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Towards Sustainable Infrastructure Development: Drivers, Barriers, Strategies, and Coping Mechanisms

Brenda Mutanu Munyasya [1] and Nicholas Chileshe [2,*]

[1] School of Natural and Built Environments, University of South Australia, Adelaide, SA 5001, Australia; munby002@mymail.unisa.edu.au

[2] School of Natural and Built Environments, Centre for Natural and Built Environment (NBERC), University of South Australia, Adelaide, SA 5001, Australia

* Correspondence: nicholas.chileshe@unisa.edu.au; Tel.: +61-8-830-22252

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Abstract: Despite the advent of the new Sustainable Development Goals, and noted benefits around the social, economic, and environmental aspects, the sustainable infrastructure development (SID) implementation process faces a number of challenges. Moreover, while there is a plethora of studies around sustainable infrastructure, there are limited studies undertaken on the influencing drivers and barriers particularly within the South Australian construction industry. This paper is aimed at filling that knowledge gap by identifying and ranking the drivers and barriers of SID implementation in South Australian construction organizations. A sequential mixed methods approach comprising questionnaires and interviews was conducted among construction professionals. The highly ranked drivers were identified as innovation, standardization of the word 'sustainability' (knowledge improvement), and close interaction of all involved stakeholders. "Lack of steering mechanism", "multi-disciplinary nature of the word "sustainability", and "lack of cooperation and networking" were the critical barriers. Suggested strategies and coping mechanisms for overcoming these barriers include instilling sustainability awareness, sustainability specifications, and governance frameworks. Strong and positive relationships were evident amongst all the drivers. This paper provides further insights into the knowledge and awareness of these drivers, which are cardinal to increased uptake of SID by the stakeholders, and barriers to overcome.

Keywords: drivers; barriers; implementation; coping mechanisms; correlation analysis; sustainable infrastructure; South Australia; construction industry

1. Introduction

The concept of sustainable development has been gaining popularity across various disciplines, including infrastructure. To enhance sustainability in the Australian construction industry, the national infrastructure network [1] identified priorities in maintaining economic success and environmental stability. Australia is also keen to develop new civil and construction networks while ensuring green construction. Therefore, Australia is considering ideas to improve its transportation infrastructure using green construction and sustainable development. In addition, with the emergence of green construction, Australia has become very keen to apply it to all the domains of construction, such as buildings, roads, and railway networks [2]. For this study, the concept around "infrastructure" refers to civil infrastructure within the Australian green infrastructure scope. The benefits of sustainable infrastructure have also been acknowledged in developing countries as well. For example, infrastructure has also been identified as the key driver that can accelerate the balance among the economic, social, and environmental aspects forming the triple bottom line (TBL) in several developing countries [3].

However, the need of focusing on sustainable infrastructure development (SID), both in Australia and globally, has become more significant. According to [4] it has also been projected that, by 2050, about 66% of the world's population might live in urban areas. This has a significant impact with the population directly or indirectly responsible for about 75% of greenhouse gases. Likewise, sustainable infrastructure adoption also faces a great deal of challenges. This can be improved if the involved stakeholders are aware of barriers and drivers to the adoption of SID. While numerous Australian studies have been conducted around sustainability and infrastructure development, recent ones focus on infrastructure procurement [5], social infrastructure in the areas of PPPs [6], development of sustainability reporting tools [7], and sustainable management through decision-making tools [8]. However, there is an obvious omission of South Australian and construction-specific studies. To narrow this knowledge gap, the study aims to identify and rank the critical drivers and barriers to the implementation of SID in South Australia. This study is significant as it sheds light and provides insights on the understanding of the drivers and barriers to the implementation of SID within the South Australian construction sector. The findings and the drivers can be used by the practitioners and stakeholders in the South Australian construction industry as a road map for the successful implementation of SID. The identification of the barriers further enables the development of appropriate strategies and coping mechanisms in overcoming them.

The rest of this paper is structured as follows: First, the insights into the conceptualisation of SID and several definitions of sustainable development are presented. Section 3 presents a brief discussion of the results of the literature survey on critical barriers and drivers (thus labelled antecedents) to the implementation of SID. The research methodology adopted is explained in Section 4, which is followed by discussion of the results in Section 5. Section 6 focusses on the strategies and coping mechanisms for dealing with the implementation of SID followed by a recommendations and implications. Finally, Section 7 presents the conclusions and areas of further research and emergent limitations are singled out.

2. Conceptualisation of Sustainable Infrastructure Development

To facilitate the examination of the drivers and critical barriers faced by South Australian construction organisations, the concepts of the SID, sustainable infrastructure, and sustainable development need to be defined. This study draws upon the definitions provided by the World Commission on Environment Development [9] wherein sustainable development refers to the development that meets the need of the present generation without comprising the ability of the future generation to meet its own needs. The following definitions of infrastructure, sustainable development, sustainability, and sustainable infrastructure provided by various authors (e.g., [10–13]); are worth noting. For example, [13] defines sustainable infrastructure as:

> The adoption of principles of sustainable development in infrastructure development projects execution by striking a balance between environmental protection wellbeing and economic prosperity for the benefits of both the present and future generations.

Whereas [11] defines sustainable development as: 'development aiming to maintain the economic and progress while protecting the long-term value of the environment'. In contrast, [12] has the following definition of sustainability as: All future generations will inherit substantive environmental and democratic rights—control over the means of survival, an increased ecological base, and genuine social choice (not 'substituted' by manufactured capital)." Finally, [10] defines infrastructure as typically including utilities such as roads, ports, railways, power lines, water pipes, power generation buildings, sewer plants, and other tangible structures.

Acknowledging the importance for sustainability infrastructure as defined by [13] for the study, the sustainable infrastructure in the construction applications could be redefined to include the following:

> "An interrelationship of organised principles that create favourable built environment that meets the present needs without degrading the ecological sustainability and jeopardising the ability of the future generations to meet theirs."

Irrespective of the numerous definitions, it is quite evident that the aspirations and meanings are common with the main focus on protecting the future generations.

3. Literature Review

The professionals in the infrastructure sector generally agree on adopting sustainable solutions into designs, construction and operation of infrastructure facilities. However, in practice they are facing great challenges in adopting sustainability principles into their professional domains and real projects to deliver tangible outcomes [14]. Therefore, the following subsections summarize and discuss the selected studies on the 'barriers' and 'drivers' to SID adoption.

3.1. Barriers to SID Implementation

The number of barriers influencing the adoption of SID by are well documented in literature [15–20]. For example, Ref. [15] identified the following barriers as affecting the adoption of SID: steering mechanisms, economics, a lack of client understanding, process (procurement and tendering, timing, cooperation, and networking), and underpinning knowledge (knowledge and common language, the availability of methods and tools, innovation). Similarly, in India, Ref. [17] identified amongst the challenges affecting the SID as follows: lack of stakeholder and local participation; lack of transparency and accountability; knowledge about sustainability; and transaction cost. Conversely, in Australia, Ref. [18] identified critical cost components relating to sustainability measures based on perspectives of industry stakeholders, whereas, Ref. [20] established that there are three major barriers to green infrastructure in Australia including higher cost, lack of steer mechanism by the government and risk of increased pollution. Within the United States construction context, Ref. [16] study on drivers and barriers identified the first cost premium of the project amongst the most significant barriers to sustainable design and construction. Table 1 presents a summary of some of the selected barriers) to the adoption of SID.

As can be seen from Table 1, the significance or importance of the 'economics/finance' and 'steering mechanism' as barriers to SID are quite evident based on the frequency of citation in the studies reviewed. In summary, using the 'neglect spotting' model of the reviewed literature, the lack of empirical studies around the drivers and barriers for SID adoption within the South Australian construction industry context are highlighted. In addition, Table 1 provides further evidence around the limited studies on the barriers. Hence, to fill that knowledge gap, this study identifies and ranks the critical drivers and barriers to the implementation of SID in South Australia. Some coping strategies and mechanisms for overcoming the barriers are also proposed. Within the context of this study, the terminologies of "strategies" and "coping mechanisms" are used interchangeably.

3.2. Drivers for SID Implementation

The literature review highlighted and identified studies which investigated the drivers for SID. These drivers ranged from innovation [20–22] standardization of word sustainability or knowledge improvement [15,17] to, and closer interaction and networking among involved stakeholders [14,17]. The other notable driver is associated with the economic and financial category, for example, several studies, such as [17,21,23] have singled the presence of financial incentives among the drivers. In contrast, the Australian study by [20] acknowledged that there are two core drivers for sustainable construction (SC) in every industry such as transportation, buildings, and other construction projects. However, these drivers include innovation and sustainability. Similarly, recent studies, such as [22], recommended reusing clay as this enables major civil infrastructure development to contribute to a circular economy. Development of holistic sustainable technologies and solutions, such as the application of recyclable aggregate concrete, are also suggested to achieve sustainable infrastructure [24].

Table 1. Summary of literature review on implementation barriers of SID.

Barriers	Studies												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Economic/finance	√	√	√	√	√	√	√	√	√	√	√	√	12
Steering mechanism	√	x	√	√	√	√	√	√	√	√	√	√	11
Underpinning knowledge	x	x	√	√	√	√	√	x	√	√	√	√	9
Innovation	√	x	√	√	√	x	x	√	√	√	√	√	9
Corporation and networking	x	x	√	x	√	x	√	√	√	√	x	√	7
Procurement and tendering process	x	x	√	x	√	√	√	x	√	√	√	x	7
Availability of integrated methods	x	x	√	x	√	x	√	√	√	√	x	x	7

Notes: [1] [23]; [2] [25]; [3] [26]; [4] [27]; [5] [15]; [6] [28]; [7] [29]; [8] [30]; [9] [31]; [10] [32]; [11] [33]; [12] [21].

4. Materials and Methods

In this study, an explanatory sequential mixed methods approach was adopted. This consisted of the following six steps: (1) literature review; (2) pilot survey; (3) questionnaire survey; (4) interviews; (5) statistical analysis; and (6) content analysis. The quantitative approach (questionnaire survey) had more emphasis than the qualitative one (interviews). This mixed methods approach allows for the emphasizing qualitative more or emphasizing quantitative more [34]. The rationale for this approach was to enhance validity and complementarity [35], whereas the explanatory sequential mixed methods design enabled the qualitative data despite the limited sample to help explain the quantitative results [36].

4.1. Design of the Questionnaire Survey

The questionnaire comprised the following four distinct sections:

- *Section 1* encompassed the general demographics;
- *Section 2* aimed to capturing the perceptions on the influence of the barriers to SID;
- *Section 3* comprised the drivers; and
- *Section 4* was open ended with respondents asked to propose strategies and coping mechanisms for dealing with the implementation of sustainable infrastructure.

For both the barriers and drivers' sections, respondents were asked to rate their opinions using a five-point Likert-scale (5 = strongly disagree, 4 = disagree, 3 = neutral, 2 = agree, and 1 = strongly agree). As recommended by [37] (p. 332) the Likert scale included and measured both the *direction* (i.e., by 'agree'/disagree) and *intensity* (i.e., by 'strongly' or not). Furthermore, this scale was adopted due to its ability to detect the feelings that respondents have about their attitudes [37].

4.2. Quantitative Data Analysis

Quantitative data as collected was analysed using the IBM SPSS software (version 25, Chicago, IL, USA). Four methods were employed:

- *Parametric tests* were undertaken to measure the significance of the 'drivers' and 'barriers' to the adoption of SID;
- *Descriptive statistics tests such as measures of central tendencies and frequency analysis* enabled further ranking analyses to obtain the relative importance of the 'drivers' and 'barriers';
- *Correlation analysis* to examine the relationships among the different pairs of variables comprising SID's critical drivers and barriers. Whilst acknowledging that there varied interpretations of the Pearson Correlation coefficients, this study draws upon the following five classification as provided by [38] as follows with the emphasis on '*strength*' and '*direction*': (i) 1.0 to −0.7, strong negative association; (ii) −0.7 to −0.3, weak negative association; (iii) −0.3 to +0.3, little or no association; (iv) +0.7 to +0.3, weak positive association; and (v) +0.7 to +1.0, strong positive association. This approach has also been used in recent studies such as [39].

- The *coefficient of variation* (COV) is used as a general measure of the standardised skewness or variability of the responses [40]. This was computed using the standard deviation as a percentage of the mean score. Rank differentiation was used where two or more barriers or drivers had the same mean values. This was achieved through examination and selection of the variable (driver or barrier) with the lowest standard deviation or COV.

As the study objectives included the identification and ranking of the main critical drivers and barriers of sustainable infrastructure development implementation (SID), to ascertain their levels of significance, rather than simply taking mean values below 3.0 as important or critical (due to the reverse scoring on the Likert scale), a single-sample *t*-test was conducted to find out if the mean values were significantly different from 3.0 or even 2.5 (which approximates to 2.0, i.e., agree on the five-point scale). Drawing upon previous studies such as the works of [41–44]; the cut-off point for the five-point scale was set at 2.5 ($\mu = 2.5$), with a hypothesis introduced to measure the criticality of the variables (i.e., the drivers and barriers of sustainable infrastructure development implementation). As previously stated, the normal middle point for a five-point Likert scale would be the value of 3. However, this value would only identify or be equivalent to 50% of the drivers and barriers affecting SID implementation. Given the importance and the lack of SID related studies within the South Australian context as identified from the literature review, a value higher than 50% of the drivers and barriers was deemed appropriate. To that end, the μ value was set at 2.5.

4.3. Population and Sampling

The *population* and *sampling* strategy employed was by contacting the Consumer and Business Services of South Australia for a list all registered construction organisation based in South Australia. Adelaide being the capital city of South Australia was selected as the study's population due to most of the construction organisations being based there. The study used both survey monkey, in which a link was sent to organizations whose information was available on yellow pages and hard copy questionnaires which were physically handed to the organisation and others were sent to the organisations' email accounts. This 'non-probability' sampling was employed due to the researcher's knowledge about specific South Australian cases [45]

In total, 250 questionnaires were sent to organisations whose contact details were readily available on the yellow pages, and 50 responses were obtained, representing a response rate of 20%. This sampling strategy was designed as a mobiliser and kick-starter for the data collection as several studies have used a similar approach or method in collecting data [15]. The unit of analysis was also identified as the construction organisation. Finally, while the response rate of 20% might be deemed as too low, according to [46] (p. 494), if high-quality survey data are obtainable from a smaller sample drawn using well-developed selection criteria, meaningful findings can still result.

4.4. Semi-Structured Interviews

The questions posed to the interviewees related to the exploration of how sustainable infrastructure can be implemented in Australia, specifically the challenges and facilitators. In total, three semi-structured interviews were conducted with the key stakeholders in the construction sector. Each interview was conducted with a set of structured questions. The interview contained six questions, which focused to explore how sustainable infrastructure can be implemented in South Australia. The standardization of the interview questions provided a common platform for evaluation of the findings obtained. The interview was structured to end in a time frame between 10–20 min. These six questions were as follows:

- What is the importance of adopting sustainable construction?
- Is the government fulfilling its role in enabling adoption of sustainable infrastructure?
- What are the challenges and barriers to adopting sustainable infrastructure in the Australia?
- What are the drivers of green construction in Australia?

- Is the cost of infrastructure most important for Australia?
- Propose strategies and coping mechanism for the adoption of sustainable construction?

The rationale and justification for adopting semi-structured interviews strategy is that, they are flexible enough to explore questions into areas that could provide new dimensions of issues not pre-conceived [47]. Moreover, as suggested by [48], the semi-structured approach is nested within the 'localist' perspective and geared towards having an empirical situation (i.e., South Australian-specific) that can be studied. Denscombe further highlighted that the interview is an effective tool when the researcher wishes to gain people's opinions, feelings, emotions, and experiences [49].

5. Survey Results and Discussions

5.1. Background Information about Respondents

Table 2 shows the profile of respondents according to the designation, sector and academic qualification. Out of the total, 22 (44.0%) were from Chief Executive Officers (CEOs), nine (18.0%) from land surveyors; seven (14.0%) from architects; six (12.0%) from quantity surveyors; and the remaining four (8.0%) selected the option of other professions. Based on academic qualifications, the majority twelve (24.0%) had a graduate diploma. An equal number of 10 (20.0%) had PhDs and undergraduate degrees.

Table 2. Profile of respondents by designation, sector, and academic qualifications.

Description	Frequency	Percentage	Cumulative %
Designation			
Chief executive officer (CEO)	11	22.00	22.00
Architects	7	14.00	36.00
Project managers	6	12.00	48.00
Engineers	7	14.00	62.00
Quantity surveyors	6	12.00	74.00
Land surveyors	9	18.00	92.00
Others	4	8.00	100.00
	50	**100.00**	
Sector			
Private	21	42.00	42.00
Public	29	58.00	100.00
	50	**100.00**	
Academic qualification			
PhD	10	20.00	20.00
Master's degree	4	8.00	28.00
Postgraduate diploma	12	24.00	52.00
Postgraduate certificate	10	20.00	72.00
Bachelors (BSc)	7	14.00	86.00
Certificate	7	14.00	100.00
	50	**100.00**	

Based on working experience (or length of service), the majority twenty-one (42.0%) had more than 10 years of service or experience, 13 (26.0%) respondents had 6–10 years of experience, and 10 (20.0%) had less than a year's experience. Sector-wise, twenty-nine (58.0%) were drawn from the public sector and the remaining 21 (42%) from the private sector.

In terms of responsibilities engaged in SID, fifteen (30.0%) were from project management, 11 (22.0%) from design, cost, and budgetary, an equal number of seven (14.0%) from facility management and organisation management, six (12.0%) from training, and four (8.0%) selected the 'others' option. Based on diverse professional background and experience of respondents, it could be concluded that the information as gathered was representative and valid. Moreover, the respondents can provide, operational, technical, and strategic perceptive of SID.

5.2. Reliability Analysis

The measurement sub instruments were also tested for validity and internal consistency. The Cronbach Alpha coefficient was found to be 0.986 (F-statistic = 18.955, sig. = 0.000); and 0.649 (F-statistic = 0.440, sig. = 0.780) for the 'drivers' and 'barriers' sub-instruments, respectively. While the Cronbach coefficient value was greater than 0.7 for the 'drivers' sub-instrument, thus conforming the high reliability of the sub-instrument [50], the value of 0.649 for the 'barriers' could be deemed as accepted as numbers close to 1.00 are considered as very good [50]. Furthermore, studies such as that of [51] have highlighted that a high alpha coefficient value does not always mean a high degree of internal consistency. Most importantly, examination of the item-total correlations for the 'drivers' sub-instrument showed that all the correlations were greater than 0.7, and therefore considered desirable [50]. Furthermore, investigation of the 'item-total statistics' and 'alpha if item deleted' revealed that only the deletion of the highest ranked item, namely, 'lack of steering mechanism' would improve the reliability to 0.830. Due to the importance attached to 'Lack of steering mechanism', this item was not deleted, but included in the overall survey instrument. Some studies such as Ref. [42] have indeed applied the recommendations as suggested by [51] in reporting on the reliability of the measurement instruments as employed.

5.3. Agreement and Consistency of Responses

Barriers

Table 3 shows the results of the Kendall's concordance analysis for the barriers and drivers at the pre-defined significance test value of 0.05.

Table 3. Results of Kendall's concordance analysis—barriers and drivers.

Descriptions	**All Respondents (N = 50)**	
	Barriers	**Drivers**
Number of respondents (N)	501	50
Kendall's coefficient of concordance (W)	0.018	0.294
Chi-square	3.651	88.153
Degrees of freedom (df)	4	6
Critical value of chi-square	9.49	12.59199
Asymp. significance	0.455	0.000

To establish whether they were any agreement and consistency of responses around the seven drivers for SID implementation, the Kendall's concordance analysis at a pre-defined test value of 0.05 was undertaken [52]. The W values obtained for the 'drivers' and 'barriers' were 0.294 and 0.018, with significance values of 0.000 and 0.455, respectively. As suggested by [52], the chi-square (χ^2) was used for the drivers than the computed W values due to the number of attributes (i.e., drivers) exceeding seven. From the results obtained, the critical value of the χ^2 was 12.5919 and less than the computed value of 88.153 with degrees of freedom (df) of six, thus confirming that there was agreement in the levels of consensus in the scoring of the drivers among the respondents. Similarly, based on the W value of the 'barriers' which was 3.651 further confirms that there was agreement in the ranking of the factors by the respondents and significance (p) value of 0.455 was, nevertheless, greater than 0.05. Despite the critical value of χ^2 being 9.49 and greater than the computed value of 3.651, the rationale for using the W value for determination of the level of consensus or concordance for the 'barriers' was due to the number (n = 5, i.e., df = 4) of the variables being less than seven. From the results, this confirms that there was disagreement in the levels of consensus in the scoring of the barriers among the respondents.

5.4. Ranking of the Antecedents (Drivers and Barriers)

Table 4 presents the descriptive results of analysis for the antecedents comprising seven drivers for SID adoption.

Table 4. Ranking of the antecedents (drivers).

Drivers	MS	Std	COV %	Rank
Dr2	2.08	1.275	61.29	**1**
Dr4	2.10	1.266	60.29	2
Dr7	2.24	1.287	57.46	3
Dr5	2.46	1.373	55.81	4
Dr3	2.52	1.165	46.23	5
Dr6	2.60	1.262	48.54	6
Dr1	2.64	1.336	50.61	7

Notes: Dr1 = Presence of financial incentives; Dr2 = Innovation; Dr3 =Culture that incorporate sustainability in daily management decisions; Dr4 = Standardization of word sustainability (knowledge improvement); Dr5 = Presence of steering mechanism; Dr6 = Modern procurement methods; and Dr7 = Close interaction and networking among involved stakeholders; MS = Mean score of the drivers variable where 1 = strongly agree; 2 = agree; 3 = neutral; 4 = disagree; and 5 = strongly dis agree; COV = coefficient of variation.

5.4.1. Ranking of the Adoption Drivers

As illustrated in Table 4, the mean agreement for the 'drivers' scores ranged from 2.08 to 2.64. The COV of the drivers ranged between 46.23 and 61.29 with the least ranked drivers unsurprisingly demonstrating higher levels of agreement among the respondents. It is beyond the scope of this study to discuss all seven drivers. Therefore, only the top three scoring below 2.40 and the least ranked due to their relevance have been singled out. To test whether there is a significant difference in the means of the drivers or barriers a one-sample independent *t*-statistical analysis was carried out. A test value of 2.5 was selected. Rather than simply taking mean values below 3.0 as important or critical, the authors deemed it appropriate to conduct statistical tests, for example, a *t*-test to find out if the mean values are significantly different from 3.0 or even 2.5 (which approximates to 2.0, in other words, to 'agree' on the five-point scale). This approach has been used in previous studies [44]. The results of the one-sample *t*-tests for the combined antecedents (drivers and barriers) are given in Tables 5 and 6, respectively.

Table 5. Results of one-sample *t*-test for the antecedents (drivers).

Drivers	Test Value (μ) = 2.5					
	t	*df*	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Dr1	0.741	49	0.462	0.140	−0.24	0.52
Dr2	−2.329	49	0.024 *	−0.420	−0.78	−0.06
Dr3	0.121	49	0.904	0.020	−0.31	0.35
Dr4	−2.235	49	0.030 *	−0.400	−0.76	−0.04
Dr5	−0.206	49	0.838	−0.040	−0.43	0.35
Dr6	0.560	49	0.578	0.100	−0.26	0.46
Dr7	−1.429	49	0.159	−0.260	−0.63	0.11

Notes: Dr1 = Presence of financial incentives; Dr2 = Innovation; Dr3 =Culture that incorporate sustainability in daily management decisions; Dr4 = Standardization of word sustainability (knowledge improvement); Dr5 = Presence of steering mechanism; Dr6 = Modern procurement methods; and Dr7 = Close interaction and networking among involved stakeholders. * *df* = degrees of freedom; * Results significant at 95% level ($p < 0.05$).

Table 6. Results of one-sample *t*-test for the antecedents (barriers).

Barriers	Test Value (μ) = 2.5					
	t	*df*	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Br1	−1.548	49	0.128	−0.260	−0.60	0.08
Br2	−1.348	49	0.184	−0.240	−0.60	0.12
Br3	−0.224	49	0.824	−0.040	−0.40	0.32
Br4	−0.510	49	0.612	−0.080	−0.39	0.23
Br5	−0.673	49	0.504	−0.120	−0.48	0.24

Notes: Br1 = Lack of steering mechanism; Br2 = Multidisciplinary nature of the word sustainability; Br3 = Increased cost associated with sustainable construction; Br4 = Traditional procurement methods; and Br5 = Lack of cooperation and networking. *df* = degrees of freedom.

As can be seen from Table 5, the results show a *p*-value ranging from 0.24 to 0. 907 which imply that at 95% significance level all drivers are not equally important some are more important than others. Driver 4 (standardization of word sustainability, knowledge improvement) and 2 (Innovation) have a *p*-value of less than 0.05 meaning that there are significantly different to other drivers. This also implies that the respondents perceived these two drivers as more significant than the others.

Innovation

The driver "innovation" (mean = 2.08) is the most important driver influencing the adoption of SID among the various private and public professionals. This driver was also statistically significantly different from the population mean score of 2.5 ($t = -2.329$, $p = 0.024 < 0.05$). Support of this finding was also evident from the qualitative findings as Interviewee A identified innovation as the main driver of SID in Australia. The Interviewee A further advocated for new approaches in the construction rather than sticking to the traditional and "safe" methods. This finding is also consistent with antecedents to adoption of SID literature [21,23,53]. For example, the study by [53] emphasized that it is important for every business to implement innovative ways of doing business in their operations. Similarly, [21] proposed that construction industry should select from a range of innovations in addressing sustainability issues in the construction as the development of a green technology strategy involves a strong innovation focus. The key lessons and implications from the higher ranking of 'innovation' further suggests that sustainable development requires change of the status quo. This implies the need to help reduce energy consumption and improve construction efficiency. Alternatively, the second option would be to substitute the traditional and harmful construction methods and materials, with innovation being required to develop less harmful solutions (i.e., development of materials with lesser carbon footprints).

Standardization of Word Sustainability (Knowledge Improvement)

"Standardization of word sustainability (knowledge improvement)" (mean = 2.10) was ranked as the second most important driver for the adoption of SID. The higher ranking of this driver is further evidenced by being statistically significantly different from the population mean score of 2.5 ($t = -2.235$, $p = 0.030 < 0.05$). The finding is further supported by the Interviewees. For example, standardization of the word "sustainability" was also identified as the most important driver. Similarly, Interviewee A observed that, most people seem to associate sustainability with environmental degradation only forgetting the economic and social part of it. Interviewee A further viewed this misconception as presenting the greatest challenge to SID noting: "unless all the stakeholders have a common understanding of what SC is, then it's impossible to develop SID". Similarly, Interviewee C observed that improving/installing knowledge about sustainability such that all parties have a common understanding of what sustainable or green building means could probably facilitate adoption of SC. This finding is also consistent with the SID literature regarding the adoption barriers ([15,17]).

Closer Interaction and Networking among Involved Stakeholders

The third most important driver is "Closer interaction and networking among involved stakeholders" (mean = 2.24). Surprisingly, this driver was not statistically significantly different from the population mean score of 2.5 ($t = -1.429$, $p = 0.159 > 0.05$). This finding confirms [14] study which emphasized the importance of corporation and networking among all the key stakeholders involved in the infrastructure projects to ensure sustainability in these projects. The finding is also consistent with [17] study which identified lack of stakeholder and local participation among the challenges or barriers affecting sustainable infrastructure development. Within the Australian context, a study by [54] pointed out that Infrastructure projects involve different stakeholders; therefore, it is important to ensure close interaction between them not only to ensure successful completion but also to ensure that the sustainability needs of the projects are adequately communicated. Therefore, it is important to ensure close interaction between them not only to ensure successful completion, but also to ensure that the sustainability needs of the projects are adequately communicated.

Presence of Financial Incentives

The least ranked driver is "presence of financial incentives" (mean = 3.51). This driver was also not statistically significantly different from the population mean score of 2.5 ($t = 0.741$, $p = 0.462 > 0.05$). The qualitative data also lends support to this finding. For example, Interviewee B suggested that financial incentives and fiscal arrangement could facilitate green building noting that there is a "misconception "among the involved stakeholders that green building cost more. This finding is also consistent with antecedents to adoption of the SID literature [17,21,23,54]. For example; full recovery of the costs associated with PPP SID projects was identified as a key driver by [17]. Likewise, [55] considered fiscal arrangements and financial incentives among the most significant motivational factors that drive an organization towards the adoption of SID.

5.4.2. Ranking of the adoption barriers

Table 7 presents the descriptive results of analysis for the antecedents comprising five barriers for SID adoption.

Table 7. Ranking of the antecedents (barriers).

Description (Br)	MS	Std	COV %	Rank
Br1	2.08	1.275	61.29	1
Br2	2.10	1.266	60.29	2
Br5	2.24	1.287	57.46	3
Br4	2.46	1.373	55.81	4
Br3	2.52	1.165	46.23	5

Notes: Br1 = Lack of steering mechanism; Br2 = Multidisciplinary nature of the word sustainability; Br3 = Increased cost associated with sustainable construction; Br4 = Traditional procurement methods; and Br5 = Lack of cooperation and networking; MS = Mean score of the drivers variable where 1 = strongly agree; 2 = agree; 3 = neutral; 4 = disagree; and 5 = strongly disagree; COV = coefficient of variation.

As illustrated in Table 7, the mean agreement scores of the barriers ranged from 2.24 to 2.46. The COV values ranged between 45.79 and 55.71 demonstrating higher levels of (dis)agreement among the respondents. Table 7 also shows a p-value of the barriers as ranging from 0.128 to 0.824 which means that at the 95% significance level all barriers are significantly critical, and none of the barriers is more critical than the other.

Lack of Steering Mechanism

The barrier "lack of steering mechanism" (mean = 2.24) is the most important influencing the adoption of SID among the various private and public professionals. Surprisingly, despite the higher ranking of this barrier, it was not statistically significantly different from the population mean score of 2.5 ($t = -1.548$, $p = 0.128 > 0.05$). However, support of this finding is also consistent with construction specific literature ([15,19,32]). For example, Ref. [32] emphasizes the value of programmes and strategies as an instrument to support and promote SC. The survey findings and literature view were reinforced by the interviewees, whereas Ref. [19] identified and acknowledged that steering mechanism facilitated by the government play an important role in the development of sustainable infrastructure. Lack of steering mechanism was also identified as the most critical barrier to the adoption of SC in Australia (Interviewee B). The interviewees further noted that the building/construction authorities and councils' supervisors should reinforce their role by providing SC related information and organizational support.

Multidisciplinary Nature of the Word Sustainability

The barrier "multidisciplinary nature of the word sustainability" (mean = 2.26) is the second most ranked in influencing the adoption of SID. This barrier was also not statistically significantly different from the population mean score of 2.5 ($t = -1.348$, $p = 0.184 > 0.05$). Support of this finding is also consistent with construction specific literature ([15,28]). For example, Ref. [28] observed that for the construction design team to integrate sustainability in construction designs, sustainability issues should be clearly communicated in the project brief. The above findings were also further reinforced by the interviewees. For example, one interviewee revealed that there is a partial lack of knowledge of sustainability development, and various stakeholders have different views when it comes to what SC is. The interviewee noted that there is considerable concern on the environmental issues, which is only one aspect of sustainability. Integrating and describing the sustainability requirements across the various stages of the project life cycle were also highlighted by Interviewee C. Accordingly, failure to describe sustainability requirements during initiation stage of infrastructure project was singled out as one of the key challenges for green construction.

The above findings confirm that knowledge and awareness of the concept of sustainability plays a major role in facilitating sustainable construction. To overcome this barrier, attaining sustainability could be achieved if all the stakeholders including the community are well informed on all the aspects of sustainability. Therefore, increased awareness programs could play a crucial role here.

Lack of Cooperation and Networking

The third ranked barrier influencing the adoption of infrastructure development was "lack of cooperation and networking" (mean = 2.38), and not statistically significantly different from the population mean score of 2.5 ($t = -0.673$, $p = 0.504 > 0.05$). The implication from this finding is that to implement a SC, good cooperation and effective communication among all the involved stakeholders is required. The emergent implication from this finding is that, this "lack of cooperation and networking" would make it difficult for the construction organisations to describe sustainable requirements of construction when developing project brief. For example, studies such as [15], identified this among the barriers (and drivers) for sustainable building. Similarly, [17] also identified the lack of stakeholder and local participation among the challenges affecting SID.

To overcome this barrier, the following suggestions are provided: (1) A close interaction of suppliers, designers, all involved professionals and end users to incorporate high compatibility of all domains of design, construction and user behaviour; and (2) use of new procurement methods such as design-build-operate and maintain would integrate all the involved parties, that is, the designers, contractors, operation and maintenance team, and the client from the beginning, since studies have demonstrated that SC requires intense interdisciplinary collaboration, highly complex design analysis and careful material selection in every phase of the project.

Increased Costs Associated with Sustainable Construction

Additional costs associated with the construction of sustainable infrastructure were not considered as critical as the barriers as evidenced by being rated as the least ranked (5th) barrier influencing the adoption of infrastructure development (mean = 2.46). While this was also not statistically significantly different from the population mean score of 2.5 ($t = -0.224$, $p = 0.824 > 0.05$) with a mean difference of -0.040, there is adequate support of the barrier as inhibiting the implementation of SID in the literature ([23,26]). The qualitative findings also provided some contradictory findings with most of the interviewees acknowledging the importance of cost as a general deciding factor for investments This suggests that in view of infrastructure development consuming a lot of finances and resources, the clients would need some assurance that the rate of return from their investment is enough to motivate the investment in SID. Equally, studies, such as [27], have observed that despite the misconceptions among various stakeholder around the higher capital costs associated with SC, the utilization of energy efficient buildings can offer cost savings during operation. Therefore, the South Australian practitioners are encouraged to consider such energy efficient buildings as mitigation against cost in the long-term.

Additional Barriers

In additional to barriers identified and reported in Table 7, the respondents were further asked to highlight the different barriers. The following barrier associated with the lack of organizational culture that emphasizes the importance of sustainability was identified. This finding is also consistent with [56]. For example, [56] also identified that there is a need to develop an organizational culture, which will support sustainable infrastructure development.

5.5. Correlation Analysis

Examining and discussing the extent of the relationship among all the antecedents (barriers and drivers) is beyond the scope of this research. However, only the highest and largest are singled out for detailed discussion. Notwithstanding this approach, the results as presented in Tables 8 and 9 show the support of how these barriers and drivers respectively do not exist in isolation.

5.5.1. Barriers to Sustainable Infrastructure Development

Table 8 shows the correlations and coefficients of determinations amongst the barriers to SID. As shown in Table 8, the highest and large, but weak correlation ($r = 0.669$; $n = 50$; $p = 0.000 < 0.01$) was between "increased costs associated with sustainable construction" and "lack of cooperation and networking". The relationship was also significant at the 0.01 level. The coefficient of determination ($0.669^2 = 0.4475$) further illustrates that 44.75% of the variance in the organisation's ability to reduce the costs associated with adopting SID can be accounted for by the level of increased cooperation and networking amongst the stakeholders. The results also showed that 60.00 per cent of the total ten correlations were significant at $p < 0.01$, whereas the remaining 40.00 per cent were not significant at $p > 0.01$. This suggests a hindrance to cooperation among the involved stakeholders which, in turn, affects innovative solution creation [15].

Furthermore, this increased cost associated with sustainable infrastructure might also limit the construction organisations and discourage them towards the importance of sustainability. There was also a weak correlation ($0.3 < r < 0.7$) between the "multidisciplinary nature of the word sustainability, (Br2)" and "lack of cooperation and networking, (Br5)", and between the barriers, "lack of steering mechanism, (Br1)", and "multidisciplinary nature of the word sustainability, (Br2)", which was also not significant ($p = 0.443 > 0.05$).

Table 8. Correlations analysis amongst the barriers.

		Coefficient of Determination (r^2) or Amount of Variance				
Barriers (Br)	**MS**	**Br1**	**Br2**	**Br3**	**Br4**	**Br5**
Barrier 1	Pearson Correlation	1	1.23	4.45	3.49	2.07
	Sig. (2-tailed)					
Barrier 2	Pearson Correlation	−0.111	1	20.16	16.24	36.72
	Sig. (2-tailed)	0.443				
Barrier 3	Pearson Correlation	−0.211	**0.449 ****	1	32.83	44.76
	Sig. (2-tailed)	0.142	0.001			
Barrier 4	Pearson Correlation	−0.187	**0.403 ****	**0.573 ****	1	36.00
	Sig. (2-tailed)	0.194	0.004	0.000		
Barrier 5	Pearson Correlation	−0.144	**0.606 ****	**0.669 ****	**0.600 ****	1
	Sig. (2-tailed)	0.318	0.000	0.000	0.000	

Notes: ** Correlation is significant at the 0.01 level (2-tailed); for the full description and labels of barriers see the footnotes in Tables 6 and 7; N = 50.

Table 9. Correlations analysis amongst the drivers.

		Coefficient of Determination (r^2) or Amount of Variance						
Dr	**MS**	**Dr1**	**Dr2**	**Dr3**	**Dr4**	**Dr5**	**Dr6**	**Dr7**
Dr1	Pearson Correlation	1	77.26	85.01	77.09	91.97	86.49	84.27
	Sig. (2-tailed)							
Dr2	Pearson Correlation	**0.879 ****	1	79.57	98.80	78.85	82.45	75.86
	Sig. (2-tailed)	0.000						
Dr3	Pearson Correlation	***0.922 *****	***0.892 *****	1	79.39	86.86	95.65	82.63
	Sig. (2-tailed)	0.000	0.000					
Dr4	Pearson Correlation	***0.878 *****	***0.994 *****	***0.891 *****	**1**	**79.03**	82.26	76.56
	Sig. (2-tailed)	0.000	0.000					
Dr5	Pearson Correlation	***0.959 *****	***0.888 *****	***0.932 *****	***0.889 *****	**1**	87.05	88.55
	Sig. (2-tailed)	0.000	0.000	0.000	0.000			
Dr6	Pearson Correlation	***0.930 *****	***0.908 *****	***0.978 *****	***0.907 *****	***0.933 *****	**1**	81.54
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000		
Dr7	Pearson Correlation	*0.918 ***	***0.871 *****	***0.909 *****	***0.875 *****	***0.941 *****	***0.903 *****	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	

Notes: ** Correlation is significant at the 0.01 level (2-tailed); For the full description and labels of drivers (Dr1 through Dr7) see the footnotes in Tables 5 and 6; N = 50.

5.5.2. Drivers to Sustainable Infrastructure Development

Table 9 shows the correlations and coefficients of determinations amongst the drivers to SID. As shown in Table 9, all the 28 correlations were significant at the 0.01 level (2-tailed) with the highest large correlation (r = 0.994; n = 50; p = 0.000 < 0.01) was between "innovation" and "standardisation of the word sustainability (knowledge improvement)". The relationship was also significant at the 0.01 level. The coefficient of determination (0.994^2 = 0.988) further demonstrated that 98.80% of the variance in the organisation's ability for standardisation of the word sustainability (knowledge improvement) can be accounted for by the level of the innovation within organisation. This finding suggests that SID will be adopted widely only if innovation aspects take into consideration the standardisation of the word sustainability (knowledge improvement). This finding is consistent with previous studies by [21,33] and reinforces the opinions of Interviewees.

The second strongest correlation was between the organisation's culture that incorporates sustainability in daily management decisions and modern procurement methods. This is because having an organisational culture that incorporates sustainability in the daily management's decisions (Dr3) and modern procurement methods (Dr6), which was significant at the 0.01 level (r = 0.978; n = 50; p = 0.000 < 0.01). The inference from this result is that the culture has significant roles in framing people's relationship and attitudes towards the built and the natural environments hence should be prioritized and placed at the centre of development strategies [57]. In so doing, the ability of the organisation to incorporate sustainability in daily decisions should be underpinned by a strong culture, and this would also be matched by the effective application of modern procurement methods. Such an approach would lead to the attainment or achieving the required performance with the minimum environmental impact and, at the same time, encouraging economic and social improvement is a significant challenge [30] As shown in Table 9, the least ranked, but still strong correlation (r = 0.903; n = 50, p = 0.000 > 0.05), was between the drivers "modern procurement methods" (Dr6) and "close interaction and networking among involved stakeholders" (Dr7) which was also significant (p = 0.308 < 0.01).

6. Strategies and Coping Mechanisms

The participants highlighted different strategies, which can be used to ensure SID. The most important strategies include incorporating eco-friendly construction materials and re-engineering of the building and maintenance process. While some strategies have been suggested in the literature for delivering SID, the focus of our study was on identifying strategies and coping mechanisms for the adoption of SC from the South Australian perspective. The following are the identified mechanisms:

- *Multidisciplinary nature of the word 'sustainability'* as a barrier could be mitigated by instilling sustainability awareness, responsibilities and consideration right from the project conception throughout the project lifecycle is suggested as a viable coping mechanism. Similarly, specification of sustainability requirements and criteria in the infrastructure projects right from the design to asset management is suggested as a viable coping mechanism to the "*traditional procurement methods*" barrier.
- *Innovation* as a driver could be sustained by the proactive strategy of developing initiatives to enhance resource management, water conservation and innovative renewable energy. Likewise, "*lack of steering mechanism*" could be addressed by the following: (i) establishing a governance framework to encourage greater transparency and responsibility in reporting and communicating sustainable requirements; and (ii) resource usage at the project development and implementation stages.
- The interviewees also recommended for the introduction of new assessment tools and labelling system could promote SC. The rationale being that although current assessment and measurement tools for SC exist, these are too complicated and take a great deal of time. However, support of these sustainability rating tools is quite evident in the literature with [58] arguing the assessment rating tools have strong influence on sustainability awareness and practice within the infrastructure industry. Likewise, some studies have also previously proposed assessment methods for infrastructure sustainability [59]. Finally, the interviewees observed that the adoption of SC requires strong governance structure and management. This is due to the constant control and monitoring not just during the project lifecycle, but also during the usage product and the afterlife.

The above coping strategies are also consistent with the existing literature. For instance, some strategies have been suggested in the literature for delivering sustainable road infrastructure in Europe. For example, Ref. [60] identified and proposed avenues towards more SID, such as green procurement, strategic asset management, and relational contracting. In addition, Ref. [61] recommended developing a methodology for the planning of infrastructure development, incorporating proposals from stakeholders in the sector and integrating the national infrastructure program, as well as a portfolio of strategic investment projects. These can be developed under the criteria of infrastructure, efficiency, economic and social profitability, and regional integration, a formation of global chains of value, competitiveness, productivity, technical, legal, environmental feasibility, financial responsibility, and transparency.

7. Conclusions

The paper highlights the main antecedents (drivers and barriers) influencing the implementation of SID in South Australian construction organisations. Strategies and coping mechanisms are also presented. The motivation for the study arose from the limited studies around the topic within the South Australian context despite the recognition of Australian construction industry that a shift toward a more sustainable country must be inherently underpinned by more of the right infrastructure. Through a mixed methods approach, the results conclude that innovation, standardization of the word 'sustainability', and close interaction of all involved stakeholders are the most critical drivers for SID implementation. The most critical barriers were: lack of steering mechanism; multi-disciplinary nature of the word "sustainability"; and lack of cooperation and networking. Finally, the incorporation of eco-friendly construction materials and re-engineering of the building and maintenance process were among the strategies and coping mechanisms suggested for overcoming the barriers. The correlation analysis further demonstrated the importance of all the drivers in the quest for the SID adoption as evidenced by the positive, stronger and higher correlations amongst all the drivers. To ensure sustainability in the environment through the construction sector, it is important for the government of Australia to increase awareness of sustainability in the construction sector. It is also important to analyse public and private investment scenarios in strategic infrastructure while reviewing the economic and social profitability by sectors and regions, which enhance the integration of economic corridors.

7.1. Recommendations and Practical Implications

The findings of this study provide empirical evidence of the critical drivers and inhibitors to SID adoption, as well as supporting literature. Given the significance and importance of the noted drivers, South Australian construction organisations and practitioners must pay due attention to culturally-related issues and revisit their procurement approaches for the effective adoption of SID. Secondly, the correlation analysis provided evidence that practitioners need to appreciate the potential of SID. For instance, through the strong positive correlation between "innovation" and "standardization of the word sustainability (knowledge improvement)", and between "culture that incorporates sustainability in daily management decisions" and "modern procurement methods", which further indicates a significant linear relationship between the higher correlations of the different pairs of the variables. This further highlights the need to manage sustainability knowledge to improve the understanding and end-results of sustainability during projects' lifecycles.

For policy-makers and government bodies, the higher ranking of innovation as a driver and its positive and strong relationships with other drivers reinforces the need for guidance and incentive mechanism existence to encourage adoption of more sustainable solutions. Likewise, the government should invest in innovative research to discover more innovative designs and building technologies less harmful to the environment. The study makes some significant contributions by providing insights and increased awareness around the drivers and barriers associated with the adoption of SID in a previously under research area. The findings from this study further extends the previous work undertaken by [33], further contributes to the discourse of the most challenging issue in attaining sustainable infrastructure, namely that of the potential difficulty of developing infrastructure that is sustainable economically, socially, and ecological.

7.2. Research Limitations and Areas of Further Research

This study population sample was restricted to only one city and industry in South Australia, namely Adelaide and construction respectively. Consequently, the findings may not generalize to other states and countries or adoption of SID which limits the usage of the findings in the practice of other areas. However, this limitation opens avenues for extending and broadening the scope of this study to states in Australia and using a larger sample size. Second, the interview sample (n = 3) was very limited. However, the quantitative data as engaged had more priority than the qualitative data and as the explanatory sequential design, the intent of this approach is to use the qualitative data to help explain the quantitative results. Moreover, as highlighted by [62], the size of the sample in qualitative research becomes irrelevant since the value of the study is based on the quality of data. However, future studies could employ a large sample size of interviews to further validate these findings. Finally, mechanisms for managing knowledge to promote sustainability in South Australian construction projects should be explored further.

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