiversity, and promoting overall liveability [8,45,46]. GI combines natural and engineered resources to help improve sustainable and resilient urban configurations. Unlike traditional or grey infrastructure, which focuses on engineered solutions, GI leverages natural processes to deliver a range of ecosystem services [47]. The benefits of transportation applications include stormwater runoff and air quality management, as well as the benefits of atmosphere cooling because of permeable pavement, bioswales, and green roofs. Other advantages manifested in these include decreased infrastructure costs, an improved quality of life, and enhanced public health in urban regions. Overall, GI helps cities adapt to climate change, and, by integrating GI into urban transportation systems, cities can strengthen their resilience to extreme weather events while promoting environmental sustainability and improving the quality of life for urban residents.

GI has an important role in building urban resilience especially in the transportation networks [48]. Through the integration of GI elements such as green corridors, permeable pavements, rain gardens, vegetated swales, street trees, among others, urban connectivity, redundancy, and flexibility in transportation networks can be improved. Different studies have demonstrated how specific elements have aided in protecting the transport networks from issues like stormwater management, flooding, and urban heat, amongst others [9,48–53]. These studies show that the presence of these components enables cities to resist and recover better from disruptions, such as flood or heatwaves, by way of alternative routes and environmental stress reduction. Recent studies have reported the efficacy of GI in promoting sustainable transport and reducing the vulnerability of transport infrastructure to climate hazards [9,48]. Despite these trends, however, there still exists a need

for integrated frameworks that clearly link the GI measures with transport resilience in urban planning.

However, integrating GI into urban transportation remains challenging due to varying climatic, geographic, and socio-economic conditions [54]. These conditions were examined in the Ukonze, et al. [2] study. While existing GI frameworks address themes such as policy integration, multifunctionality, and performance evaluation across components, they often lack a strong emphasis on practical planning processes, stakeholder collaboration, and transdisciplinary integration. The framework proposed by Ukonze, et al. [2] responds to this gap by combining interdisciplinary insights from urban resilience, environmental science, and urban planning, to introduce three key components: stakeholder collaboration approaches, confounding factors vs. positive indicators, and considerations of best practices for resilience building. These are presented in four stages, three of which will be tested through the chosen case study. A hypothesis will be used to conduct this test and provide an answer to the main research question: To what extent does stakeholders' perception align with GI theory in urban planning transport?

3. Methodology

This study employed a case study approach involving the use of a questionnaire survey to assess Ukonze, et al. [2]'s GI conceptual framework from the perception of different stakeholders. This study further integrated into analysis, the 'Totally Gorgeous' Project (TGP), a streetscape upgrade project in Ōtepoti Dunedin, Aotearoa New Zealand. This project is a major streetscape redevelopment initiative in George Street, Dunedin, aimed at enhancing urban resilience and sustainability. TGP integrates GI elements such as street trees and rain gardens into upgraded grey infrastructure to improve stormwater management, reduce urban heat, and create a more pedestrian-friendly environment. The project is a practical example of how GI can be incorporated into urban transport infrastructure to support climate adaptation and enhance public spaces. Four streets were integrated into the project, focusing on George Street. The George Street Project, as it is alternatively called, originated from several maintenance and upgrade projects that were postponed and accumulated to embark on a much larger project, thereby integrating a climate adaptation strategy to address the issues that the area (Dunedin City) has faced. Although this study does not aim to generalise the findings globally, this case study provides critical insights into GI integration challenges in medium-sized, climate-vulnerable cities, which may inform other urban contexts with similar profiles. Also, the framework provides critical insights into GI integration on a practical level for urban transport and building resilience, which, when adapted into similar urban settings, might be a change in current ineffective discourse.

The survey was distributed to participants online. As there was no accessible record of Green Infrastructure professionals in New Zealand, a combination of two non-probability sampling approaches was used: purposive and snowballing techniques. This ensures the adequate capture of insights from different organisational contexts with direct experience in GI-related projects and urban transport planning. This method was chosen to ensure that the participants have the experience and therefore could provide informed insights relevant to validating the conceptual framework [55]. Initial contact was with professional associations and related organisations (purposive sampling). While some were willing to distribute through networks or websites, others were less cooperative. Snowball sampling was subsequently used to extend this invitation to other relevant stakeholders within their professional network to maximise response. Although this approach allowed for exposure to differing practitioner perspectives, it is also plagued with issues regarding potential selection bias and a lack of full representativeness, acknowledged throughout the inter-

pretation of the findings. The sample of participants included urban planners, engineers, architects, surveyors, environmental scientists, and policymakers involved in transportation and sustainability planning with special reference to Green Infrastructure. The diverse sample frame is to enhance the relevance and applicability of the findings to real-world contexts and professional perspectives in urban planning and infrastructure development. The study population was from key professional associations in New Zealand, wherein responses were received from the New Zealand Planning Institute, Survey and Spatial NZ, Engineering New Zealand, and Infrastructure NZ, who are either academics or in practice. These professional institutions were selected to ensure that a good representation was gathered from different cities in the country. Although no predefined sample size was established, 94 responses were received, representing a meaningful cross-section of key stakeholders actively engaged in urban transport and sustainability planning.

The distribution included equal representation from major cities such as Tāmaki Makaurau Auckland, Te Whanganui-a-Tara Wellington, Ōtautahi Christchurch, Ōtepoti Dunedin, and other cities across New Zealand. While this study did not comprehensively cover all government organisations within these cities, the sample frame enhances the relevance and applicability of the findings by reflecting a broad spectrum of professional perspectives.

Using the standard formula for sampling error [56], the sampling error for a sample size of 94 was approximately $\pm 10.1\%$, at a 95% confidence level [56]. This indicates that 95% of the time, the results would fall within $\pm 10.1\%$ of the actual population value if this study were conducted again under the same circumstances. The findings offer important insights into the opinions and experiences of important stakeholders in the area, even though they cannot be entirely generalised to the whole population of urban transport professionals.

The survey, containing 21 questions, was sent out, and 94 responses were received. There were 56 complete responses and 38 partial responses (see Supplementary Material). The 38 partial responses were still very useful to this study. This is because the missing data were handled through pairwise analysis, ensuring that each question was assessed based only on the valid responses it received. This survey was carried out using an online software, ‘Survey Monkey’, which conducted the descriptive analysis (total, weighted average, and percentages) needed for further analysis. The survey was collected within a period of 2 months from June to July 2024. However, this paper draws upon some closed questions in the questionnaire using a 5-point Likert scale to test the conceptual framework from Ukonze, et al. [2]. Participants were asked to tick all boxes that applied to them, after which the results were collated and analysed.

Data Analysis

Descriptive analysis was used in analysing the survey responses, and this was carried out in the SurveyMonkey online software. A pilot study involving a small number of stakeholders ($n = 3$) was conducted to ensure clarity and construct validity. The stakeholders selected from the target population include urban planners, engineers, architects, surveyors, and policymakers involved in transportation and sustainability planning. Feedback was conducted via follow-up discussions on their comments to improve the participants’ easy comprehension and completion of the survey. The instrument was revised for clarity, sequence, and order. A reliability test using Cronbach’s Alpha shows a value of $\alpha = 0.97$ (see Supplementary Material, indicating internal consistency).

The test of the hypothesis was conducted to answer the main research question, which states,

H0: *There is no significant relationship between stakeholder perceptions of GI and the dimensions of the conceptual framework.*

H1: *There is a significant relationship between stakeholder perceptions of GI and the dimensions of the conceptual framework.*

This was analysed using Monte Carlo testing in the Statistical Package for the Social Sciences (SPSS) software Version 30.0.0.0 (172) to test for the relationship. This was selected to enhance the reliability of the results, given the small sample size, with the number of categories being large and a lower expected count of less than 5. In comparison to the chi-square tests, which rely on large-sample approximations, exact small-sample methods like Monte Carlo may serve as an alternative [57] that provide more accurate *p*-values under the conditions presented. Hence, when there is sparse data or assumption violations of the chi-square test, Monte Carlo method is preferred, making it especially useful for contingency tables with low expected frequencies [57]. Therefore, applying it in this study indicates a solid justification for validating the significance of observed associations between stakeholder perceptions and the conceptual framework dimension. To conduct this test, the categories were transformed from five (strongly agree, agree, neutral, disagree, and strongly disagree) to three (agree, neutral, and disagree) research scale categories, and new variables were created using the ‘transform–recode in different variable’ function to ensure that there is no error in the result. The variables tested are in Q18, Q19, Q20 (c), and (d) (see Supplementary Material), which focus on testing the level of stakeholders’ GI knowledge, confounding factors, and positive indicators alongside best practices. Other questions, which may not have been tested but are included in the analysis, are Q8, Q9, Q10, Q15, and Q16. Those questions deal with benefits of GI and stakeholder collaboration models. The number of responses varied across each question. The Monte Carlo test was run with variables in Q18–20 with the complete responses $n = 56$, whereas other variables that helped in further analysis fluctuated from 56 to 76 on average, as seen in Figure 2.

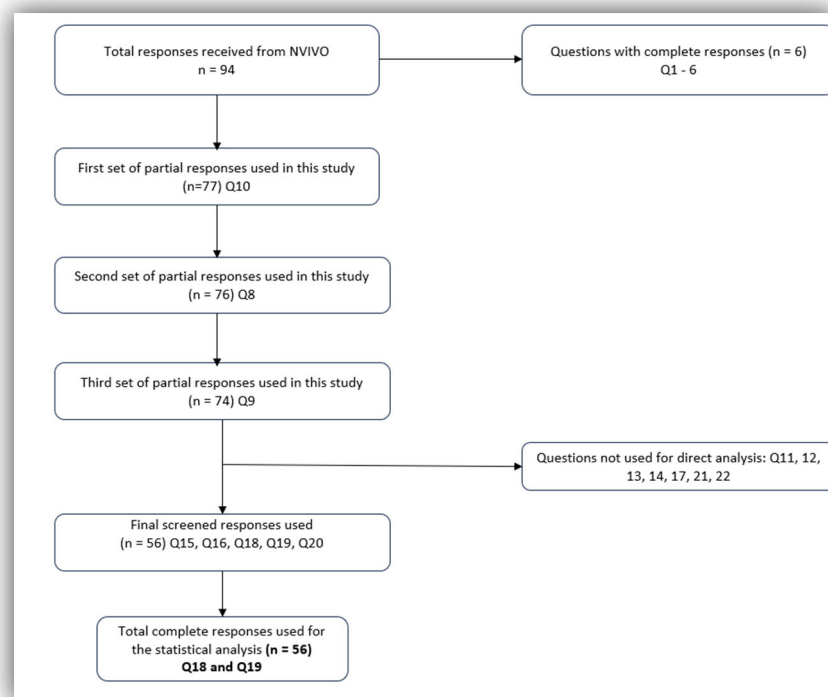


Figure 2. Survey question response counts with thresholds.

4. Results

This study confirms that stakeholders, particularly urban planners and engineers, strongly understand Green Infrastructure (GI). Still, gaps remain in recognising specific

benefits such as air quality improvement and hazard mitigation. While multidisciplinary collaboration is well-established, interdisciplinary and transdisciplinary approaches are less utilised, showing the need for more integrated planning. Statistical tests showed a significant relationship ($p < 0.05$) between stakeholder perceptions and the framework's dimensions, validating the framework's applicability for assessing GI effectiveness. Strengthening stakeholder training, improving policy support, and promoting empirical evidence are recommended to bridge the gap between knowledge and implementation.

The analysis (Supplementary) showed that the cities with the most responses were Dunedin, Christchurch, Auckland, and Wellington, with other cities from both the South Island and the North Island. The professionals with the most responses were engineers and urban planners. The Monte Carlo test at $p < 0.01$ significance level was employed owing to the small sample size and low expected counts of less than 5.

First, it was vital to test the knowledge of the respondent's concept of GI to validate other responses in the questionnaire. Q8 (see Supplementary Material) includes rating their knowledge of GI. Table 1 showed that the respondents had good knowledge of GI, and urban planners had the most involvement in GI planning, although others had a good understanding of GI (agree, 70), and only a few were neutral ($n = 6$) about what it entails. However, 16 respondents did not answer that question, which can be presumed to be a result of limited or no knowledge of the concept.

Table 1. Analysis of the online survey on GI perception amongst stakeholders.

Profession	Understanding of the Concept of GI			Taken Up a Role in GI Planning		
	Agree	Disagree	Neutral	Yes	No	Total
Scientist	5	0	0	3	2	5
Engineer	12	0	3	8	7	15
Urban Planner	29	0	3	25	6	30
Policy Analyst	10	0	0	6	4	10
Natural Resource/Environmental Planning	1	0	0	1	0	1
Transport Planner	3	0	0	3	0	3
Ecologist	5	0	0	4	1	5
Heritage Specialist	1	0	0	0	0	1
Biodiversity Infrastructure	1	0	0	1	0	1
Governance	1	0	0	1	0	1
Quantity Surveyor	1	0	0		1	1
Architect	1	0	0	1	0	1
Total	70	0	6	52	20	74

Data presented in Table 1 showed that 76 respondents answered the question testing their understanding of the concept of GI, whereas 74 indicated whether they have taken up a role in GI planning. This table shows a strong awareness of Green Infrastructure (GI) among stakeholders, with 70 out of 76 respondents understanding the concept. Urban planners (29), engineers (12), and policy analysts (10) demonstrated the highest levels of familiarity, reflecting their key roles in GI planning. Scientists, ecologists, and transport planners also showed full agreement, highlighting broad interdisciplinary awareness.

Despite this, only 52 respondents had actively participated in GI planning, with urban planners (25 out of 30) and engineers (8 out of 15) as the most engaged. Other professions, such as scientists (3 out of 5) and ecologists (4 out of 5), also contributed, but governance specialists, heritage experts, and quantity surveyors showed little to no involvement.

The gap between knowledge and participation suggests barriers such as institutional roles or policy constraints. While awareness is high, greater collaboration among key

stakeholders is needed to translate understanding into action and strengthen GI integration in urban planning.

Further testing was conducted to test the level of understanding of the concept using the benefits of GI (Q10). All the perceived benefits of GI were included as options and to inquire if the same percentage of respondents who have good knowledge of GI also chose the whole selection as benefits. While the majority agreed or strongly agreed that GI has benefits, some respondents still expressed uncertainty regarding specific GI benefits. The presence of 'disagree' or 'strongly disagree' responses suggests that a small subset of respondents may lack confidence in certain GI benefits, possibly due to limited exposure or scepticism about their effectiveness.

For this, although 70 out of 76 respondents claimed an excellent understanding of GI, this might not be the case, as some of the benefits had neutral and disagree responses. For example, air quality improvement, although it is one of the well-documented benefits [58–62] of GI, had 11 neutral responses. It had the highest number of disagreements/neutralities in natural hazard mitigation and sustainable transportation, while the highest number of agreements was observed in the stormwater management category, with 45 strongly in agreement. GI benefits are perceived as stronger for some than others. Stormwater management, climate adaptation, and air quality ranked higher in agreement. There are knowledge gaps despite the high self-reported understanding of GI. Also, further analysis of the different expert opinions showed that ecologists and engineers showed more neutrality or disagreement across multiple benefits as they may prioritise traditional grey infrastructure over GI for benefits like hazard mitigation, resilience, and air quality. Other experts who had some level of disagreement are the policy analysts and scientists. This shows that these professionals may prioritise projects in areas they understand the most and, in most cases, focus more on other adaptation strategies, including grey infrastructure. GI's role in some of these perceived benefits, including resilience building, may require a strong validation for these professionals, except for stormwater management, as its functionality is well recognised. Therefore, the discrepancy between GI knowledge and specific benefit recognition suggests that there is a place for improved education, empirical evidence, and case studies to raise awareness regarding the multifunctional roles played by GI for natural hazard mitigation and sustainable transport. Hence, different expert groups may need better integration in GI planning discussions to bridge gaps in perception.

Test of Respondents' Perception of the Dimensions of the GI Conceptual Framework

Following the knowledge of GI by the experts analysed, the hypothesis was then tested to know if there is a significant relationship between stakeholder perceptions of GI and the dimensions of the conceptual framework. However, one dimension of the conceptual framework, stage 2, stakeholder collaboration (see Figure 1), was also included in the assessment. Respondents' knowledge of the multidisciplinary, interdisciplinary, and transdisciplinary collaboration models was tested first to rate their level of understanding on a five-point scale from very poor to excellent. A total of 56 respondents answered (see Supplementary). Before the approaches were listed, the result showed that stakeholders are highly familiar with multidisciplinary collaboration, where professionals from different fields contribute their expertise independently without extensively integrating perspectives. This suggests that multidisciplinary collaboration is well-established in sustainability and GI planning contexts. Some stakeholders are comfortable with interdisciplinary collaboration, integrating methods and perspectives across disciplines. This could indicate that, while cross-disciplinary integration is recognised, it may not be as widely practised or understood as multidisciplinary approaches. For transdisciplinary approaches, stakeholders showed limited familiarity as it entails collaborative co-creation beyond traditional

disciplinary boundaries. This suggests a gap in understanding or applying truly integrative and innovative participatory methods in GI planning. In Q.15, further clarity on the methods that align with the three main collaboration approaches, as included in the conceptual framework, was assessed to ensure that the stakeholders understood the approaches. The results showed a larger number of respondents agreed that the following should be grouped under multidisciplinary: relevant stakeholders' involvement, information sharing, adaptive management, consultation, and knowledge-sharing platforms. For interdisciplinary engagement, relevant stakeholder involvement and consultation were mainly selected. Co-creation, community-based participatory learning, and new frameworks and methodologies stood out for the transdisciplinary approach.

This finding showed that transdisciplinary approaches are not yet widely integrated into GI practices except for methods explicitly designed for co-creation and community involvement. This demonstrates potential gaps in how stakeholders perceive inclusive, boundary-spanning collaboration, which could affect the effectiveness of GI implementation. However, the moderate selection of interdisciplinary approaches suggests some openness to integrating knowledge across disciplines, which may pave the way for the broader future adoption of transdisciplinary practices. With the dominance of traditional multidisciplinary collaboration, there is a potential gap between the framework's ideal and actual stakeholder practices. Hence, there is a need to raise awareness programmes and organise training, increase stakeholder familiarity with interdisciplinary and transdisciplinary practices, bridge the gap, and promote more integrated, holistic approaches in GI development and sustainable planning projects.

Further to that result, a statistical test was conducted where the dimensions of the conceptual framework are shown in Q17, Q18, Q19 (c), and (d). The null hypothesis H0 states the following: There is no significant relationship between stakeholders' perception and the dimensions of the conceptual framework. Table 2 shows a summary of the results derived from the SPSS analytical tool.

Table 2. Analysis of statistical test using Monte Carlo test.

Conceptual Framework Dimension	Chi-Square Value (χ^2)	<i>p</i> -Value	Phi Value (Strength) (Φ)	Relationship Strength
Inclusive Stakeholder Engagement	46.06	<0.001	0.487	Moderate-to-Strong
Stronger Policy	25.387	<0.001	0.362	Moderate
Data Integration	23.259	0.001	0.346	Moderate
Economic Sustainability	29.627	<0.001	0.391	Moderate
Technical and Maintenance Considerations	27.921	<0.001	0.379	Moderate
Comprehensive Planning	28.715	<0.001	0.385	Moderate
Transdisciplinary Approach	44.707	<0.001	0.48	Moderate-to-Strong
Positive Indicators	31.83	<0.001	0.405	Moderate
<i>Conditions necessary for GI Integration</i>				
Maturity of Government	24.042	0.001	0.352	Moderate
Increasing Strength	62.8	<0.001	0.569	Strong
Time Availability	52.048	<0.001	0.518	Strong

The key results showed that the Pearson chi-square and the likelihood ratio test were significant for all the tested variables at *p*-values less than 0.05, indicating stakeholder perceptions in most GI cases related to many elements in the conceptual framework. The *p*-values are supported as robust, confirmed by the Monte Carlo significance tests. Several

crosstabs involve expected counts of less than five, limiting the robustness of chi-square results. However, Monte Carlo and exact tests compensate for this shortcoming somewhat. The results provided compelling statistical evidence to reject the null hypothesis, supporting the alternate hypothesis that a significant relationship exists between stakeholder perceptions of GI and the dimensions listed in the conceptual framework. The findings suggest that stakeholder perceptions align with key factors influencing GI integration, reinforcing the conceptual framework's validity in assessing GI effectiveness in urban planning.

Furthermore, to illustrate the practical significance of these results in Table 2, the phi values (varying from 0.346 to 0.569) were analysed. According to Cohen [63] thresholds, values above 0.3 indicate moderate relationships, while those nearing 0.5 or above suggest strong associations. And there were strong relationships found in elements like “increasing strength” ($\Phi = 0.518$) and “time availability” ($\Phi = 0.518$), demonstrating that limited institutional capacity and time unavailability are commonly recognised barriers for GI integration. Moderate-to-strong correlations were also found for “inclusive stakeholder engagement” ($\Phi = 0.487$) and “transdisciplinary approaches” ($\Phi = 0.480$), showing the importance of cross-sector coordination for GI planning. These results also suggest that the responses may be a result of differing views of how professional groups such as engineers, planners, policy analysts, and scientists, among others, perceive their institutional roles. For instance, urban planners and policy analysts may view GI through a governance and systems lens, prioritising coordination and regulatory support, whereas engineers and environmental scientists may focus more on technical feasibility and performance outcomes. This demonstrates the importance of transdisciplinary participation in any project to bridge the GI knowledge and expertise gap, which is a central focus of the Ukonze et al. [2] framework.

5. Discussion

From the survey analysis results, it can be established that the stakeholder perception of GI is significantly correlated with the dimensions in the conceptual framework, as evidenced by the tested variables at p -values being less than 0.05. This was an assurance that various dimensions comprise stakeholder engagement, policy strengthening, data integration, and technical considerations towards successful integration.

5.1. Inclusive Stakeholder Engagement

The analysis reveals a strong association of inclusive stakeholder engagement with the perceptions of GI integration ($p < 0.05$) as seen in Table 2. This corroborates other studies [15,64] that identify participatory planning as an essential ingredient in the success of GI initiatives. The high level of knowledge about GI reported by policy analysts, engineers, and urban planners indicates that the conceptual awareness of GI is firmly established within professional communities. However, the result did not show each professional's GI knowledge. There is still a disconnect between learning and active involvement in GI planning, which demonstrates institutional and functional barriers to implementation. However, the New Zealand education system actively integrates sustainability in its curriculum framework and programmes like EnviroSchools [65]. The extent of GI discussions needs to be examined to see at what level the concept is introduced and to which professionals. While planners and engineers reported the most significant levels of involvement, governance and other professionals, for example, reported minimal or no involvement. This resonates with the conclusions in those previous studies that knowledge does not necessarily drive action, especially in siloed governance structures where GI responsibility may be poorly defined.

Although 70 out of 74 respondents showed strong familiarity with GI, individual benefits like air quality improvement, hazard mitigation, and sustainable transportation were met with mixed responses. This suggests that most stakeholders may not be knowledgeable about the ‘multifunctionality’ principle of GI or may lack exposure to its broader applications beyond stormwater management. Also given the professional background of the sample, there is thus a good chance that participants would have overestimated their familiarity or been reluctant to acknowledge gaps in their area of expertise. These results support the literature that states that GI benefits beyond hydrology, such as microclimate regulation or disaster resilience, among others, are less often quantified and communicated in practice [58]. The high agreement on stormwater-related benefits shows that there is a need for the targeted education and dissemination of GI’s full value amongst professionals.

5.2. Collaboration Models: The Practice–Framework Gap

One of the primary observations from this research is in evaluating collaboration models. While multidisciplinary collaboration is widely understood and practised, there is limited awareness of other models, interdisciplinary and transdisciplinary, together with their application in governance and organisations. This corroborates the existing literature identifying that cross-sectoral planning tends to regress to consultation rather than co-creation [66,67]. The findings suggest that, while professionals are open to inclusive processes, institutional norms, policies, and less experience with collaborative design methods can constrain the use of more integrative methods. Respondents strongly associate multidisciplinary collaboration with information sharing and adaptive management, while transdisciplinary approaches such as participatory learning and co-creation were less recognised. This implies the need to build stakeholder capacity in technical knowledge and transdisciplinary processes across disciplinary and societal boundaries. The transdisciplinary model has been demonstrated as being particularly important in climate-resilient planning challenges [2,68–70] yet remains aspirational in most settings due to deeply ingrained planning hierarchies and sectoral mandates. In New Zealand, strengthening transdisciplinary governance should involve leveraging partnerships across local iwi, regional councils and professional institutions, and all GI stakeholders. Discussions within and between private developers, contractors, councils, and the government should transcend the normal multidisciplinary/interdisciplinary approach. This would align with the Resource Management Act’s direction for integrated and participatory decision making and reduce silos in these organisations.

5.3. Framework Validation

Statistical testing, including the Monte Carlo simulation for small sample size correction, vouched for a significant correlation between stakeholder perception and dimensions of the GI conceptual framework. Inclusive stakeholder engagement, policy strength, data integration, and economic feasibility were all significant factors that yielded moderate-to-high correlation coefficients, confirming the applicability and consistency of the framework with real-life perceptions. More than any other item, ‘Transdisciplinary Approach’, ‘Increasing Strength’, and ‘Time Availability’ emerged with the most tremendous statistical significance and strength of association ($\Phi = 0.48, 0.569$, and 0.518 , respectively), highlighting their critical function in making GI planning possible. The close linkage between stakeholder engagement and GI integration is thus consistent with other research, notably that of Haase, Frantzeskaki [71], where participatory governance is highlighted as a basis for sustainable urban transformation.

Also, the findings reveal that, even where there is widespread agreement on the value of GI, operational issues—such as time pressures, a lack of coordination between

departments, or poorly defined mandates—continue to frustrate its implementation. These findings support the argument by Kabisch, Larondelle [72], that structural conditions, rather than conceptual clarity, are more likely to be the principal obstacles to mainstreaming GI in urban settings. Additionally, building urban resilience not only requires physical interventions but also adaptive capacity, flexibility, and the ability to co-evolve with changing conditions [73,74]. In Green Infrastructure (GI) planning, this means embracing integrative approaches that acknowledge the boundary and fuzzy nature of the concept [75,76], allowing room for uncertainty and encompassing diverse knowledge systems.

In addition to demonstrating connection, this study's associations between stakeholder perceptions and GI framework elements also highlight important methods by which GI supports urban resilience. Particularly, the substantial links with transdisciplinary approaches and inclusive stakeholder participation imply that collaborative planning procedures that incorporate a variety of values and areas of expertise promote resilience. Resilience channels that are based on system efficiency, long-term sustainability, and operational reliability are further reinforced by the emphasis placed on information integration, economic viability, and technical and maintenance concerns. By facilitating adaptive planning, providing essential ecosystem services, reducing climate vulnerabilities, and fostering institutional capacity, these studies show how GI promotes resilience. In the process, stakeholder perceptions are translated into more than opinion—these are interpreted into actionable knowledge that can inform more robust, context-sensitive planning decisions.

Importantly, this suggests that the conceptual framework developed in this study could underpin the creation of future tools to bridge the GI knowledge–implementation gap. Such tools need to have capacity building as a central focus and be in alignment with broader urban resilience and transdisciplinary governance strategies. In the New Zealand context, this means building on initiatives like the Enviroschools programme and Te Mana o te Wai principles that already encourage nature-based, community-led planning approaches.

5.4. Implications for Practice and Policy

These findings have significant practical implications. They initially present the necessity to develop targeted training and capacity-building programmes to aid stakeholder understanding of integrative planning mechanisms. Secondly, they provide enabling case studies, empirical findings, and cross-sectoral learning that can strengthen GI's overall benefits beyond water management. Third, the moderate-to-strong statistical confirmation of the conceptual framework dimensions indicates its promise as a diagnostic instrument for evaluating the maturity of GI planning practices in various urban settings. For policy, this study recognises the need to ground transdisciplinary collaboration in planning mandates and allow sufficient time and resources for participatory, inclusive GI design. Cities must move beyond traditional consultation models and embrace deeper co-creative practices to optimise GI as a tool for constructing resilience.

Projects like the Totally Gorgeous Street Project (TGS) faced issues with major elements proposed due to a lack of knowledge and technical knowledge on GI implementation, together with the level of collaboration employed [2]. Hence, such a project from findings would benefit from this framework when managed with the right collaboration tool due to the boundary nature of GI [15,27]. These findings have implications for cities seeking to transition toward sustainable urban development. The inconsistency in stakeholder perceptions underlines the importance of transdisciplinary collaboration to ensure that GI planning incorporates a variety of expertise and is understood across sectors.

6. Limitations and Future Research

This analysis draws on self-reported data collected through an online survey, which allows for broad participation across sectors. But the responses were shaped by individual perspectives, which professional biases, role-specific knowledge, or assumptions about GI implementation may influence. As a result, the findings reflect how the respondents perceive the usefulness of each element and stage of the framework. This individual perception might limit clarity on how it performs in real-world applications. Future research will adopt focus groups or interviews, offering a platform for deeper dialogue and reflection among planners, policymakers, and community members. Furthermore, the lack of a defined population or sampling frame (registry of environmental professionals in New Zealand) encouraged the use of both a purposive and snowball sampling technique. This led to the use of expert judgement and an organisational network to reach a relevant audience. Hence, the sampling strategy may have been more favourable to the connected or visible professionals. This in turn may potentially overlook more marginal perspectives. Future studies could strengthen sample diversity by combining these methods with a random sampling approach.

Also, the participants were derived from a limited population in Aotearoa New Zealand. Most respondents were based in Aotearoa New Zealand, which was selected because of the country's climate change issues and its growing efforts to meet climate emission standards. From this geographic limitation, the findings may be interpreted as exploratory and context-dependent. Although there is concern for the applicability of the framework in other geographical areas with differing political climates, this study suggests that it can be applied in other urban areas. Notably, to ensure efficiency in its application, the framework needs to be adapted in light of the concrete local policies applied in different cities. Hence this realisation indicates that this study can be applied to other policy consideration frameworks [25]. Furthermore, while these contexts provide essential insights, the framework was not tested against the unique conditions of the Global South, where infrastructure constraints, informal development, and governance challenges may significantly influence the feasibility of GI integration. Future research will test this framework in the Global South to improve the generalizability of the findings to diverse international settings.

Due to time constraints, this study was limited to how stakeholders engage with and assess the framework, which is an important step. This study, however, does not further assess how the framework influences actual planning processes, policy decisions, or resilience outcomes over time. The next step will include a longitudinal data or performance-based evaluation, making an assessment of the outcomes rather than perceptions. This will also be focused on a GI-related project, making it easy to assess the outcome of the framework.

Finally, further research would explore the development of a practical tool, such as a GI-readiness score card or guide, which could support GI professional practitioners in operationalizing the framework. Such a tool would aid cities record and assess their progress, identify gaps, and make more informed decisions about where and how to invest in GI for not only transport but also for urban resilience.

7. Conclusions

The results affirm that stakeholders' perceptions of GI are highly significantly related to the dimensions within the conceptual framework. The findings further reinforce the validity of the conceptual framework when assessing the effectiveness of GI as stakeholder engagement, policy support, economic considerations, technical sustainability, governance, and time allocation represent material elements for the integration of GI. Based on the research, one of the most relevant conclusions is that self-reported familiarity with GI

contrasts significantly with the recognition of specific GI benefits. Stakeholders reported knowledge in GI, though there is a disconnect in the detailed multifunctional benefits other than stormwater management. In addition, the dominance of multidisciplinary collaboration suggests a need for more efforts towards integrating interdisciplinary and transdisciplinary approaches for holistic GI planning.

Best practices recommendations to improve GI integration thus focus on

- **Increased Education and Awareness:** Stakeholder training and public awareness about underrecognized GI benefits—for example, improving air quality and mitigating natural hazards—should be conducted.
- **Empirical Evidence and Case Studies:** More practical applications with quantified evidence of the effectiveness of GI should be shared with professionals to firm up confidence in GI solutions.
- **Improved stakeholder collaboration:** GI policy initiatives can stimulate more multi- and transdisciplinary collaboration on how GI planning better captures diverse perspectives and expertise.
- **Availability of Time for GI Planning:** This includes time for sufficient stakeholder inclusion and iteration across the planning stages that may help enhance GI results.

This study thus underlines the need to close the gap in knowledge as well as increasingly integrative collaborative approaches toward GI planning. As the conceptual framework already provides an applicable basis from which to both understand and advance integration of the GIs, meeting the gaps regarding stakeholder perceptions and interdisciplinary cooperation will be impossible without additional research and intervention policy efforts. Although this study provides a solid basis for understanding and advancing GI integration, the geographically limited sample and absence of real-world implementation or longitudinal performance tracking can be noted. Additionally, the framework has not yet been tested in Global South contexts where infrastructure and governance dynamics may differ significantly. However, this study presents vital theoretical implications and opens up opportunities for developing tools to help cities operationalize and access GI investments. Future research will then apply this framework through empirical case studies to test its applicability in GI projects. Also, further studies will evaluate possible performance gaps using a geospatial assessment tool, which can offer a replicable methodology for cities to measure GI's contribution to resilience and inform future investments.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/su17135697/su17135697/s1>, Supplementary S1: Descriptive analysis of survey, Supplementary S2: Data analysis results using spss—reliability test and monte carlo test, Supplementary S3: Online survey questions.

Author Contributions: The authors' contributions are specified as follows: F.I.U.: conceptualization, methodology, software, validation, formal analysis, investigation, resources, formal analysis, writing—original draft preparation, visualisation, project administration, and funding acquisition. A.M.: software, writing—review and editing, visualisation, supervision, and resources. G.L.: writing—review and editing, visualisation, supervision, and resources. B.D.: methodology, validation, writing—review and editing, supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Tertiary Education Trust Fund Nigeria and the University of Otago Dunedin New Zealand.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of New Zealand and approved by the Institutional Review Board (or Human Ethics Committee)

of the University of Otago (Reference no: 24/0144 and date of approval: 7 June 2024) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The original data presented in this study are openly available in <https://doi.org/10.1016/j.uclim.2024.102254> Elsevier, Urban Climate Journal Volume 59.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of this study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

- de Abreu, V.H.S.; Santos, A.S.; Monteiro, T.G.M. Climate Change Impacts on the Road Transport Infrastructure: A Systematic Review on Adaptation Measures. *Sustainability* **2022**, *14*, 8864. [\[CrossRef\]](#)
- Ukonze, F.I.; Moore, A.B.; Leonard, G.H.; Daniel, B.K. A conceptual analytical framework for green infrastructure (GI) towards resilience building in urban contexts: A Stakeholders' collaboration perspective. *Urban Climate* **2025**, *59*, 102254. [\[CrossRef\]](#)
- Dhanya, B.; Ramananda, S.; Dhyan, S. Mainstreaming blue-green infrastructure in policy and planning for urban resilience in the global South: Promises and pitfalls. In *Blue-Green Infrastructure Across Asian Countries: Improving Urban Resilience and Sustainability*; Springer: Singapore, 2022; pp. 499–518.
- Umoh, A.A.; Nwasike, C.N.; Tula, O.A.; Ezeigweneme, C.A.; Gidiagba, J.O. Green infrastructure development: Strategies for urban resilience and sustainability. *World J. Adv. Res. Rev.* **2024**, *21*, 020–029. [\[CrossRef\]](#)
- Wijesinghe, A.; Thorn, J.P.R. Governance of Urban Green Infrastructure in Informal Settlements of Windhoek, Namibia. *Sustainability* **2021**, *13*, 8937. [\[CrossRef\]](#)
- Tayouga, S.J.; Gagné, S.A. The Socio-Ecological Factors that Influence the Adoption of Green Infrastructure. *Sustainability* **2016**, *8*, 1277. [\[CrossRef\]](#)
- Benedict, M.A.; McMahon, E.T. Green Infrastructure: Smart conservation for the 21st century. *Renew. Resour. J.* **2002**, *20*, 12–17.
- Benedict, M.; McMahon, E. *Green Infrastructure: Linking Landscapes and Communities*, 1st ed.; Conservation Fund Island Press: Washington, DC, USA, 2006; 320p, ISBN 9781597267649.
- Segovia Aranibar, E.L.; Esenarro, D.; Ascama, L.; Rodriguez, C.; Julca, M.S.Y.R. Design of green infrastructure for sustainable urban transportation in lomas del paraiso in villa maria del triunfo. *J. Green Eng.* **2020**, *10*, 11180–11192.
- Pamukcu-Albers, P.; Azevedo, J.C.; Ugolini, F.; Zuniga-Teran, A.; Wu, J. Urban resilience through green infrastructure. In *Adapting the Built Environment for Climate Change: Design Principles for Climate Emergencies*; Woodhead Publishing: Cambridge, UK, 2023; pp. 53–69.
- Al-Humaiqani, M.M.; Al-Ghamdi, S.G. The built environment resilience qualities to climate change impact: Concepts, frameworks, and directions for future research. *Sustain. Cities Soc.* **2022**, *80*, 103797. [\[CrossRef\]](#)
- Zhang, J.; Yang, Z.; He, B. Does Digital Infrastructure Improve Urban Economic Resilience? Evidence from the Yangtze River Economic Belt in China. *Sustainability* **2023**, *15*, 14289. [\[CrossRef\]](#)
- Campbell, A.; Chance, V.; Schindler, M. Developing a Conceptual Framework for Characterizing and Measuring Social Resilience in Blue-Green Infrastructure (BGI). *Sustainability* **2024**, *16*, 3847. [\[CrossRef\]](#)
- Martin-Moreau, M.; Menansce, D. Urban resilience: Introducing this issue and summarizing the discussions. *J. Field Actions* **2018**, 6–11.
- Mell, I.C. Green infrastructure: Reflections on past, present and future praxis. *Landsc. Res.* **2017**, *42*, 135–145. [\[CrossRef\]](#)
- Hansen, R.; Pauleit, S. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for Urban Areas. *Ambio* **2014**, *43*, 516–529. [\[CrossRef\]](#)
- Cilliers, E.J. Reflecting on green infrastructure and spatial planning in Africa: The complexities, perceptions, and way forward. *Sustainability* **2019**, *11*, 455. [\[CrossRef\]](#)
- Diep, L.; Dodman, D.; Parikh, P. Green Infrastructure in informal settlements through a multiple-level perspective. *Water Altern.* **2019**, *12*, 554–570.
- Ortega, A.D.; Rodríguez, J.P.; Bharati, L. Building flood-resilient cities by promoting SUDS adoption: A multi-sector analysis of barriers and benefits in Bogotá, Colombia. *Int. J. Disaster Risk Reduct.* **2023**, *88*, 103621. [\[CrossRef\]](#)
- Artmann, M.; Kohler, M.; Meinel, G.; Gan, J.; Ioja, I. How smart growth and green infrastructure can mutually support each other—A conceptual framework for compact and green cities. *Ecol. Indic.* **2019**, *96*, 10–22. [\[CrossRef\]](#)
- Chen, H.; Wang, N.; Liu, Y.; Zhang, Y.; Lu, Y.; Li, X.; Chen, C.; Liu, Y. A green infrastructure planning framework—guidance for priority, hubs and types. *Urban For. Urban Green.* **2022**, *70*, 127545. [\[CrossRef\]](#)

22. Semeraro, T.; Aretano, R.; Barca, A.; Pomes, A.; Del Giudice, C.; Gatto, E.; Lenucci, M.; Buccolieri, R.; Emmanuel, R.; Gao, Z.; et al. A conceptual framework to design green infrastructure: Ecosystem services as an opportunity for creating shared value in ground photovoltaic systems. *Land* **2020**, *9*, 238. [\[CrossRef\]](#)
23. Adedapo, O.; Solanke, B.; Iriogbe, H.O.; Ebeh, C.O. Conceptual frameworks for evaluating green infrastructure in urban stormwater management. *World J. Adv. Res. Rev.* **2023**, *19*, 1595–1603. [\[CrossRef\]](#)
24. Abunnasr, Y.; Infield, E.M.H. The green infrastructure transect: An organizational framework for mainstreaming adaptation planning policies. In *Planning for Climate Change: A Reader in Green Infrastructure and Sustainable Design for Resilient Cities*; Routledge: Oxford, UK, 2018; pp. 184–194.
25. Suárez, M.; Rieiro-Díaz, A.M.; Alba, D.; Langemeyer, J.; Gómez-Baggethun, E.; Ametzaga-Arregi, I. Urban resilience through green infrastructure: A framework for policy analysis applied to Madrid, Spain. *Landsc. Urban Plan.* **2024**, *241*, 104923. [\[CrossRef\]](#)
26. Vujičić, D.; Vasiljevic, N.; Radic, B.; Tutundzic, A.; Galečić, N.; Skocajic, D.; Ocokoljić, M. Conceptualisation of the Regulatory Framework of Green Infrastructure for Urban Development: Identifying Barriers and Drivers. *Land* **2024**, *13*, 692. [\[CrossRef\]](#)
27. Mell, I. ‘But who’s going to pay for it?’ Contemporary approaches to green infrastructure financing, development and governance in London, UK. *J. Environ. Policy Plan.* **2021**, *23*, 628–645. [\[CrossRef\]](#)
28. Voyde, E.; Fassman, E.; Simcock, R. Stormwater mitigation by living roofs in Auckland, New Zealand. In Proceedings of the Low Impact Development 2010: Redefining Water in the City—Proceedings of the 2010 International Low Impact Development Conference, San Francisco, CA, USA, 11–14 April 2010; pp. 1406–1416.
29. King, D.N.T.; Skipper, A.; Tawhai, W.B. Maori environmental knowledge of local weather and climate change in Aotearoa—New Zealand. *Clim. Chang.* **2008**, *90*, 385–409. [\[CrossRef\]](#)
30. Denys, P.H.; Beavan, R.J.; Hannah, J.; Pearson, C.F.; Palmer, N.; Denham, M.; Hreinsdottir, S. Sea Level Rise in New Zealand: The Effect of Vertical Land Motion on Century-Long Tide Gauge Records in a Tectonically Active Region. *J. Geophys. Res. Solid Earth* **2020**, *125*, e2019JB018055. [\[CrossRef\]](#)
31. Hanna, C.; White, I.; Fu, X.; Crossland, K.; Serrao-Neumann, S. Green or Grey Pandemic Recovery? Revealing the Blue–Green Infrastructure Influences in Aotearoa-New Zealand’s “Shovel Ready” COVID-19 Response. *Urban Policy Res.* **2022**, *41*, 38–54. [\[CrossRef\]](#)
32. Nguyen, T.T.; Meurk, C.; Benavidez, R.; Jackson, B.; Pahlow, M. The effect of blue-green infrastructure on habitat connectivity and biodiversity: A case study in the Ōtākaro/avon river catchment in christchurch, new zealand. *Sustainability* **2021**, *13*, 6732. [\[CrossRef\]](#)
33. Benicio de Albuquerque, F.; Maraqa, M.; Chowdhury, R.; Mauga, T.; Alzard, M. Greenhouse gas emissions associated with road transport projects: Current status, benchmarking, and assessment tools. *Transportation Res. Procedia* **2020**, *48*, 2018–2030. [\[CrossRef\]](#)
34. Mehrotra, S.; Lefevre, B.; Zimmerman, R.; Gerçek, H.; Jacob, K.; Srinivasan, S. Climate change and urban transport systems. In *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network*; Rosenzweig, C., Solecki, W.D., Hammer, S.A., Mehrotra, S., Eds.; Cambridge University Press: Cambridge, UK, 2011.
35. Doost Mohammadian, H.; Rezaie, F. Blue-Green Smart Mobility Technologies as Readiness for Facing Tomorrow’s Urban Shock toward the World as a Better Place for Living (Case Studies: Songdo and Copenhagen). *Technologies* **2020**, *8*, 39. [\[CrossRef\]](#)
36. Toan, T.D. Smart Planning and Management Solutions for Smart Mobility. In Proceedings of the CIGOS 2021, Emerging Technologies and Applications for Green Infrastructure, Ha Long, Vietnam, 28–29 October 2021; Springer Nature: Singapore, 2022; pp. 1397–1405.
37. Gudmundsson, H.; Regmi, M.B. Developing the Sustainable Urban Transport Index. *Transp. Commun. Bull. Asia Pac.* **2017**, *87*, 35.
38. Wong, Z.; Chen, A.; Shen, C.; Wu, D. Fiscal policy and the development of green transportation infrastructure: The case of China’s high-speed railways. *Econ. Chang. Restruct.* **2022**, *55*, 2179–2213. [\[CrossRef\]](#)
39. Robin, E.; Acuto, M. Global urban policy and the geopolitics of urban data. *Political Geogr.* **2018**, *66*, 76–87. [\[CrossRef\]](#)
40. Fratini, F. Climate Change and “Local Nature Based Solution” Towards Resilience. In *New Metropolitan Perspectives. Lecture Notes in Networks and Systems*; Calabr, F., Spina, L.D., Piñeira Mantiñán, M.J., Eds.; Springer International Publishing AG: Cham, Switzerland, 2022; Volume 482 LNNS, pp. 2680–2691.
41. Derkzen, M.L.; van Teeffelen, A.J.A.; Verburg, P.H. Green infrastructure for urban climate adaptation: How do residents’ views on climate impacts and green infrastructure shape adaptation preferences? *Landsc. Urban Plan.* **2017**, *157*, 106–130. [\[CrossRef\]](#)
42. Oorschot, J.; Remme, R.; Slootweg, M.; Sprecher, B.; Voet, E. Optimizing green and grey infrastructure planning for sustainable urban development. *npj Urban Sustain.* **2024**, *4*, 41. [\[CrossRef\]](#)
43. Sini, R. Singapore’s Green Infrastructure and Biophilic Urbanism. In *Advances in 21st Century Human Settlements*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 211–251.
44. Ahern, J. Green Infrastructure For Cities: The Spatial Dimension. *Cities Future Towards Integr. Sustain. Water Landsc. Manag.* **2007**, *13*, 267–283.
45. USEPA. *Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure*; USEPA: Washington, DC, USA, 2010.

46. Staddon, C.; Ward, S.; De Vito, L.; Zuniga-Teran, A.; Gerlak, A.K.; Schoeman, Y.; Hart, A.; Booth, G. Contributions of green infrastructure to enhancing urban resilience. *Environ. Syst. Decis.* **2018**, *38*, 330–338. [\[CrossRef\]](#)
47. Cameron, R.W.F.; Blanuša, T. Green infrastructure and ecosystem services—is the devil in the detail? *Ann. Bot.* **2016**, *118*, 377–391. [\[CrossRef\]](#)
48. Hapriyanto, A.R.; Azmi, H. Implementation of Green Infrastructure in Sustainable Transportation in Supporting Urban Mobility: A Literature Review. *Eng. Proc.* **2025**, *84*, 25. [\[CrossRef\]](#)
49. Almaaitah, T.; Appleby, M.; Rosenblat, H.; Drake, J.; Joksimovic, D. The potential of Blue-Green infrastructure as a climate change adaptation strategy: A systematic literature review. *Blue-Green Syst.* **2021**, *3*, 223–248. [\[CrossRef\]](#)
50. Schoeman, C.; Schoeman, I. Green infrastructure: Implications for spatial, land use and transportation planning. *Int. J. Environ. Impacts* **2019**, *2*, 72–84. [\[CrossRef\]](#)
51. Mei, C.; Liu, J.; Wang, H.; Yang, Z.; Ding, X.; Shao, W. Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed. *Sci. Total Environ.* **2018**, *639*, 1394–1407. [\[CrossRef\]](#) [\[PubMed\]](#)
52. Khodadad, M.; Aguilar-Barajas, I.; Khan, A.Z. Green Infrastructure for Urban Flood Resilience: A Review of Recent Literature on Bibliometrics, Methodologies, and Typologies. *Water* **2023**, *15*, 523. [\[CrossRef\]](#)
53. Gill, S.E.; Handley, J.F.; Ennos, A.R.; Pauleit, S. Adapting cities for climate change: The role of the green infrastructure. In *Planning for Climate Change: A Reader in Green Infrastructure and Sustainable Design for Resilient Cities*; Routledge: Oxford, UK, 2018; pp. 195–205.
54. Zuniga-Teran, A.A.; Staddon, C.; de Vito, L.; Gerlak, A.K.; Ward, S.; Schoeman, Y.; Hart, A.; Booth, G. Challenges of mainstreaming green infrastructure in built environment professions. *J. Environ. Plan. Manag.* **2020**, *63*, 710–732. [\[CrossRef\]](#)
55. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; Wisdom, J.P.; Duan, N.; Hoagwood, K. Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Adm. Policy Ment. Health Ment. Health Serv. Res.* **2015**, *42*, 533–544. [\[CrossRef\]](#)
56. Krejcie, R.V.; Morgan, D.W. Determining Sample Size for Research Activities. *Educ. Psychol. Meas.* **1970**, *30*, 607–610. [\[CrossRef\]](#)
57. Agresti, A. *Categorical Data Analysis*, 3rd ed.; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2012; p. 752.
58. Charlesworth, S.M.; Booth, C.A. The Benefits of Green Infrastructure in Towns and Cities. In *Solutions to Climate Change Challenges in the Built Environment*; John Wiley & Sons: Hoboken, NJ, USA, 2012; pp. 163–179.
59. Kim, D.; Song, S.K. The multifunctional benefits of green infrastructure in community development: An analytical review based on 447 cases. *Sustainability* **2019**, *11*, 3917. [\[CrossRef\]](#)
60. Rodrigues, M.; Franco, M. Taxonomy of Holistic Performance of Current Creative Cities: Empirical Study. *J. Urban Plan. Dev.* **2020**, *146*, 04019030. [\[CrossRef\]](#)
61. Russo, A.; Cirella, G.T. Urban ecosystem services: Current knowledge, gaps, and future research. *Land* **2021**, *10*, 811. [\[CrossRef\]](#)
62. Russo, A.; Chan, W.T.; Cirella, G.T. Estimating air pollution removal and monetary value for urban green infrastructure strategies using web-based applications. *Land* **2021**, *10*, 788. [\[CrossRef\]](#)
63. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Taylor and Francis Group: Oxfordshire, UK, 1988; Volume 540, ISBN 9781134742707.
64. Meerow, S.; Newell, J.P. Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit. *Landsc. Urban Plan.* **2017**, *159*, 62–75. [\[CrossRef\]](#)
65. Eames, C. *Education for Sustainability in New Zealand Schools: An Evaluation of Three Professional Development Programmes*; Ministry of Education: Wellington, New Zealand, 2010; ISBN 978-0-478-34264-2.
66. Lang, D.J.; Wiek, A.; Bergmann, M.; Stauffacher, M.; Martens, P.; Moll, P.; Swilling, M.; Thomas, C.J. Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustain. Sci.* **2012**, *7*, 25–43. [\[CrossRef\]](#)
67. Ahern, J.; Cilliers, S.; Niemelä, J. The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landsc. Urban Plan.* **2014**, *125*, 254–259. [\[CrossRef\]](#)
68. Breed, C.A.; Engemann, K.; Pasgaard, M. A transdisciplinary multiscaled approach to engage with green infrastructure planning, restoration and use in sub-Saharan Africa. *Urban Ecosyst.* **2024**, *27*, 895–907. [\[CrossRef\]](#)
69. Ortega Sandoval, A.D.; Rodríguez Sánchez, J.P.; Bharati, L. A transdisciplinary approach for assessing the potential feasibility of Sustainable Urban Drainage Systems: Case study, Bogotá, Colombia. *Urban Water J.* **2023**, *20*, 1081–1094. [\[CrossRef\]](#)
70. Cervera, M.; Bell, S.; Muñoz, F.; Mishra, H.S.; Fleming, L.E.; Grellier, J.; Carrasco-Turigas, G.; Nieuwenhuijsen, M.J.; Vert, C.; Gascon, M. A transdisciplinary approach to recovering natural and cultural landscape and place identification: A case study of Can Moritz Spring (Rubí, Spain). *Int. J. Environ. Res. Public Health* **2021**, *18*, 1709. [\[CrossRef\]](#)
71. Haase, D.; Frantzeskaki, N.; Elmqvist, T. Ecosystem services in urban landscapes: Practical applications and governance implications. *Ambio* **2014**, *43*, 407–412. [\[CrossRef\]](#)
72. Kabisch, N.; Larondelle, N.; Reeve, A. *Human-Environmental Interactions in Cities: Challenges and Opportunities of Urban Land Use Planning and Green Infrastructure*; Cambridge Scholars Publishing: Newcastle upon Tyne, UK, 2014.

73. Ahern, J. From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landsc. Urban Plan.* **2011**, *100*, 341–343. [[CrossRef](#)]
74. Meerow, S.; Newell, J.P.; Stults, M. Defining urban resilience: A review. *Landsc. Urban Plan.* **2016**, *147*, 38–49. [[CrossRef](#)]
75. Smets, J.; De Blust, G.; Verheyden, W.; Wanner, S.; Van Acker, M.; Turkelboom, F. Starting a participative approach to develop local green infrastructure; from boundary concept to collective action. *Sustainability* **2020**, *12*, 10107. [[CrossRef](#)]
76. Hansen, R.; van Lierop, M.; Rolf, W.; Gantar, D.; Erjavec, I.Š.; Rall, E.L.; Pauleit, S. Using green infrastructure to stimulate discourse with and for planning practice: Experiences with fuzzy concepts from a pan-European, a national and a local perspective. *Socio-Ecol. Pract. Res.* **2021**, *3*, 257–280. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.