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Housing Indicators for Sustainable Cities in Middle-Income Countries through the Residential Urban Environment Recognized Using Single-Family Housing Rating Systems

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Received: 9 July 2019; Accepted: 30 July 2019; Published: 7 August 2019

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Abstract: This study presents a comparative analysis of the housing indicators used by the single-family housing rating systems (SHRSs), in which the residential urban environment (RUE) influences buildings' certification scores, emphasizing the relationships of six systems developed by middle-income countries (MICs)—BEST, CASA, GBI, BERDE, Green Homes, and LOTUS—and the two most-recognized rating systems, BREEAM and LEED. The aim is to provide new housing indicators that are capable of bringing the concept of sustainability into the cities of MICs. The results reveal that the percentage of influence that single-family housing (SFH) can achieve in the metric established by each system is relatively low. However, considering all of the identified indicators, this influence could increase to 53.16% of the total score in multi-criteria evaluations. Furthermore, a significant lack of indicators for mandatory criteria evaluations was found, with CASA being the only system that considers their inclusion. This paper identifies 37 indicators for multi-criteria assessments and two for mandatory-criteria assessments, providing new perspectives on several topics. Furthermore, the methodology established to obtain the indicators could be useful for other researchers in the identification of new sustainable indicators.

Keywords: housing indicators; residential urban environment; rating systems; single-family house; sustainable cities; residential sector; comparative approach; middle-income countries

1. Introduction

1.1. Background and Research Objectives

According to recent estimates, the planet will be populated by over 8.5 billion people in 2030 [1]. Considering the enormous impact of human activity, e.g., climate change and environmental destruction [2–4], as well as the constant trend toward urbanization [5,6], the unavoidable truth is that humanity must face up to the challenge of creating livable and sustainable urban habitats while maintaining and developing cities [7–9].

Housing indicators are resources that make it possible to study the issues and conditions of human settlements, as well as providing the basis for their monitoring [10]. They are also considered as useful resources to help in promulgating sustainable political decisions [6]. It is important to consider these indicators during the planning process of cities because the qualities of residential urban environments (RUEs) can seriously affect their livability [11–15].

Several researchers have recently applied housing indicators in order to achieve or enhance sustainability [16–23]; some of these investigations refer to social housing [17,18,21,22]. Among the indicators that were analyzed are those referring to household vulnerability; these studies found that social housing tends to be inhabited by people with below-average incomes [18,21] who are vulnerable to energy poverty. To solve this issue, Llera-Sastresa proposed a methodological approach based on indicators that improves energy management in social housing [21]. In this sense, Monzón et al. [17] developed a system of indicators to detect multifamily dwellings that have weak energy, acoustic, and accessibility performance. Similarly, Morganti et al. [20] proposed an indicator called building mass, which may contribute to the reduction of energy demand. Other works have proposed social and economic indicators that can help to predict the origin of mortgages as well as housing prices [16]. On the other hand, some researchers have studied indicators for green housing [19,23]. Among these, the most recognized global rating systems (BREEAM, LEED, GBTool, CASBEE) and their implications on sustainability indicators have been evaluated [23].

The relevance of the study of the indicators recognized by rating systems is that these systems, among the plethora of existing instruments used to evaluate building sustainability, have become commonly used in the building industry [24–28]. The flexible framework of these methods makes them receptive to covering more sustainability aspects [29], connecting the neighborhood and community, and thus contextualizing them on a broader scale [30]. One of the virtues of rating systems is their ability to evaluate a wide variety of different indicators as a whole, even though these might have different units of measurement [31]. This makes them a unique method by which to obtain indicators that have been proven in the construction sector in different regions around the world, and which in turn, have the support of experts who have participated in the development of each of the systems.

The comparison of the level of the indicators in rating systems comprises a minor part of the studies carried out in the academic field using a comparative approach [32]. However, this level of detail is recommended to obtain results for a specific aspect [32]. In contrast to other studies that focus on the level of the indicators [33–37], this work has centered on the initial situation of RUEs during the SHRS criteria scoring process. The significance of focusing on the study and acquisition of indicators has been shown in several publications, in which it is argued that the success of any evaluation process depends mostly on the indicators used [31,38–41].

The primary aim of this paper is to identify single-family housing indicators concerning RUE characteristics (SHI^{RUEs}), recognized as green, ecological, or sustainable by the single-family housing rating systems (SHRSs). The objective is that these indicators will be of use to those in charge of configuring RUEs in the pursuit of safer, more inclusive, resilient, and sustainable human settlements in middle-income countries (MICs).

In parallel with the primary aim, it is expected that this study will provide a picture of the current situation in which the SHRSs of MICs consider the impact that RUEs have on a home's classification as green, ecological, or sustainable. Moreover, although the findings are directed toward obtaining useful indicators for MICs, the discussion of the results provides new perspectives about different topics. This may prove helpful for others involved in the development of a SHRS, as well as in carrying out policies related to the residential sector and to single-family housing (SFH).

1.2. Why Address Single-Family Housing of the Middle-Income Countries through the Residential Urban Environment?

In the United Nations Conference on Housing and Sustainable Urban Development (UN-Habitat III), held in Ecuador in October 2016, it was pointed out that "housing has not been appropriately integrated into urban policies in spite of residential land use occupying between 65 and 75 percent of the surface of a city." [42]. This situation is most evident in the MICs, in which the need for the prioritization of these issues has been established in several previous studies [43–48].

One of the main causes of the lack of integration between housing and the RUE is that priority has been given to the search for efficient buildings, instead of providing an environment that integrates both elements [49,50]. This, by analyzing the relationship between the building and the qualities of its immediate environment, can provide strategies to achieve energy efficiency, mitigate greenhouse gases, and improve adaptation to climate change in cities [24,51,52].

Single-family housing (SFH) is the most representative housing type in the MICs and has the most significant environmental impact [53–55]. Furthermore, most housing stock financing is still dedicated to it [56]. According to the World Bank, more than half of the places that will be urbanized by 2030 have not yet been built [57]; it is expected that a significant number of these constructions will be in the MICs [58]. Therefore, the characteristics and configurations that these countries establish as intrinsic to defining sustainable housing (green or ecological housing) will have a decisive impact on the cities since more than 65% of their surface corresponds to the residential sector [42].

Research, such as that of Papargyropoulou et al. [59], suggest that the use of rating systems should be a mandatory requirement in the planning process of the buildings in the MICs. Nevertheless, the findings of this study reveal an urgent need to either redesign the weighting of the SHI^{RUEs} used or to contemplate integrating a more significant quantity. This coincides with the concerns of several international bodies, such as the United Nations and the World Bank, to give priority attention to themes related to how the construction industry comprehends the current and future situation of the RUE in the developing countries.

The features of the SFHs in developing countries will have a significant environmental impact on a global scale, which makes it necessary to establish clear and sustainable criteria for them [60]. Therefore, the significance of this study lies in the search for a way to achieve urban sustainability in the residential sector of MICs; this will be achieved by modifying the current paradigms with which the construction industry evaluates and builds millions of sustainable homes around the world.

2. Research Method

Four processes were developed to obtain housing indicators that would allow the concept of sustainability to be assimilated into the MIC's cities using the characteristics of the RUE. The first defined the rating systems that were used as the basis for the analysis; the second selected the indicators that were the targets of the study; the third obtained the values of each of the chosen indicators; finally, the fourth performed a comparative analysis and obtained the total of the SHI^{RUEs} with their respective descriptions and influence percentage ranges.

2.1. Definition of the Rating Systems

The definition of a SHRS considered those that are recognized by both the construction industry and the academic sector (Figure 1). The SHRSs were obtained from two independent processes. On the one hand, six systems were identified from the analysis of the 52 green building rating systems (GBRSs) recognized by the World Green Building Council (Figure 1a; [61]); on the other hand, a systematic review was carried out in which five systems were identified from the analysis of 226 articles published in journals indexed in Scopus (Figure 1b).

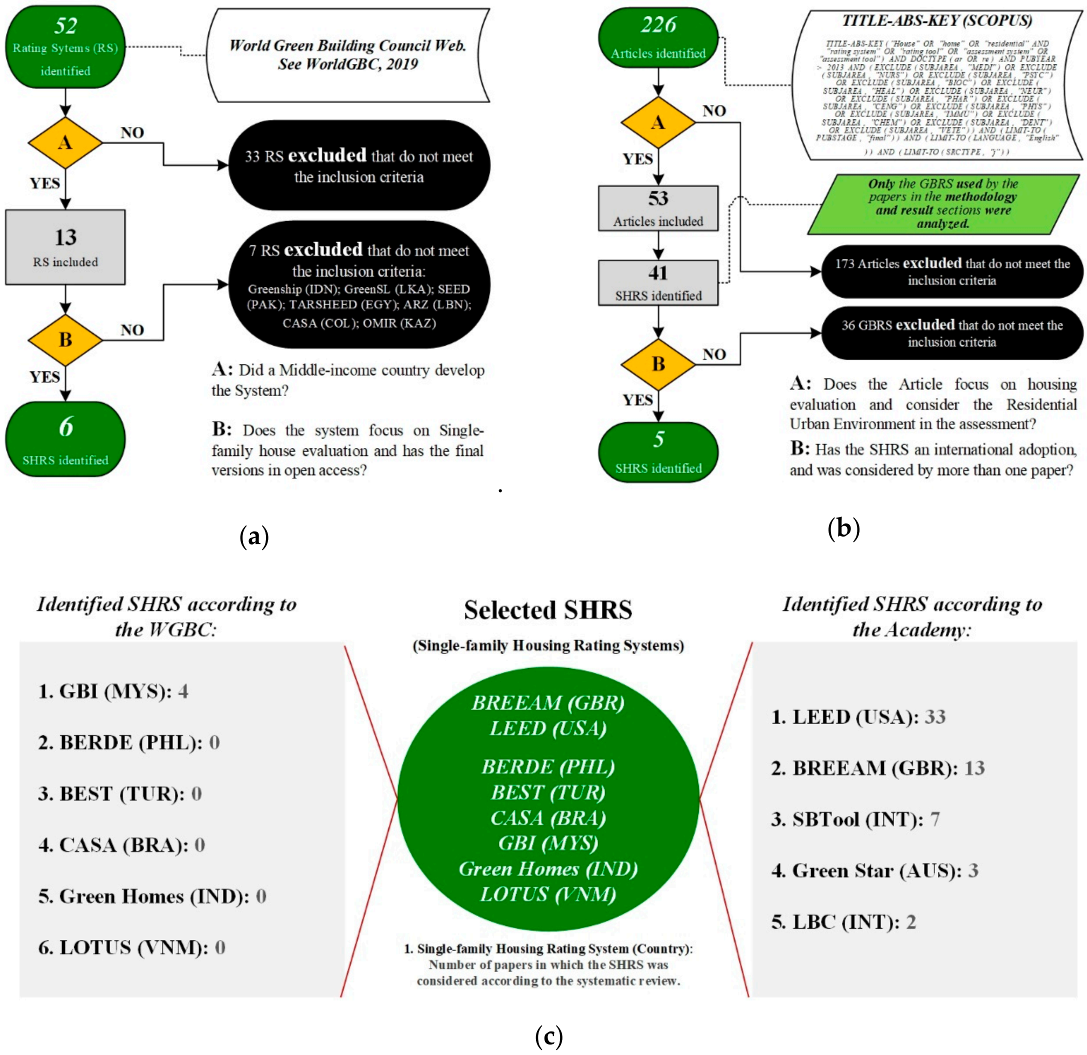


Figure 1. Flowchart of the single-family housing rating systems (SHRSs) definition: (**a**) the SHRSs identification by a decisive hierarchical process according to the systems identified by The World Green Building Council, (**b**) the identification of the SHRSs with an international adoption through a systematic review, and (**c**) definition of the SHRSs.

The rating systems' definition process shows the significance of LEED and BREEAM as the most recognized schemes in the academic sector (Figure 1), which is in accordance with what has been shown by various studies [26,32,62,63]. Likewise, researchers show a clear lack of interest in the SHRSs developed by the MICs, given that just 7.5% of the studies analyzed in the systematic review only considered the GBI rating system [37,60,64,65].

The analyzed versions of each of the SHRSs correspond to those currently used by the construction industry (Table 1). Here, it is possible to identify three classes of systems: (i) those developed by a high-income country (HIC) with an international adoption, (ii) those developed by an upper-middle-income country (UMC) with a national adoption, and (iii) those developed by a lower-middle-income country (LMC) with a national adoption.

The SHRSs selected include contexts drawn from different regions of the planet; the East Asia and Pacific region show greater representativeness in this study with the consideration of the systems developed in Malaysia, Philippines, and Vietnam (Table 1). Moreover, the consideration of BERDE, BEST, CASA, Green Homes, and LOTUS provides added value to this work because they can be studied as a novel contribution to the knowledge in this subject developed thus far (Figure 1c).

Table 1. Description of the SHRSs.

SHRS	Version–Year	Country–Income Level	Adoption	Scoring: Rating System
BREEAM	SD233 2.0–2016 [A]	United Kingdom (GBR)–HIC	International	**% Score**: Pass (≥ 30), Good (≥ 45), Very good (≥ 55), Excellent (≥ 70), Outstanding (≥ 85).
LEED	V4 BD+C–2013	United States (USA)–HIC	International	**Points**: Certified (40–49), Silver (50–59), Gold (60–79), Platinum (80+).
BEST	1.0–2018	Turkey (TUR)–UMC	National	**Points**: Approved (45–64), Good (65–79), Very good (80–99), Excellent (100).
CASA	CASA–2017	Brazil (BRA)–UMC	National	**Points**: Certified (40–49), Silver (50–59), Gold (60–79), Platinum (80+).
GBI	RNC 3.1–2014	Malaysia (MYS)–UMC	National	**Points**: Certified (50–65), Silver (66–75), Gold (76–85), Platinum (86+).
BERDE	NC 2.2.0–2018	Philippines (PHL)–LMC	National	**Stars**: 1 Star (51–60 points), 2 Star (61–70 points), 3 Star (71–80 points), 4 Star (81–90 points), 5 Star (91+ points).
Green Homes	2.0–2012 [B]	India (IND)–LMC	National	**Points**: Certified (38–44), Silver (45–51), Gold (52–59), Platinum (60–75).
LOTUS	Homes V1–2017	Vietnam (VNM)–LMC	National	**Points**: Certified (32–43), Silver (44–51), Gold (52–59), Platinum (60+).

References: [66–73]. [A] Only "partially fitted" was considered. [B] Includes Addendum of October 2016 and January 2014 [74,75].

2.2. Selection of the Single-Family Housing Indicators That Focuses on the Residential Urban Environment

The chosen indicators (SHI^{RUEs}) correspond to those showing incidences in specific areas of the RUE around the SFH, i.e., in all the indicators in which the characteristics of the urban environment enable the housing to obtain a specific score. On the other hand, the analysis excluded all those indicators in which the required compliance criteria are performed in the private space of the dwelling, or in which there is a possibility of compliance through some activity carried out in the residence. The selection process is described in Figure 2, which ends with the consideration of four types of indicators: (i) $SHOCI^{RUEentirely}$; (ii) $SHOCI^{RUEpartially}$; (iii) $SHMCI^{RUEentirely}$; and (iv) $SHMCI^{RUEpartially}$.

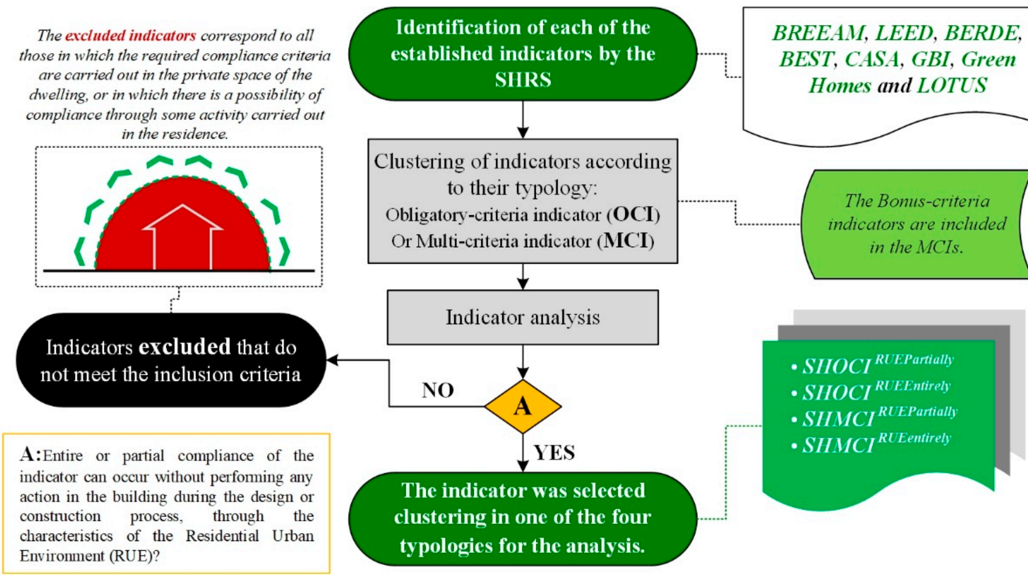


Figure 2. Flowchart of the selection of the SHI^{RUEs}.

The severance of the obligatory-criteria indicators (OCI) and the multi-criteria indicators (MCI) has been carried out in previous studies [60,76,77]. These showed that one of the advantages of following this process is that it produces results that refer directly to the green or sustainable characteristics considered intrinsic to each GBRT, while also allowing the analysis of the dispensable features without any constraints.

The determination of the partial and entire typologies was made because there are a considerable number of indicators in which only some of their compliance criteria focus on the qualities of the RUE. Likewise, there are also indicators in which all of their compliance criteria are related to the urban environment that surrounds the home.

2.3. Obtainment of the Values of the SHI^{RUEs}

The current range of SHRSs allows the evaluation schemes to be adapted to their respective contexts; however, this complicates the comparative analysis of the different methodologies [78]. To overcome this impediment, this paper proposes the extraction of the corresponding values for each of the $SHOCI^{RUE}$ and $SHMCI^{RUE}$.

To obtain the values that each SHRS assigns to each type of SHI^{RUE} in relation to the other indicators, two equations are studied (Equations (1) and (2)), both in the $SHOCI^{RUEs}$ and in the $SHMCI^{RUEs}$:

$$SHI^{RUE_{entirely}} = \left(I^{Max}/C^{Max}\right) \times WC^{I} \quad (1)$$

where I^{Max} is the maximum value assigned to the indicator by the SHRSs; C^{Max} is the maximum value assigned to the category in which the indicator is located; and WC^{I} is the weight of the category in which the indicator is located.

$$SHI^{RUE_{partially}} = \left(SHI^{RUE_{entirely}}/IR^{Total}\right) \times IR^{RUE} \quad (2)$$

where IR^{Total} is the total number of requirements established by the SHRS for the compliance of the indicator and IR^{RUE} is the number of requirements that can be met through the RUE.

Regarding the WC^{I} of each indicator, the one defined by each SHRS was used, except in those cases where the tool did not specify the weighting of each category; in this case, the values were obtained through Equation (3):

$$WC^{I} = C^{Max}/\sum C^{Max} \quad (3)$$

During the score obtainment process, all of the $SHOCI^{RUEs}$ were considered to have a value of one. Moreover, only 50% of the value of the indicators was considered in cases in which the SHI^{RUEs} showed criteria that the house must necessarily meet in conjunction with the RUE (these indicators were considered as $SHI^{RUEpartially}$), e.g., materials, where the RUE is required to have an infrastructure capable of providing a defined percentage of the dwelling. Additionally, some consideration was given to the different rating systems, as specified in Table 2.

Table 2. Considerations made in the selected SHRS.

SHRS	Special Considerations
BREEAM	BREEAM allows the weights of each category to differ regarding the location of the home in which the certification is to be made. Therefore, to obtain a quantitative analysis with the least possible bias, all the WC^{I}s were obtained using Equation (3). On the other hand, the OCIs vary according to the rating level desired; however, for this analysis, those required for a "pass" level were addressed. In addition, the $SHMCI^{RUEs}$ indicated in the innovation category were considered to be independent of the categories to which they refer to respect the weight that should correspond to them.
LEED	The point floors were discarded.
BERDE	The four OCIs presented by this tool are located in the categories of management (MN), and use of land and ecology (LE). In the MN category, the OCIs were located in the commitment to sharing resource data, and compliance with building and environmental laws, regulations, and mandatory standards. The other two OCIs were located in the LE category: distinct and clear boundaries, and initial site assessment. Finally, each OCI was considered with a value of 0.25.
BEST	The available points in Table 1 (see Reference [68]) were considered to obtain the maximum values granted by the SHRS for each indicator.
LOTUS	The categories of innovation (INN) and best practice credits (BPC) were discarded, both in the OCIs and in the MCIs, because the tool does not consider a specific weight for this category.

Note: There are no special considerations in the SHRS: CASA, GBI, and Green Homes.

Obtaining the values of each SHI^{RUE} makes it possible to ascertain the maximum influence that the RUE has on each rating system (through quantitative data); this, in turn, allows the comparative analysis of the different systems to be carried out.

2.4. Comparative Analysis and Description of the SHI^{RUEs} Identified

Li et al. [32] state that there are four levels of comparison among the rating systems: (i) general, (ii) category, (iii) criterion (sub-category), and (iv) indicator. This work focuses on the comparative analysis corresponding to level four. In this case, the criteria established by the systems are compared in each of the indicators, obtaining both the existing relationships between the different schemes, as well as those indicators of exclusive consideration by each of the systems, allowing new indicators to be identified and described.

The establishment of relationships among the rating systems means that any discussion of the results must involve a certain amount of complexity and subjectivity [79]; this uncertainty may be reduced by applying a criteria normalization process [24,60,80], which consists of reorganizing the selected indicators into new macro-areas (NMAs).

The process of clustering the indicators into the NMAs was based on the relationships between the SHRSs concerning the categories in which the SHI^{RUEs} were identified. Once the indicators have been relocated in the NMAs, it was possible to discern their relationships, as well as to see the peculiarities that each SHRS establishes in its evaluation methodology.

Once the relationships were established between the SHI^{RUEs} located in each NMA presented by each system, the maximum and minimum percentages of influence of each indicator were obtained. Additionally, the schemes that establish more rigorous compliance criteria were identified, as well as the more accessible compliance criteria.

3. Results and Discussion

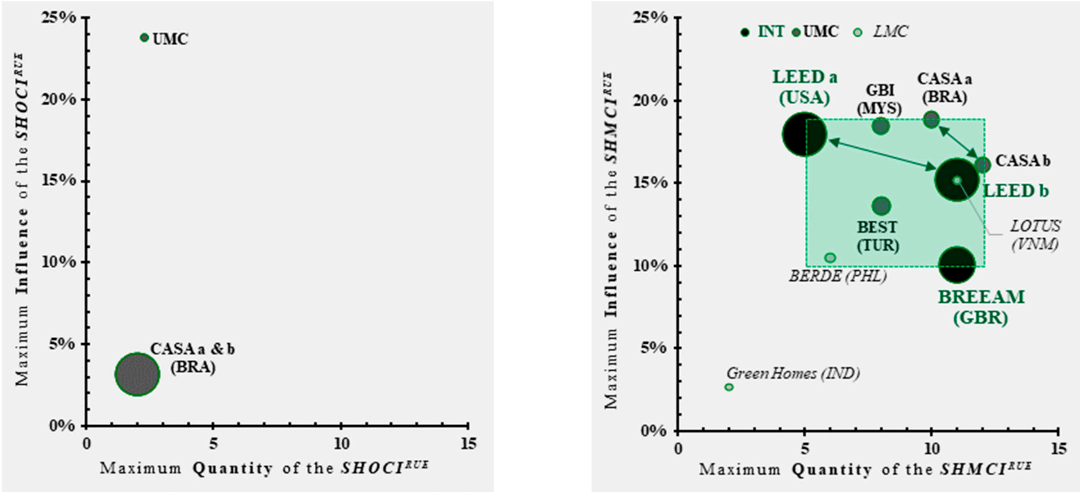
The results and their discussion are presented in two sections: First, it shows the current situation of the conception that rating systems have of the RUE that surrounds the SFH, as well as the similarities and divergences among the systems. Second, it presents the identified indicators and their integration possibilities in the MICs, outlining the advantages that their use would have for these countries.

3.1. The RUE Recognized by the SHRSs: Their Influence and Relationships among the Schemes

This study notes that the urban environment recognized by the SHRSs needs to be addressed in a better way to provide housing that allows the sustainability of cities in the MICs to be improved. Based on each rating system's own scheme, the maximum percentage of the RUE influence on the score of the housing varies according to the SHRS used. However, it is possible to establish a significant absence of the $SHOCI^{RUEs}$ among the rating systems, with CASA being the only system that considers the inclusion of this type of indicator, with a maximum influence of 3.15%. Furthermore, the study shows that none of the systems analyzed could achieve more than 18.86%, referring to the $SHMCI^{RUEs}$ (Figure 3).

Among the peculiarities of the SHRSs selected, LEED and CASA gave two paths to follow (performance—a, prescriptive—b); therefore, both scenarios were considered within the comparative analysis to reduce the sensitivity and uncertainty.

Table 3 shows the distribution of the indicators according to each of the typologies considered. It was found that the type corresponding to the $SHI^{RUEentirely}$ provides the most weight to the maximum percentage of influence. However, there are tools in which this does not occur. In CASA, the $SHOCI^{RUEpartially}$ were the only indicators; in LOTUS, the $SHMCI^{RUEpartially}$ made up more than double the value of the $SHMCI^{RUEentirely}$; in Green Homes, the percentages between both types of $SHMCI^{RUEs}$ were equal. This highlights the weakness of the SHRSs of some MICs concerning the consideration of the RUE.



(**a**) (**b**)

Figure 3. Maximum influence and quantities according to the single-family housing indicators concerning RUE characteristics (SHI^{RUEs}) identified on the SHRS: (**a**) results according to the SHOCI^{RUEs}, and (**b**) results according to the SHMCI^{RUEs}. The size of the points corresponds to the GNI per capita [81] of the country in which the system was developed.

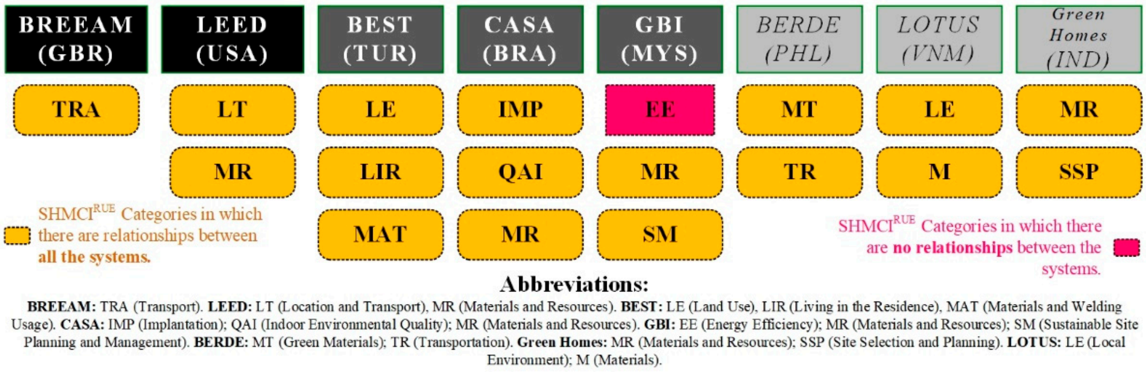
Table 3. Quantity and weight of the SHI^{RUE} identified in the SHRSs.

SHRS	Adoption	*SHOCI^{RUEpartially}*		*SHMCI^{RUEpartially}*		*SHMCI^{RUEentirely}*	
		Qty.	% *	Qty.	% *	Qty.	% *
BREEAM	International	-	-	6	2.25	5	7.81
LEED (a)		-	-	1	0.68	4	17.27
LEED (b)		-	-	1	0.68	10	14.55
BEST	National in a UMC	-	-	3	3.64	5	10.00
CASA (a)		2	3.15	6	4.32	4	14.55
CASA (b)		2	3.15	6	4.32	6	11.82
GBI		-	-	2	1.50	6	17.00
BERDE	National in an LMC	-	-	2	2.50	4	8.00
Green Homes		-	-	1	1.33	1	1.33
LOTUS		-	-	8	10.19	3	5.00

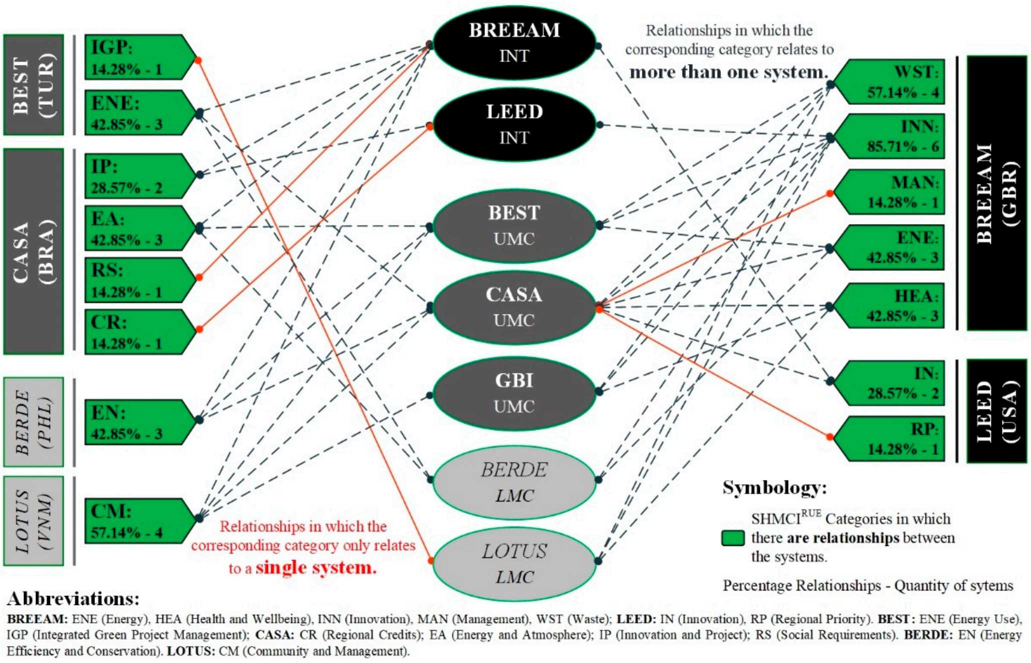
* Maximum percentage of influence that can be achieved with the compliance of the indicators. (a) and (b) refer to the performance and prescriptive paths, respectively.

Among the SHRSs developed by a MIC, CASA stands out as the only system that considers both SHOCI^{RUEs} and SHMCI^{RUEs}. This may be a reflection of the practices implemented in Brazil in recent years, especially in social housing projects [22], where dwellings that have obtained more sustainable labeling have shown a high correlation of compliance with indicators related to urban quality [77]. In contrast to CASA, Green Homes was a system in which the RUE exerts the least influence on the housing score assigned for obtaining certification. This was possibly due to there being 0.23 accredited planners per 100,000 people in India [42], so the priorities of the residential sector can be unintentionally directed toward other areas. The aforementioned is of the utmost importance because India is considered one of the three countries where the highest world population growth will occur during the next 30 years [58].

Regarding the relationships among the SHRSs, most of the systems consider the categories associated with location, materials, and transport (Figure 4a). Moreover, most of the SHRSs exhibit more categories related to two or more systems than categories that are related to one or no systems (Figure 4b). Additionally, Figure 4 exhibits the case of GBI, which possessed the only category without any relationship with another system.



(a)



(**b**)

Figure 4. Relations between the categories established by each SHRS and the remaining systems: (**a**) categories in which there are relationships between all systems and in which there are no relationships, and (**b**) categories in which there are relationships between the systems.

Each of the SHRSs has its own conception about how the urban environment impacts the labeling of housing and its maximum influence on the score; despite this, performing the normalization criteria process (NCP) allowed the identified indicators to be clustered into six new macro-areas (Figure 5): energy (ENE), innovation (INN), location (LCT), materials (MAT), transport (TRA), and waste (WST).

The clustering of the SHI$^{\mathrm{RUEs}}$ into the NMAs (Figure 6) shows that BREEAM and CASA (b) included all the NMAs proposed, and Green Homes was the system with the lowest inclusion of the areas, considering only LCT and MAT. On the other hand, the percentages of distribution among the NMAs shown by each system varied significantly, with LEED (b) and BEST, and GBI and BERDE, being the rating systems that showed a closer distribution.

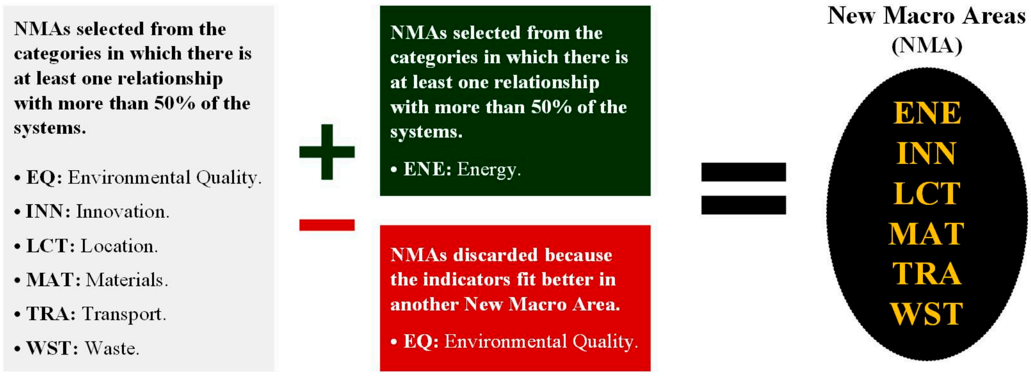


Figure 5. Scheme of the normalization criteria process (NCP).

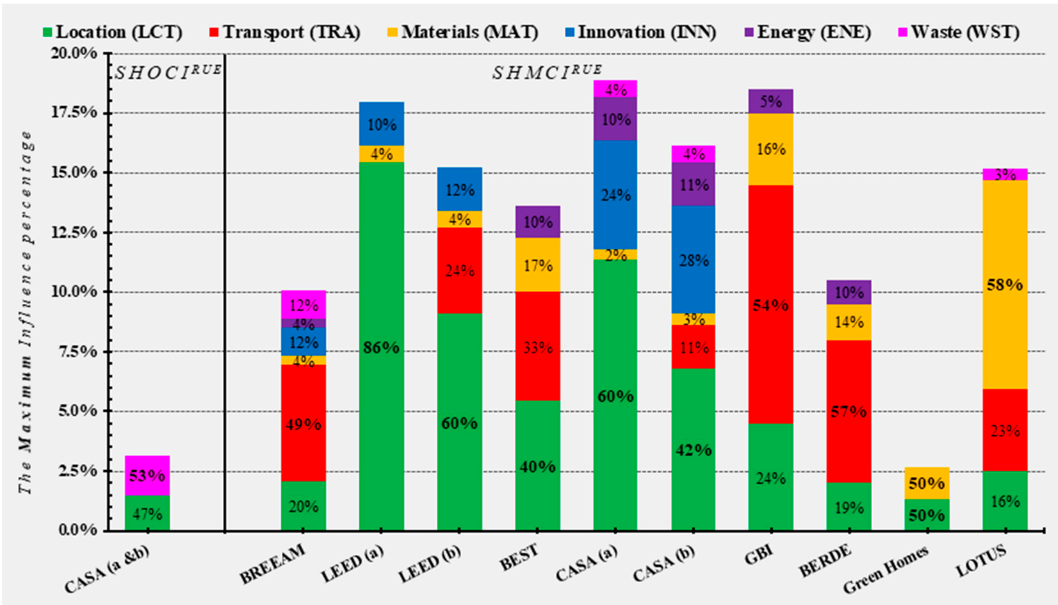
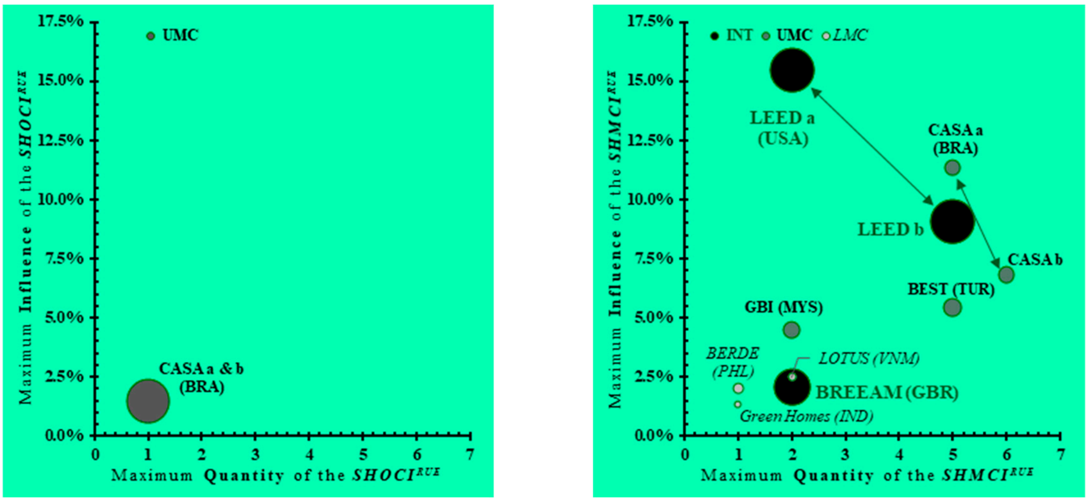


Figure 6. Maximum influence of the SHI^{RUEs} and their distribution according to each NMA.

In Figure 6, ENE, INN, and WST have the lowest percentage of representation among the SHRSs. However, their consideration as NMA allowed for valuable information for the objectives of the study to be obtained: (i) In the case of ENE, several researchers have pointed out that there is a bias toward assigning a high weight to categories that promote energy efficiency in housing [32,33,82,83]. Despite this, in the SHMCI^{RUEs}, only 63% of the systems considered them while emphasizing 100% of the tools developed by a UMC. (ii) Only BREEAM and LEED considered INN with a representativity of more than 10%. Furthermore, except for CASA, no system developed by an MIC contemplated the consideration of INN. (iii) The case of WST was unusual, as it was the second NMA that contained SHOCI^{RUEs}, but concerning the SHMCI^{RUEs}, only three of the eight systems recognized it as NMA, with values lower than 4% in CASA and LOTUS, and 12% in BREEAM.

Concerning the NMA of LCT, it is noteworthy that only CASA recognizes the SHOCI^{RUEs} (Figure 7). Therefore, an analysis of the possible reasons for this situation could be addressed in future research. Moreover, despite the acceptance of this NMA by the different systems, the difficulty of finding correlations between them was evident.



(**a**) (**b**)

Figure 7. Maximum influence and quantities according to the SHI$^{\text{RUEs}}$ identified in the SHRS, according to LCT: (**a**) results according to the SHOCI$^{\text{RUEs}}$, and (**b**) results according to the SHMCI$^{\text{RUEs}}$. The size of the points corresponds to the GNI per capita [81] of the country in which the system was developed.

TRA is another NMA in which all systems consider SHMCI$^{\text{RUEs}}$; however, LEED (a), CASA (a), and Green Homes assess the inclusion, as optional compliance criteria of amenities in the area of LCT [69,70,72]. In this NMA, GBI stood out as the rating system with the highest influence percentage, while CASA (b) showed the lowest rates (Figure 8). Moreover, three indicators were the most studied quantities by the SHRSs. Additionally, a linear behavior was seen in the quantity–influence relation between the systems developed by the MICs.

Referring to the most significant NMAs: MAT could also be regarded as a relevant NMA, given that it was considered in all of the systems, although only by the SHMCI$^{\text{RUEs}}$ (Figure 9). In this NMA, both the quantities and the percentages of influence presented in each system differed considerably; however, it was noticeable that LOTUS had a more significant influence and number of indicators, showing values very different from those of the other SHRSs; GBI and BEST also had higher figures, with two indicators each and percentages from 2.27% to 3.00%. Additionally, the results showed a group in which all systems had only one indicator, but the rates of influence varied from 0.39% to 1.50%.

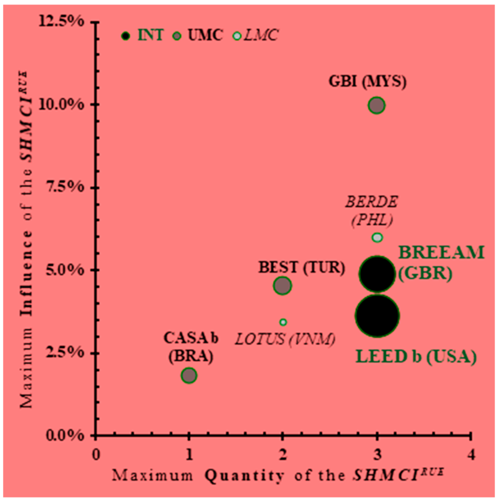
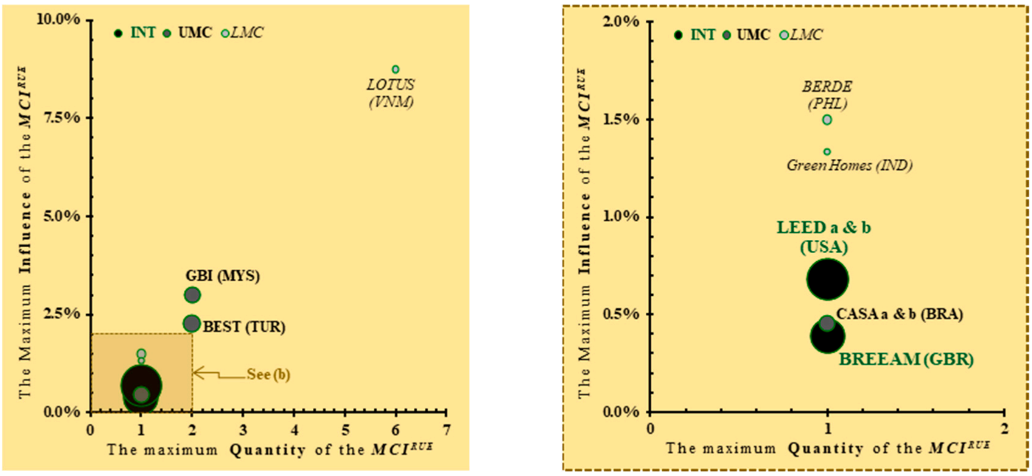


Figure 8. Maximum influence and quantities according to the SHMCI$^{\text{RUEs}}$ identified on the SHRS, according to TRA. The size of the points corresponds to the GNI per capita [81] of the country in which the system was developed.



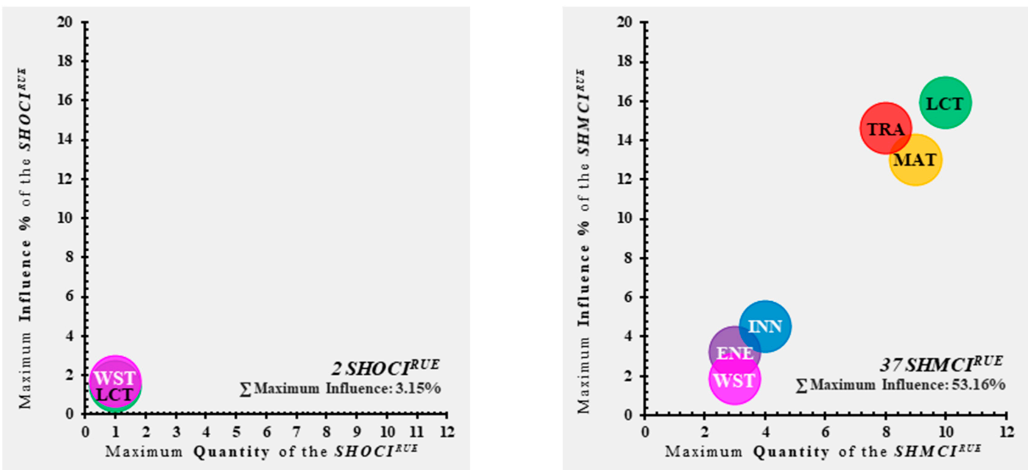
(**a**) (**b**)

Figure 9. Maximum influence and quantities according to the SHMCI^{RUEs} identified on the SHRS, according to MAT: (**a**) results according to the SHMCI^{RUEs}, and (**b**) zoom of the SHMCI^{RUEs}. The size of the points corresponds to the GNI per capita [81] of the country in which the system was developed.

Finally, the fact that LCT and TRA were positioned as the NMAs where most of the SHRSs fit a higher distribution percentage, reaching 70% or more in the BREEAM, LEED (b), GBI, and BERDE rating systems (Figure 6), this could be considered understandable in terms of the urban environment. However, the consideration of ENE, INN, MAT, and WST validated the importance of carrying out detailed comparative analyses of the compliance criteria of the indicators between different rating systems.

3.2. The SHI^{RUEs} Identified for Sustainable Cities in the Middle-Income Countries

A total of 39 SHI^{RUEs} were identified to provide the broadest possible range of solutions to the concerns regarding the RUE of the MICs. In these indicators, a maximum influence percentage of 3.15% could be achieved in the case of the SHOCI^{RUEs}, and up to 53.16% in the SHMCI^{RUEs} (Figure 10). Furthermore, if the maximum percentage that could be reached by a system in the multi-criteria evaluation was from 2.67% in Green Homes (Figure 3), the consideration of the SHI^{RUEs} and their maximum influence percentage could result in an increase up to 50.49% in the multi-criteria indicators.



(**a**) (**b**)

Figure 10. Maximum influence and quantities according to the SHI^{RUEs} identified on the NMAs: (**a**) results according to the SHOCI^{RUEs}, and (**b**) results according to the SHMCI^{RUEs}.

The next sections provide an explanation of the 39 SHI^{RUEs} identified concerning the SHOCI^{RUEs} and the SHMCI^{RUEs}.

3.2.1. The SHOCI^{RUEs} Identified for Sustainable Cities in the Middle-Income Countries

As mentioned in previous sections, the identification of the SHOCI^{RUEs} showed the null consideration that most systems had in their schemes, in which it was only possible to identify two indicators (Figure 8a). This nullity opens a new horizon in the academic field that allows for improvement in both the quantity and quality of these indicators. On the other hand, it is also striking that only the NMAs of LCT and WST were considered. In this study, it was only possible to identify two SHOCI^{RUEs}, provided by CASA (Table 4).

Table 4. Description of the SHOCI^{RUEs}.

Indicator	Influence (%)	The Influence Percentage Is Obtained When the Urban Environment:
1. Water Systems	1.47	Has an infrastructure network from which the house can be fed (sewage treatment and water supply network).
2. Waste Management	1.68	Has market agents that act in the reception of waste and waste transporters that comply with the operational requirements established in laws and regulations.

Reference: [70].

At present, increasing pressure exists worldwide for the achievement of the sustainable use of surface water resources [84]. Moreover, in developing countries, water efficiency is considered a critical issue [83]. Since, as Narain and Singh stated [85], in countries such as India, some inhabitants have difficulty accessing water, any SHRS adopted in the MICs should consider the indicator of the "water systems" as an OCI in its evaluation methodology.

On the other hand, the identification of the "waste management" indicator should also be considered by other SHRSs. This is consistent with another study [37], which shows that issues related to waste management require more attention from rating systems; most systems can omit the use of this indicator, as very few consider it to be an aspect of mandatory compliance. Additionally, waste management has a significant impact on the sustainability of a city [86]. Nguyen et al. [46] state that the MICs must seek to achieve coordination among the stakeholders, market agencies, and local communities to enhance the sustainable qualities of the cities, as also indicated by CASA [70].

3.2.2. The SHMCI^{RUEs} Identified for Sustainable Cities in the Middle-Income Countries

This study demonstrated that 31 of the 37 SHMCI^{RUEs} identified were in the range of 0.2% to 1.0% relative to the minimum influence, and 0.2% to 2.0% concerning the maximum influence that each indicator can attain in the labeling of a house (Figure 11). This insignificance in terms of influence can be considered a reflection of the concerns shown by the New Urban Agenda regarding the lack of housing integration in the countries' urban policies [42].

Future research should address the indicators that have a low percentage of influence in order to better understand the implications that the increase in these percentages could have on the sustainability of cities, as well as on the configuration of SFH (Figure 11b).

The description of the indicators is as follows: (i) the "certified neighborhood" indicator, (ii) the SHMCI^{RUEs} that are considered by all SHRSs, (iii) the SHMCI^{RUEs} that are particular to a single system, (iv) the SHMCI^{RUEs} considered by two SHRSs, and (v) the SHMCI^{RUEs} considered by three and five SHRSs.

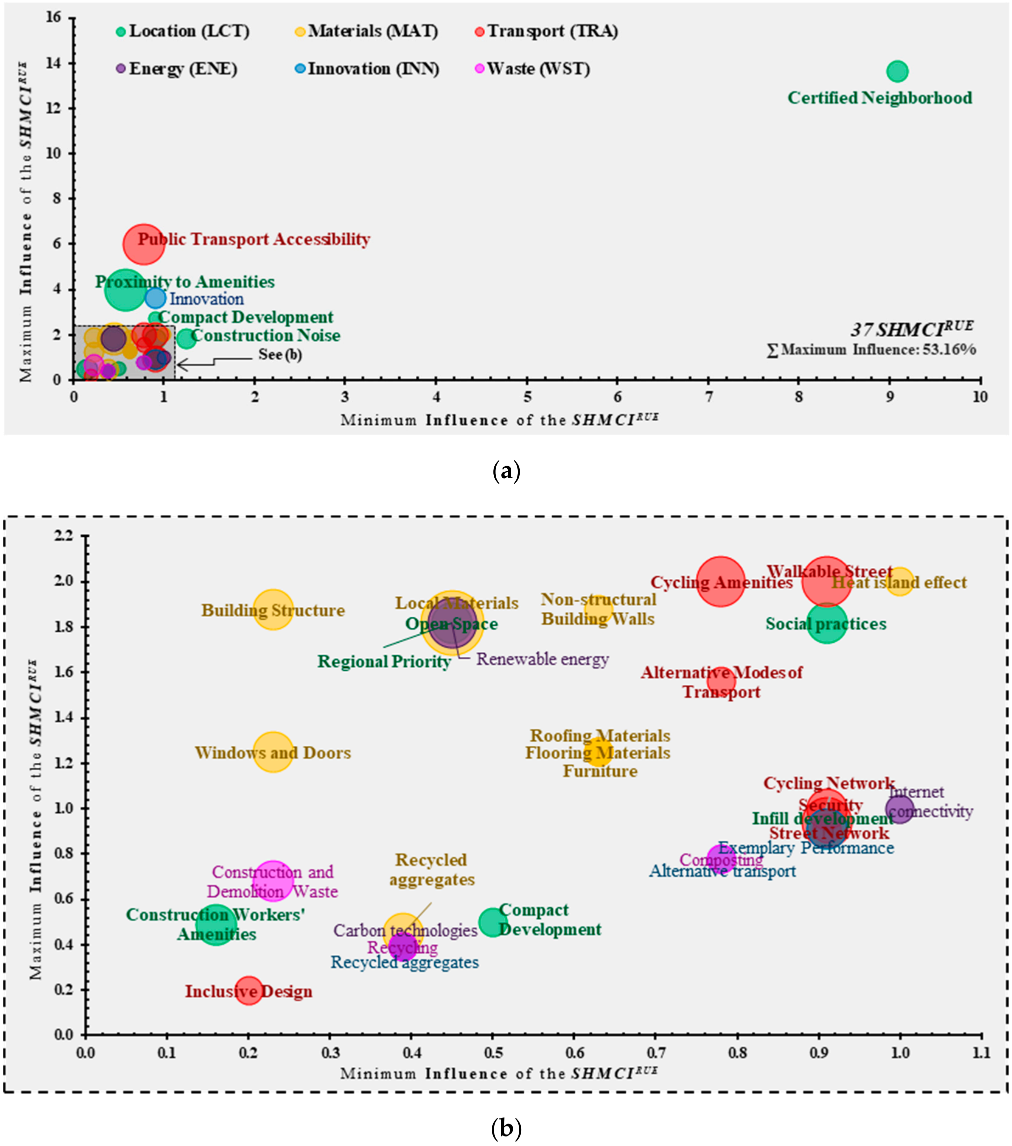


Figure 11. SHMCI^{RUEs} identified: (**a**) full picture of the SHMCI^{RUEs} identified, and (**b**) zoom of the SHMCI^{RUEs}. The size of the points corresponds to the quantity of SHRSs that consider the indicator.

The SHMCI^{RUE}: Certified Neighborhood

Certified neighborhood is the indicator that had the highest influence percentages, and was widely differentiated from the other indicators (Figure 11a). This indicator was only contemplated by LEED and CASA, with CASA being the system that presents the most considerable flexibility in terms of compliance, but at the same time, its influence percentage was 4.55% lower than the percentage that could be obtained in LEED (Table 5).

Table 5. Description of the "certified neighborhood" indicator.

Considered by:	Influence (%)	The Influence Percentage Is Obtained When the Urban Environment:
LEED	13.64	Complies with LEED certification for neighborhood development.
CASA	9.09	Complies with an environmental certification from a recognized certification body, such as AQUA-HQE Districts and Lots, LEED-ND, BREEAM Communities or SITES.

References: [69,70].

It is plausible that a home located in a certified development must comply with the majority of the criteria indicated by the rest of the SHI^{RUEs}. However, several investigations [87,88] point out that neighborhoods that have both certifications (such as the systems responsible for labeling the neighborhoods of the MICs) were not fully engaged with sustainable practices, especially in the case of social and affordable housing.

The SHMCI^{RUEs} Considered by All SHRSs

Only two SHMCI^{RUEs} are considered by all SHRSs: "public transport accessibility" and "proximity to amenities." This indicates that even though the criteria among the systems varied concerning the needs of each country or region, these two indicators had universal applicability among the SHRSs. In these indicators, there were significant differences in the percentile ranges of the influence that each system considered in its evaluation methodology (Figure 11).

Except for LEED, CASA, and Green Homes, the other SHRSs considered that "public transport accessibility" is an indicator that generates better sustainable conditions for housing, because this indicator had more significant influence percentages (Figure 12); in LEED, the rates between both indicators were equivalent, while CASA and Green Homes valued the inclusion of this indicator among the amenities of an SFH. On the other hand, each system's conception of the compliance criteria also varied significantly between the systems (Tables 6 and 7).

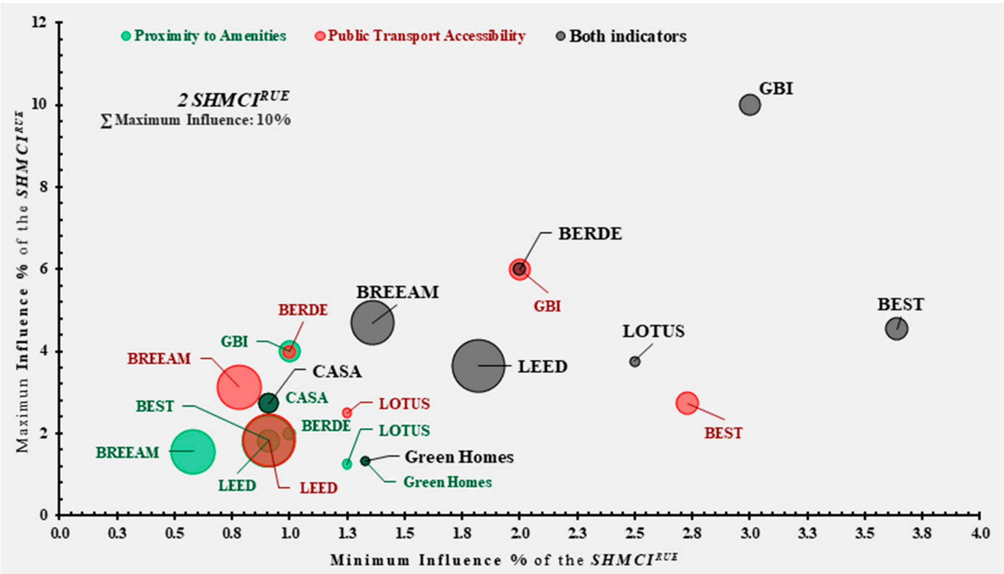


Figure 12. SHMCI^{RUEs} considered by all SHRSs. The size of the points corresponds to the sum of the GNI per capita [81] of the countries in which the systems were developed.

One of the principal hypotheses that motivated this study was that it is necessary to view housing as an essential part in the development of communities [89]. In order to achieve a residential sector that contributes to increasing the livability of cities and to fit this hypothesis in the MICs, one of the main steps is that the process of urban planning and decision-making needs to establish a cross-relation between the availability of their amenities [90] and their public transport [34,91]. All the SHRSs understand the above, given that all consider the proximity of urban amenities and public transport to the house (Table 7). Nevertheless, the definition and compliance criteria of both indicators are extremely different in each of the SHRSs. Future research could focus on the description of which facilities and types of public transport, as well as their quantity, connectivity, and accessibility, are essential for consideration in a sustainable house. Additionally, the analysis of the inclusion of these indicators and their possible implications in obligatory-criteria assessment could be a significant step in assimilating sustainability into the cities of the MICs.

Table 6. Description of the "public transport accessibility" indicator.

Considered by:	Influence (%)	The Influence Percentage Is Obtained When the Urban Environment:
BREEAM	0.78–3.13	Has a public transport accessibility index (AI) for the assessed SFH ≥ 0.5, 1, 2, or 4.
LEED	0.91–1.82	Has a bus or streetcar stop within 400 m walking distance from the SFH or bus rapid transit stops, light or heavy rail stations, or ferry terminals within 800 m walking distance. With a transit service that meets the minimum daily transit service for projects with multiple transit types; weekday trips = 72, 144, or 360; weekend trips = 40, 108, or 216; or minimum daily transit service for projects with commuter rail or ferry service only: weekday trips = 24, 40, or 60.
BEST	2.73	Has a public transportation point within 500 m from the SFH.
GBI	2.00–6.00	Has public transport stop with one route within 500 m from the SFH; and/or has public transport interchange with same mode of transport with more than one route, within 750 m from the SFH; and/or has a public transport interchange with more than one mode of transport (e.g., bus, monorail, train, ferry, etc.), within 1 km from the SFH.
BERDE	1.00–4.00	Has one or two public transport services: existing or currently planned funded commuter rail or light rail within 500 m walking distance; a bus stop for at least two public, campus, or private bus lines within 500 m walking distance; stop for at least two Asian utility vehicle (AUV) or public utility vehicle (PUV) routes within 250 m walking distance; shuttle service provided for the users from the SFH to any public transportation stops or stations; and/or has one or two appropriate transport amenities, which may include: covered walkways connecting the building entrances to transport waiting areas, covered waiting areas for public utility vehicle (PUV), terminals for PUVs and Asian utility vehicles (AUVs), and stations for public transportation routes accessible to the users of the project.
LOTUS	1.25–2.50	Has a mass transit services within 400 or 800 m from the SFH.

References: [66–69,71,73].

Table 7. Description of the "proximity to amenities" indicator.

Considered by:	Influence (%)	The Influence Percentage Is Obtained When the Urban Environment:
BREEAM	0.58–1.56	Provides at least four amenities in a proximity of 500 m from the SFH; and/or provides at least seven amenities in a proximity of 1000 m to the SFH.
LEED	0.91–1.82	Has 4–7, 8–11, or more than 12 uses within an 800 m walking distance from the building entrance.
BEST	0.91–1.82	Has at least four or eight facilities within a 500 m walking distance.
CASA	0.91–2.73	Has 4, 7, or 11 basic community resources within 500 m; and/or has 7, 11, or 14 basic community resources within 1 km; and/or has transport services with at least 30, 60, or 125 trips per day of the week within 1 km from the SFH.
GBI	1.00–4.00	Has three or six amenities within 750 m from the SFH; and/or has another three or six different amenities within 750 m from the SFH.
BERDE	1.00–2.00	Has 5–9 or 10 key establishments, within a 250-meter radius from the SFH.
Green Homes	1.33	Has at least five basic house-hold amenities within a walking distance of 1 km from the SFH.
LOTUS	1.25	Has at least five different types of basic services within a 0.5 km radius from the SFH.

References: [66–73].

Exclusive SHMCI$^{\mathrm{RUEs}}$ between the SHRSs

Among the indicators found, 16 of the 37 SHMCI$^{\mathrm{RUEs}}$ were exclusive to LEED, BREEAM, GBI, or LOTUS (Figure 13), where BREEAM had higher quantities and LOTUS had the highest percentage of influence (8.75%). Moreover, "compact development" was the indicator that had the highest influence ranges; however, its consideration among MICs should be carefully considered. Hodson et al. [92] show different points of view within the scientific field for the consideration of this indicator.

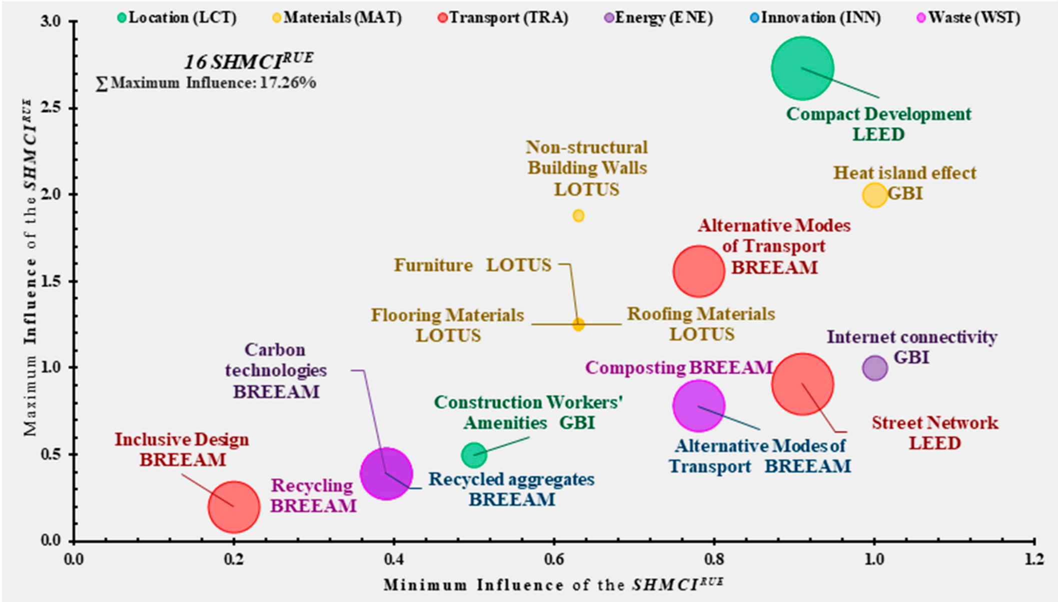


Figure 13. Exclusive SHMCI$^{\text{RUEs}}$ identified. The size of the points corresponds to the sum of the GNI per capita [81] of the countries in which the systems were developed.

Table 8 shows the description of every SHIMCI$^{\text{RUE}}$. Similarly, in the case of indicators 3 and 14, it is notable that they have the same name, but were considered separately, because BREEAM performs this same differentiation based on the rigor established between their compliance criteria [67]. Finally, any of these indicators could be accepted as innovation criteria in any system that uses this category, such as LEED and CASA [69,70].

Table 8. Description of the exclusive SHMCI$^{\text{RUEs}}$ between the SHRSs.

Indicator	NMA: Influence (%)	The Influence Percentage Is Obtained When the Urban Environment:
1. Carbon Technologies	ENE: 0.39	Has the infrastructure to provide low- or zero-carbon energy sources for the SFH.
2. Internet Connectivity	ENE: 1.00	Has infrastructure with access to internet service.
3. Alternative Modes of Transport	INN: 0.78	Has two of the following options or alternative modes of transport: communal car-club, electric recharging stations, or cycle storage spaces.
4. Recycled Aggregates	INN: 0.39	Has the infrastructure for transporting recycled or secondary aggregate, with a distance lower than 30 km by road transport to the housing unit.
5. Compact Development	LCT: 0.91–2.73	Has a DU/hectare of buildable land ≥ 17, 30, or 50.
6. Construction Workers' Amenities	LCT: 0.50	Has accommodation for construction workers and has adequate health and hygiene facilities for workers.
7. Heat Island Effect	MAT: 1.00–2.00	Provides any combination of the following strategies for 50% or 75% of the site hardscape (including sidewalks, courtyards, plazas, and parking lots): shade (within 5 years of occupancy), and/or paving materials with a solar reflectance index (SRI) of at least 29, and/or an open grid pavement system.
8. Non-Structural Building Walls	MAT: 0.63–1.88	Has infrastructure to extract, harvest, and manufacture 40%, 60%, or 80% of the non-structural walls of the SFH.

Table 8. *Cont.*

Indicator	NMA: Influence (%)	The Influence Percentage Is Obtained When the Urban Environment:
9. Flooring Materials	MAT: 0.63–1.25	Has infrastructure to extract, harvest, and manufacture 40% or 80% of flooring materials of the SFH.
10. Roofing Materials	MAT: 0.63–1.25	Has infrastructure to extract, harvest and manufacture 40% or 80% of roofing materials of the SFH.
11. Furniture	MAT: 0.63–1.25	Has infrastructure to extract, harvest, and manufacture 25% or 50% of all furniture items of the SFH.
12. Inclusive Design	TRA: 0.20	Has communal or shared parking with spaces with a width of 3300 mm and maintains the distance from the public parking space to the dwelling entrance of ??? as a minimum, and is level or gently sloping.
13. Street Network	TRA: 0.91	Has high intersection density, defined as an area whose existing streets and sidewalks create at least 90 intersections per square kilometer.
14. Alternative Modes of Transport	TRA: 0.78–1.56	Has a communal-car club, where the members share the use of a locally based fleet of vehicles, and/or provides electric recharging stations for the SFH occupants (Table 35 in [67]).
15. Composting	WST: 0.78	Has an accessible local communal or community composting service, run by either a local authority or a private organization; or has a management plan, which is in place to ensure food or green waste is appropriately removed and delivered to an alternative composting facility; or has a local authority, private organization, or green/kitchen waste collection system.
16. Recycling	WST: 0.39	Has an established recyclable waste collection scheme.

References: [67,69,71,73].

The SHMCI^{RUE} Considered by Two SHRSs

A total of 35% of the indicators were obtained from the relationship between two SHRSs (Figure 14). Of these indicators, only three come from systems developed in an MIC, of which, the “construction noise” indicator, considered by BEST and LOTUS, can be counterproductive regarding increased social responsibility in the houses, because the fulfillment of this would mean that the house is located at a large distance from any public amenity.

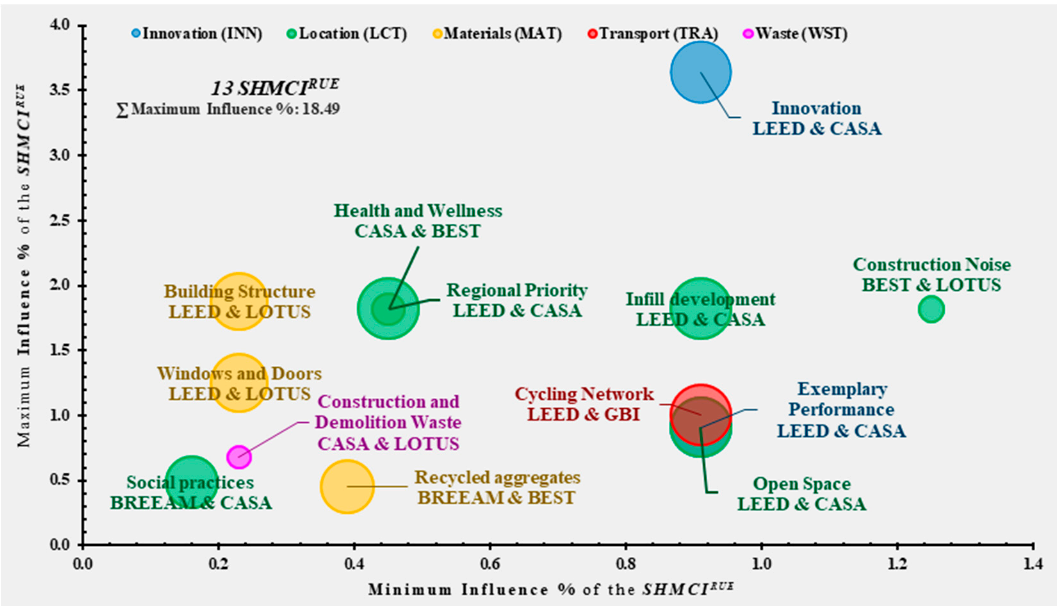


Figure 14. SHMCI^{RUEs} considered by two SHRSs. The size of the points corresponds to the sum of the GNI per capita [81] of the countries in which the systems were developed.

Table 9 shows that, for the majority of the time, the systems that were more rigorous in terms of the compliance criteria corresponded to those that were developed in the country with the highest income level. The description of each indicator, as well as the established relationships, are provided in the Appendix A.

Table 9. SHMCI^{RUEs} considered by two SHRSs.

Indicator	Considered by: Influence (%)	Variations	Most Rigorous
1. Innovation	LEED: 0.91, CASA: 0.91–3.64	1	LEED and CASA
2. Exemplary Performance	LEED: 0.91, CASA: 0.91	1	LEED and CASA
3. Social Practices	BREEAM: 0.16–0.49, CASA: 0.16–0.45	2	BREEAM
4. Infill Development	LEED: 1.82, CASA: 0.91–1.82	2	LEED
5. Open Space	LEED: 0.91, CASA: 0.91	2	LEED
6. Regional Priority	LEED: 0.91–1.82, CASA: 0.45	2	LEED
7. Construction Noise	BEST: 1.82, LOTUS: 1.25	2	LOTUS
8. Health and Wellness	CASA: 0.45, BEST: 1.82	2	BEST
9. Recycled Aggregates	BREEAM: 0.39, BEST: 0.45	2	BEST
10. Building Structure	LEED: 0.23–0.68, LOTUS: 0.63–1.88	2	LOTUS
11. Windows and Doors	LEED: 0.23–0.68, LOTUS: 0.63–1.25	2	LOTUS
12. Cycling Network	LEED: 0.91, GBI: 1.00–2.00	2	LEED
13. Construction and Demolition Waste	CASA: 0.23–0.68, LOTUS: 0.50	2	CASA

References: [67–70,73].

The SHMCI^{RUEs} Considered by Three and Five SHRSs

According to Dall'O' et al. [93], "The major causes of environmental impacts in urban areas can be linked to local traffic patterns." Additionally, although recent studies [94,95] have demonstrated the importance of developing an environment that favors pedestrian mobility in the RUE, only BEST, CASA, and GBI establish this criterion as an important issue (Figure 15). However, their relative characteristics for consideration only deal with specific cases of determined routes followed by users, and so walkability is not considered in the general environs of the SFH.

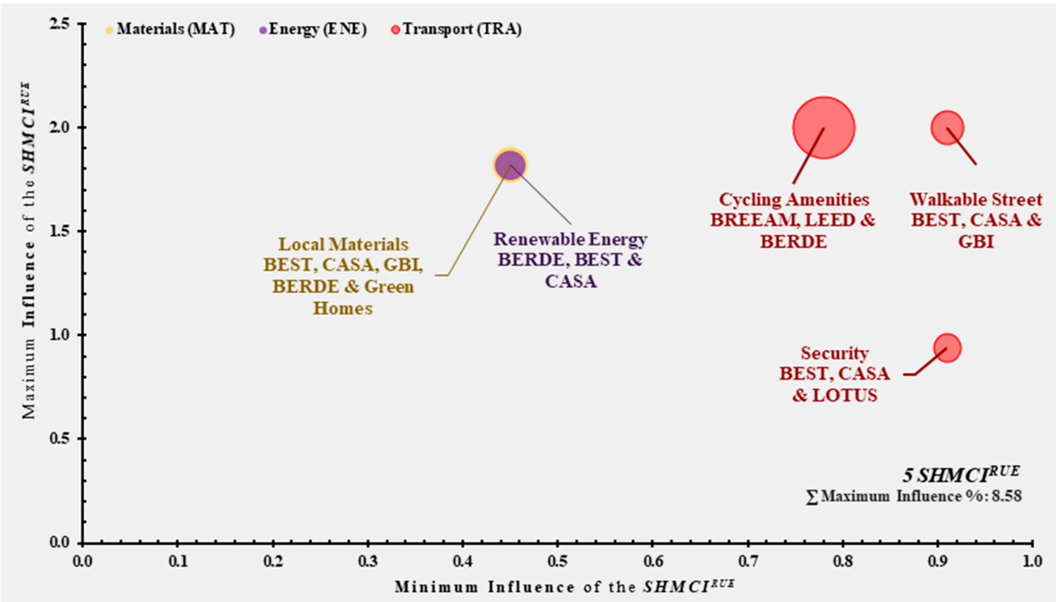


Figure 15. SHMCI^{RUEs} considered by three and five SHRSs. The size of the points corresponds to the sum of the GNI per capita [81] of the countries in which the systems were developed.

Among the SHRSs, CASA has the most standardized indicators in the industry of global construction, given that it possesses most of the indicators that have relations between two or more systems (Tables 9 and 10). On the other hand, the indicators "local materials," "renewable energy," and "security," are only considered by systems developed in MICs; therefore, a more in-depth study in terms of these would be interesting in order to understand the implications they could have on the systems developed by an HIC. The description of each indicator, as well as the established relationships, are provided in the appendices.

Table 10. SHMCI^{RUEs} considered by three and five SHRSs.

Indicator	Considered by: Influence (%)	Variations	Most Rigorous	Least Rigorous
1. Renewable Energy	BEST: 0.45–1.36, CASA: 0.45–1.82, BERDE: 1.00	2	BEST and CASA	BERDE
2. Local Materials	BEST: 0.91–1.82, CASA: 0.45%, GBI: 0.50–1.00, BERDE: 0.50–1.50, Green Homes: 0.67–1.33	5	BEST	Green Homes
3. Cycling Amenities	BREEAM: 0.78–1.56, LEED: 0.91, BERDE: 1.00–2.00	2	BERDE	BREEAM
4. Security	BEST: 0.91-1.82, CASA: 0.91–1.82, LOTUS: 0.94	2	BEST	CASA
5. Walkable Street	BEST: 0.91, CASA: 0.91–1.82, GBI: 1.00–2.00	2	LEED	CASA

References: [66–73].

4. Conclusions

This paper has provided 39 indicators (SHI^{RUEs}) for assimilating sustainability into the cities of MICs by means of the RUE recognized by the SHRSs. The study provides an image of the current situation regarding how the SHRSs consider the influence of the RUE surrounding the SFH to determine the final label of a dwelling considered as sustainable, as well as the similarities and differences between the systems analyzed (BREEAM, LEED, BEST, CASA, GBI, BERDE, Green Homes, and LOTUS).

The main findings of this work have shown that the percentages of maximum influence obtained in the multi-criteria assessment and the lack of consideration of SHOCI^{RUEs} in seven of the eight systems make certified sustainable housing possible; in which the urban environment does not meet the requirements to contribute to the sustainable development of the cities. This implies a bleak perspective for the objectives decided upon by the different countries in the new urban agenda, and also justifies the proposals of UN-Habitat III, which refers to the urgent need for different bodies (in the public and private sector) to collaborate to establish guidelines that will clarify the qualities necessary for a RUE to be considered sustainable.

The results indicate that deciding on a possible global homologation or standardization of the RUE's inherent qualities in SFH is complex and will only be realized in the long-term. Although each system has its own conception of how the urban environment impacts the labeling of housing and its maximum influence on the score, carrying out the NCP allowed the identified indicators to be clustered into six new macro-areas: LCT, TRA, and MAT being the most important, with ENE, INN, and WST making up the rest.

The relationships among the SHRSs developed by a country with a specific income level shows that those developed in a HIC (LEED and BREEAM) had a higher number of requirements than those systems developed by an MIC and, in general, were more rigorous in terms of their compliance criteria. Consequently, this had a more significant effect on improving the urban environment. However, the rating systems developed by an MIC, such as CASA, GBI, and LOTUS, also have exclusive indicators, which could be applied in the systems developed by a HIC.

On the other hand, this study also shows the lack of interest on the part of the academic sector in analyzing the SHRSs that are developed by the UMC and LMC countries. However, the methods developed show that, although several studies state that BREEAM and LEED were the most widely recognized by the construction industry and academic sector, it was also essential to consider other

SHRSs in the comparative analyses conducted to provide results in the MICs in order to acquire results that better match the specific features of these countries.

The use of the SHI^{RUEs} identified can also have significant repercussions on the policies of the MICs because many of these countries base their urban guidelines on what is established by the rating systems. Therefore, it is expected that the identification of the two SHOCI^{RUEs} and the 37 SHMCI^{RUEs} could provide a variety of real and proven instruments, which will enable sustainable urban habitats to be obtained through the construction or evaluation of the SFH.

One of the main limitations of this work is that the view of the current situation of the RUE characteristics by the SHRSs cannot be considered complete, as a study of the scores obtained by real cases is missing. Moreover, some concerns were raised regarding the identified SHI^{RUEs} during the discussion of the results, indicating the need for further investigation. Finally, the NCP carried out in this study has shown that there are criteria among the indicators that can be included in a different NMA as an exclusive indicator. Therefore, a more in-depth analysis of each criterion (or possibly a segregation of each) could lead to a more dynamic and effective understanding of the RUE, as well as the value that each SHRS gives to the requirements of each indicator.

Author Contributions: Conceptualization, H.S.-M. and J.M.G.-S.; methodology, H.S.-M., D.C.G.-G., and J.M.G.-S.; validation, S.P.A.-R.; formal analysis, H.S.-M. and J.M.G.-S.; investigation, D.C.G.-G. and R.C.-H.; resources, J.M.G.-S. and M.C.G.-S.; data curation, H.S.-M. and D.C.G.-G.; writing—original draft, H.S.-M. and S.P.A.-R..; writing—review and editing, M.C.G.-S.; supervision, S.P.A.-R. and R.C.-H; project administration, R.C.-H. and M.C.G.-S.; funding acquisition, J.M.G.-S.

Funding: This research received no external funding.

Acknowledgments: This work was supported by the National Council for Science and Technology (Spanish acronym: CONACYT) of Mexico. Acknowledgment also goes to the Sinaloa Institute of Support for Research and Innovation (Spanish acronym: INAPI) for making possible the development of this research.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ENE	Energy
HIC	High-Income Country
INN	Innovation
LCT	Location
LMC	Lower-Middle-Income Country
MAT	Materials
MCI	Multi-Criteria Indicators
MIC	Middle-Income Country
NCP	Normalization Criteria Process
NMA	New Macro Area
OCI	Obligatory-Criteria Indicator
RUE	Residential Urban Environment
SFH	Single-Family Housing
SHI^{RUE}	SFH Indicator that focuses on the RUE
SHMCI^{RUE}	SFH Multi-Criteria Indicator that focuses on the RUE
SHOCI^{RUE}	SFH Obligatory-Criteria Indicator that focuses on the RUE
SHRS	Single-Family Housing Rating System
TRA	Transport
UMC	Upper-Middle-Income Country
WST	Waste

Appendix A

Figure A1. Relationships among the SHI^{RUEs} according to energy (ENE), innovation (INN), and waste (WST).

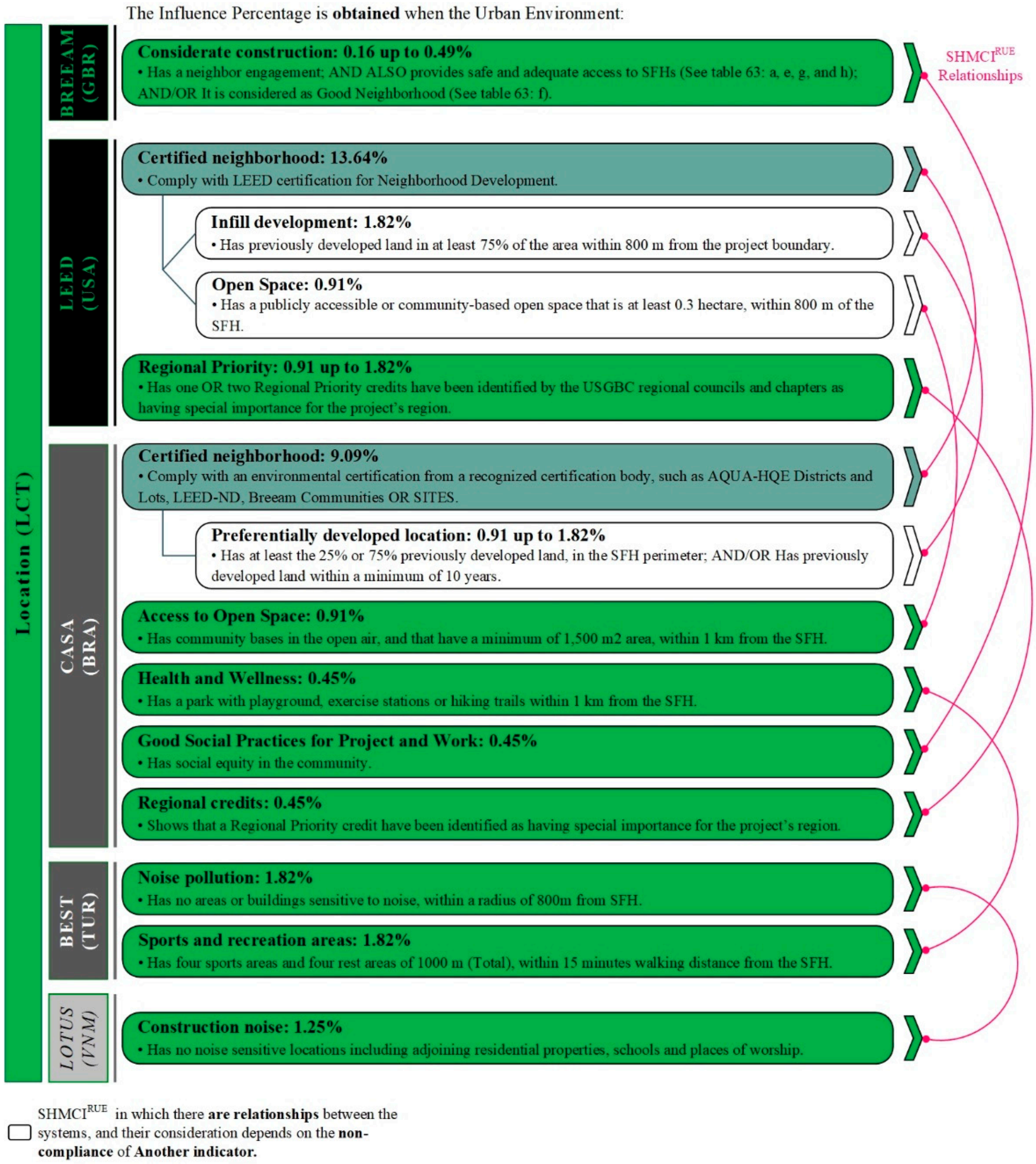


Figure A2. Relationships among the SHI^{RUEs} according to location (LCT).

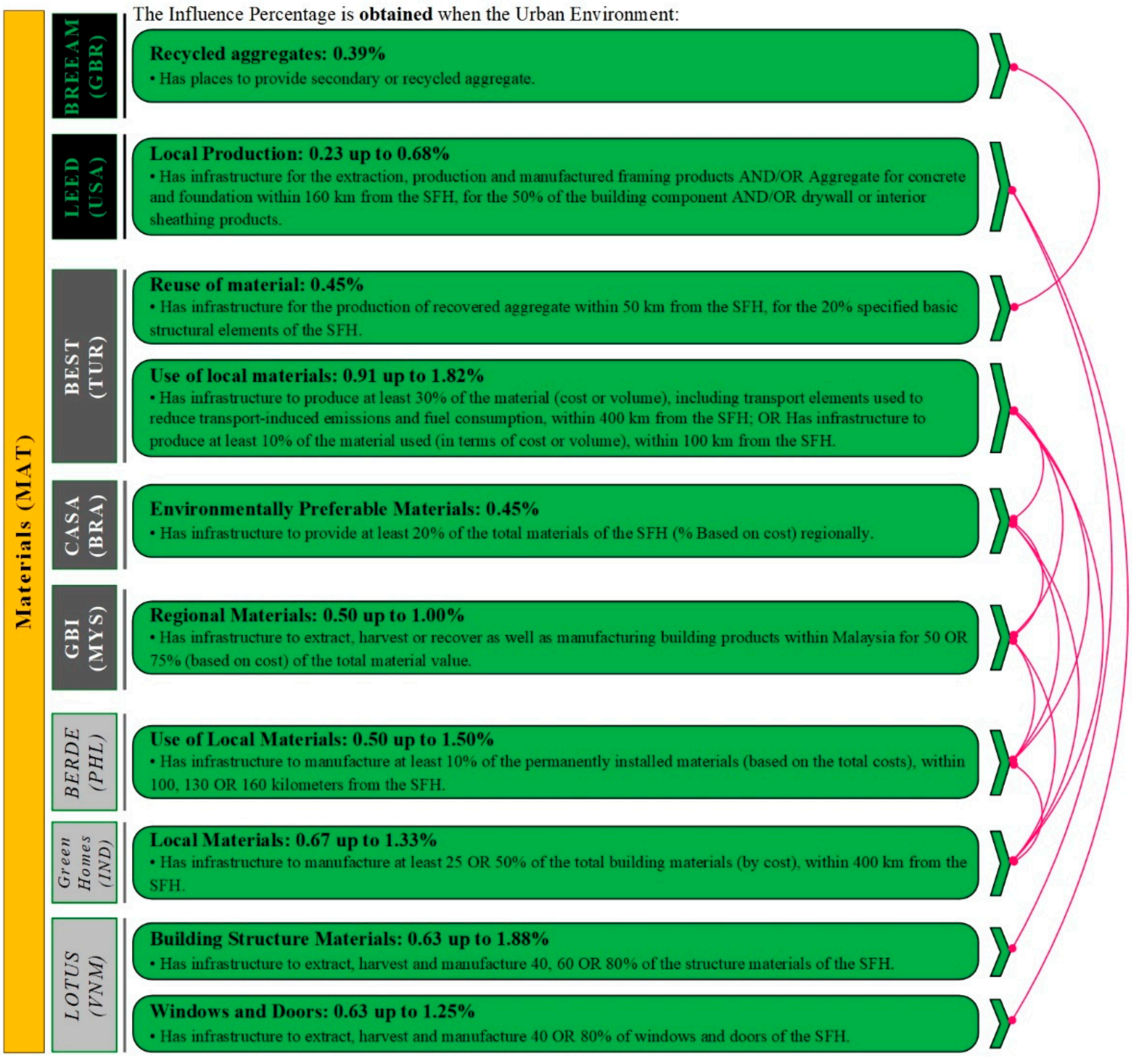


Figure A3. Relationships among the SHI^{RUEs} according to materials (MAT).

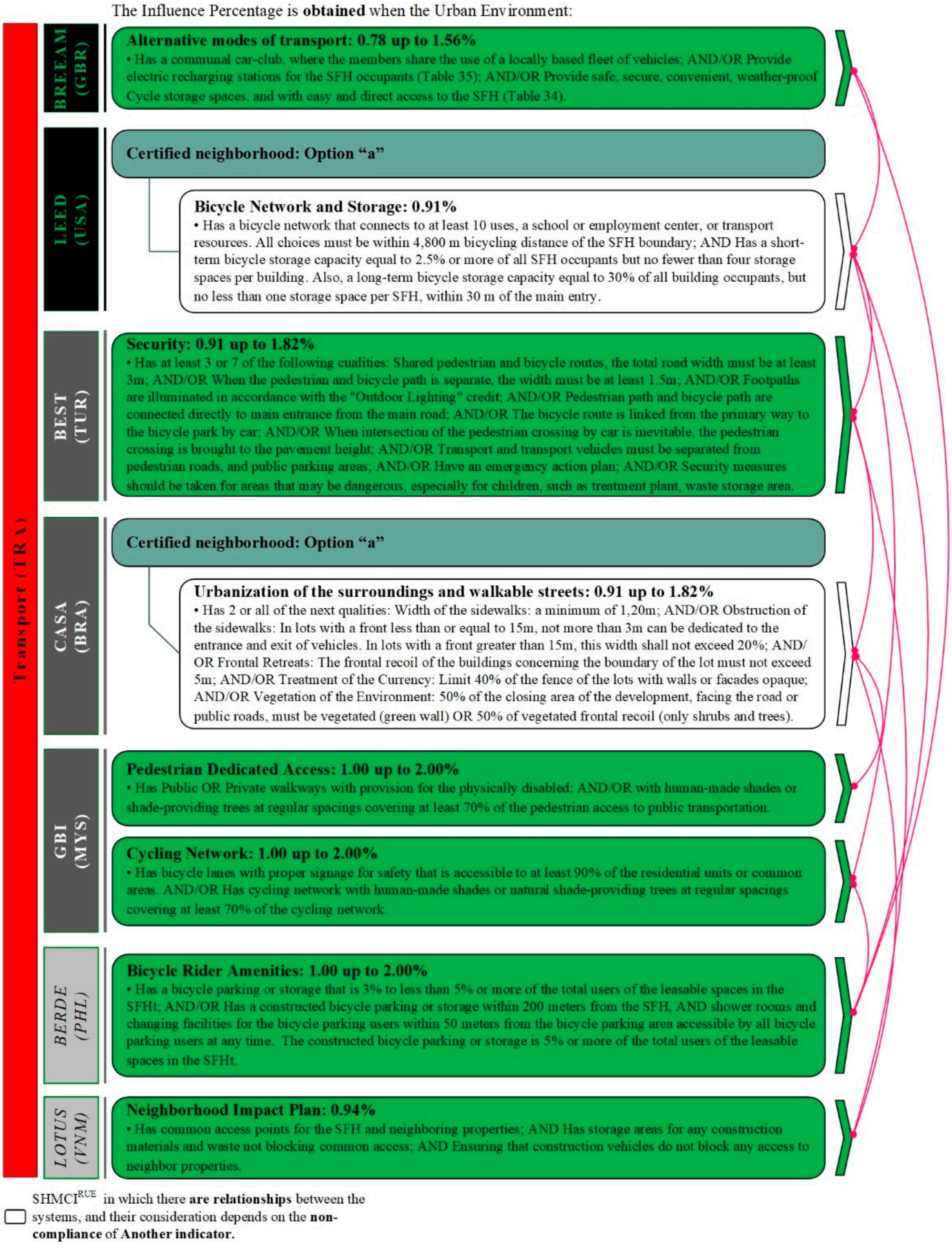


Figure A4. Relationships among the SHI^{RUEs} according to the Transport (TRA).

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