URBAN PARTICIPATION + RESEARCH + REGULATION METHOD (PRRM) TO BROADLY IMPLEMENT GREEN URBAN INFRASTRUCTURE SOLUTIONS

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ABSTRACT

The 2030 Agenda shows the path to achieve the sustainable development goals. In addition, the International Paris Agreement, the IPCC reports on climate change and the recent COP26 in Glasgow urge the international community to decarbonize their economies and move towards carbon neutral countries by 2050. As urban designers, willing to meet these international commitments through our profession, green urban infrastructure solutions (GUIS) evidence cost-efficient policy tools to respond to climate change. This paper includes the implementation of GUIS in two pilot projects in the Basque Country. In addition, the environmental benefits derived from such green intervention are analyzed, in terms of climate change adaptation, including the amelioration of stormwater runoff, reduction of urban hot spots and improvement of urban air quality. The paper also highlights the barriers and difficulties encountered when implementing these GUIS into practice. This includes the skepticism about innovative urban solutions and the lack of experience in GUIS. Therefore, the paper proposes an urban participation, research and regulation method in order to overcome current barriers and enhance a broad implementation of GUIS to comply with international commitments.

Keywords: climate change adaptation urban solutions, environmental benefits, green streets, green urban infrastructure, low impact development, nature based urban solutions, stormwater management, sustainable urban drainage system, urban participation and regulation method, water sensitive urban solutions.

1 INTRODUCTION

In 1987, the World Commission on Environment and Development already identified the goals for a sustainable development [1], which were defined in more detail in 2015 in the 2030 Agenda through the 17 sustainable development goals [2]. Among these, this paper's framework is precisely within the 11th goal: make cities and human settlements inclusive, safe, resilient and sustainable. Moreover, the International Paris Agreement in 2015 [3] achieved an international compromise to intensify the response to the risks of climate change. In addition, the recent COP26 in Glasgow [4] and the last IPCC Climate Change Reports (October 2018 and August 2021) [5] called for urgent action in order to limit climate change impact. Green urban infrastructure solutions (GUIS) are cost-efficient policy tools to respond to climate change [6]. There is usually a high return on Green Infrastructure (GI) investments and overall reviews of restoration projects typically show cost–benefit ratios in the range of 3 to 75 [7]. In addition, current research shows GUIS are effective solutions to mitigate and adapt to climate change [8].

However, this paper highlights the resistance and barriers encountered when implementing GUIS in practice. The lack of experience in GUIS, the skepticism towards this type of solutions and distrust of innovative urban interventions are the main barriers to their implementation. It proposes a design method [participation, research and regulation method (PRRM) method] based on urban participation, research and regulation of GUIS in order to minimize these barriers and better implement GUIS in practice. An application of this method to two pilot projects in the Basque Country is included.

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This application shows a community consensus and acceptance to proposed GUIS overcoming existing resistance and barriers to this type of projects. In addition, it includes the contribution of these pilot projects to reducing the impact of climate change in terms of reducing stormwater runoff, urban heat island effect and CO_2 emissions. It highlights the lessons learned and encountered barriers when applying the proposed PRRM to implement GUIS.

This paper proposes the PRRM design method in order to minimize current barriers and skepticism towards the implementation of GUIS, to broadly apply this type of solutions and to inspire other urban designers to follow a more rigorous design process. It concludes advocating the implementation of larger GUIS projects in order to meet the international compromises of the Paris Agreement.

2 PRRM DESIGN METHOD

The PRRM design method lies within the context of the LARG paradigm (Lean, Agile, Resilient and Green), a management tool in enhancing the supply chain to be more efficient, streamlined and sustainable [9], which is applied to an urban design method presented in this paper. In addition, the PRRM method takes one step further than the design process described in previous publications [8, 10]. This PRRM design method includes a new phase: Regulation, which enriches previous design methods and is crucial to definitely promote and broadly implement GUIS. The PRRM method proposes the following phases:

1. Community Engagement – it is the basis of the method in order to identify the needs of the neighbors and assess the GUIS to be included into Phase 2 (design).
2. Design – this phase integrates the GUIS selected in the community engagement process. Community support to GUIS is achieved, reducing skepticism and resistance.
3. Research – this phase analyses the contribution of selected GUIS to climate change adaptation in terms of reducing the stormwater runoff, ameliorating urban heat island effect and contributing to air quality.
4. Regulation – the method suggests that urban regulation is needed in order to broadly implement GUIS in any urban intervention.

This method is applied in two pilot projects of the Basque Country.

2.1 Community engagement

Citizens can significantly contribute to the success of the design and implementation of GUIS. In this phase, it is crucial to integrate the local community, build awareness, collaboratively select GUIS and build acceptance and consensus regarding the selected GUIS. However, many citizens are resistant to implementing such policies and other mitigation initiatives in their own neighborhoods [11]. Specific research suggests that, if individuals are provided with user-friendly, understandable and relevant information and visualization about why and how green urban interventions can help respond to climate change, their understanding and acceptance of such interventions may improve [12,13].

In this context, the paper proposes a community engagement framework to better inform, build consensus and minimize resistance toward GUIS. The framework is developed after a deep analysis of international reference models over the last 50 years, including levels of participation, key performance indicators, evaluation guidelines and quality standards and indicators for community engagement [14].

2.2 Design

Based on the input from the community engagement process, the design phase integrates the concepts arising in the engagement process into the design. The results of the engagement process are summarized in an executive summary report, which is integrated in the design phase. For instance, the design integrates, within the urban design project, the identified GUIS during the engagement process. Section 3 shows in more detail how the design process takes into account the results of community engagement.

2.3 Research

Another way to minimize the skepticism toward GUIS is to provide the data on their urban benefits. To do so, the method includes both general and specific research on the contribution of selected GUIS in terms of the reduction of runoff, the reduction of urban heat island effect and the contribution to air quality.

GUIS contribute to retaining and collecting rainwater runoff. Green roofs retain between 20% and 30% of rainwater [15]. Green walls retain 50–75% and can reach 100% [16]. By implementing green roofs, green walls and green streets solutions stormwater, runoff can be reduced by 13% [17] According to Vancouver's Rain City Strategy [18], a global green urban infrastructure strategy can retain 90% of a city's runoff. More specific data on the reduction of runoff is achieved by applying the Low Impact Development (LID) Application [19] in each particular project.

In addition, urban greenery reduces the urban heat island effect. For instance, in urban parks, for every 100 m^2 of vegetation, air temperature is reduced by 1ºC and, by increasing the ratio of green area to built area by 10%, a 0.8ºC reduction is achieved [20]. Similarly, Central Park in New York reduces the nearby temperature by 2–5ºC [21], and Shinjuku Gyoen Park in Tokyo reduces the urban heat island effect by 2ºC and decreases the temperature in adjacent areas within the range of 80–90 m from the boundary [22]. Vegetated courtyards reduce air temperature approximately 4–5ºC [23], and vegetated roofs reduce air temperature between 0.5ºC and 2ºC [24]. Urban greenery reduces urban surfaces temperature up to 20ºC [25].

GUIS also contributes to reducing CO_2 emissions. The reduction of the energy demand of buildings can be estimated to be around 10–15% [26]. The capacity of the greenery to fix air pollutants, such as CO_2, is calculated in each particular project, explained in section 3.3.

2.4 Regulation

The PRRM method includes a green urban regulation study, which is crucial to legally require the implementation of GUIS. This method suggests that green urban regulations should follow the same path as the energy efficiency regulations followed these last years. The different energy efficiency European Directives; in 2002 (2002/91/CE [27]); in 2010 (2010/31/UE [28]) and, more recently, in 2012 (2012/27/UE [29]) and 2018 (2018/844 [30]), have been requiring more and more ambitious energy efficiency regulations in order to drastically mitigate climate change by reducing buildings' CO_2 emissions. Consequently, the European states have been updating their national buildings codes in order to regulate and achieve this objective. In the case of Spain, the last update of its building code (CTE-HE 2019 [31]) suggests that by applying it 90% of buildings' CO_2 emissions will be reduced by 2050.

In the case of green urban regulations, valuable references are the 'Green Factors'. These are factors that drive an increase of the greenery within a city. The 'Green Factor' concept started in Berlin and Hamburg, Germany, during the 1990s with the Biotope Area Factor (BAF [32]). Similarly, the Greenspace Factor was implemented (2001) in a new urban development in Malmö, Sweden (Greenspace Factor [33]). In 2007, the City of Seattle developed its Green Factor (Green Factor [34]). Of note is also the 2019 Rain City Strategy of Vancouver [18] where the objective of its Rainwater Bulletin is to capture and clean 90% of the runoff of the city [35].

3 PRRM APPLICATION TO TWO PILOT PROJECTS

The PRRM method is applied in two pilot projects in Legazpi and Muxika (Basque Country). It follows the four phases of the method: community engagement process, design process, research and regulation.

3.1 Community engagement

The community engagement framework is applied in two pilot projects in Legazpi and Muxika. In both projects, the framework is divided in two major sessions, S0 and S1, both of 2 hours and both presented in different neighborhoods of the municipality. The first one, S0, shows to neighbors general concepts of climate change and adaptation solutions, with examples from other towns and cities. It then discusses, contrasts and prioritizes among participants their needs and opportunities for climate change adaptation solutions identifying them in neighborhood's maps. In the second session, S1, based on the results of session S0, the team presents the preliminary proposals in drawings and plans. Besides, participants are inquired to explore them in more detail (Fig 1) through the proposal panels, a tool designed by the engagement team, similar to the business canvas model, applied to community engagement processes.

In the case of Legazpi, the participation process was developed in two different formats: face-to-face and digital, while in Muxika, it only took place through the face-to-face format. From a gender equality perspective, participation in all sessions was quite balanced (Fig. 2), and the age of participants was mainly between 40 and 70 years.

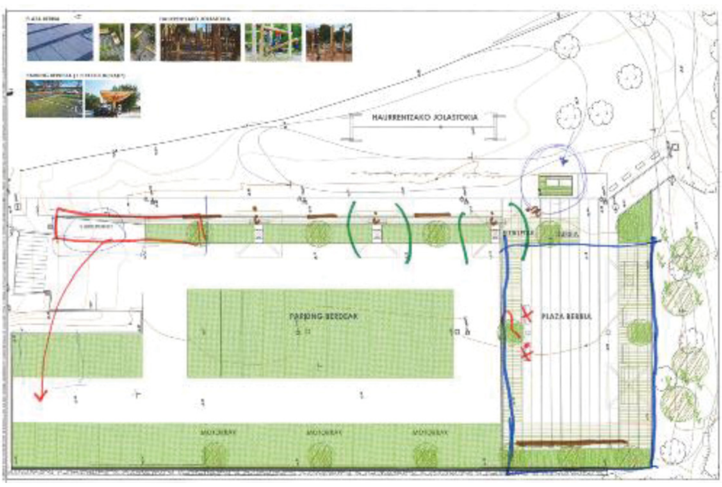

Figure 1: Participants located and prioritized GUIS on a map of Muxika (image by authors).

FOUR SESSIONS	Session 0 S0.1	Session 0 S0.2	Session 1 S1.1	Session 1 S1.2	TOTAL FACE-TO-FACE	TOTAL DIGITAL	TOTAL
Number of participants	39	47	48	29	**163**	**5** (S0)	**168**
Women (%)	47%	55%	52%	45%	**50%**	**80%**	**50%**
Men (%)	53%	45%	48%	55%	**50%**	**20%**	**50%**

Figure 2: Number of participants by gender in Legazpi (figure by the authors).

The two participation processes met the expectations [10] and provided the basis for the next phase of the PRRM method, the design, defined in the following section.

3.2 Design and integration of GUIS

Based on the input from the community engagement process, the design team integrated the identified GUIS in the designs of both pilot projects: Legazpi and Muxika. Selected GUIS in both projects included permeable paving and bio-retention areas. In addition, in Legazpi, a stormwater tank and a vegetated canopy were included and in Muxika a raingarden. The pilot project in Legazpi was recently built while the Muxika's one is currently looking for funding. The concept design of Muxika's proposal is summarized in Figure 3.

3.2.1 Permeable pavements

Both designs proposed new permeable pavements to infiltrate rainwater and prevent current generation of puddles (Fig. 4). In the case of Legazpi porous concrete was selected and in Muxika permeable asphalt into car lanes and reinforced polypropylene cells in the parking lots.

3.3.2 Bio-retention areas

Both projects included bio-retention areas to retain rainwater and infiltrate it into the ground (in the case of Muxika) or to connect rainwater to the stormwater tank (in Legazpi) Figure 5. Selected species are birches, liquidambars and tulip trees combined with esparto grass and gramineous grass.

3.2.3 Stormwater tank and raingarden

In the project in Legazpi, due to the existing ground impermeability, rainwater is collected and guided to a stormwater tank made out of reinforced polypropylene cells, covered by the waterproof elastomer membranes, (EPDM: Ethylene propylene diene terpolymer) and vegetated soil (Fig. 6). The volume of the tank is 41.85 m^3, calculated to retain a medium rainwater event of 25 l/m^2.

In the Muxika project, the overflow of the bio-retention areas is guided to the raingarden placed before the river. It is a combination of gravel and esparto and gramineous grass (*Stipa tenacissima* and *Phragmites*), which provides an average volume of 41.25 m^3 (Figure 7).

3.2.4 Vegetated Canopy

The project in Legazpi also included a vegetated wooden structure canopy, which integrated a new moss envelope system (roof and wall), tested in the project. The waterproofing layer of the canopy consisted of a bituminous roof proofing membrane, a biodegradable coconut layer and growing medium with moss plants (Figure 8).

Figure 3: GUIS implemented in Muxika's design project (figure by the authors).

Figure 4: Permeable pavements proposed in both projects (images by the authors).

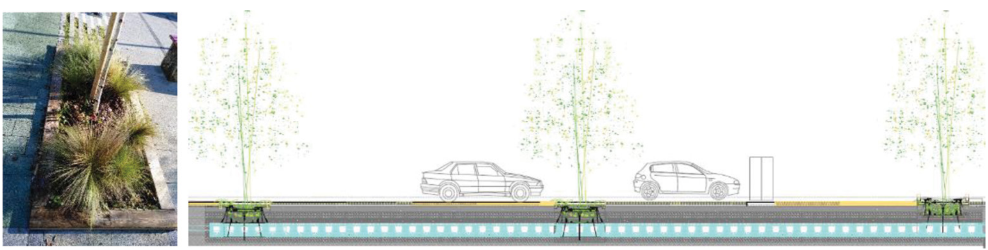

Figure 5: Bio-retention areas in Legazpi, left, and in Muxika, right (figure by the authors).

Figure 6: Details of the stormwater tank (image by Marc Rips).

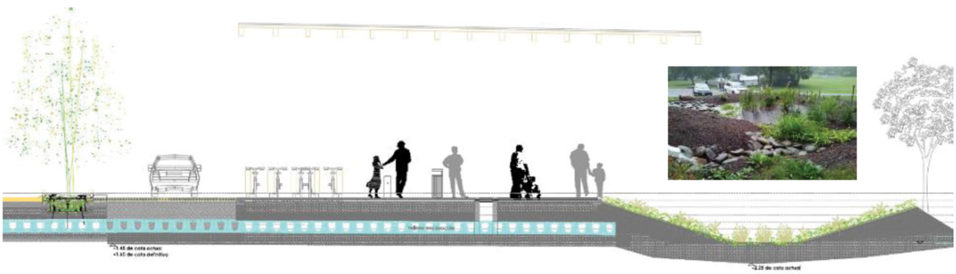

Figure 7: Bio-retention areas connected to the raingarden (drawing by the authors).

Figure 8: Vegetated canopy (figure by the authors).

3.3 Research: contribution of GUIS to climate change adaptation

In parallel to the research of the contribution of GUIS to climate change explained in section 2.3, specific research of each particular project is included. Thus, more detailed data on the contribution of each project to the reduction of runoff and to air quality is achieved.

3.3.1 Contribution to the reduction of runoff from the site

In order to achieve the runoff reduction in both projects, the LID Application [19] is applied. This is a user-friendly application to calculate during the design process, the influence of LID solutions to reduce the runoff. This kind of water balance models allows for a broad estimation only [36]. The authors consider the LID application as a useful application during the design process, as it provides estimated 'volumes' of the different LID tools to be used to manage the runoff from a site.

The pilot project of Legazpi proposed 23.3 m^2 of vegetated roof (in the vegetated canopy), 26 m^2 of bio-retention areas and a 41.85 m^3 rainwater tank. Including these GUIS areas into the application, results show an average of 25% runoff reduction (Figure 9).

Similarly, introducing the GUIS areas of the Muxika project into the LID application, results show an average of 56% runoff reduction (Figure 10).

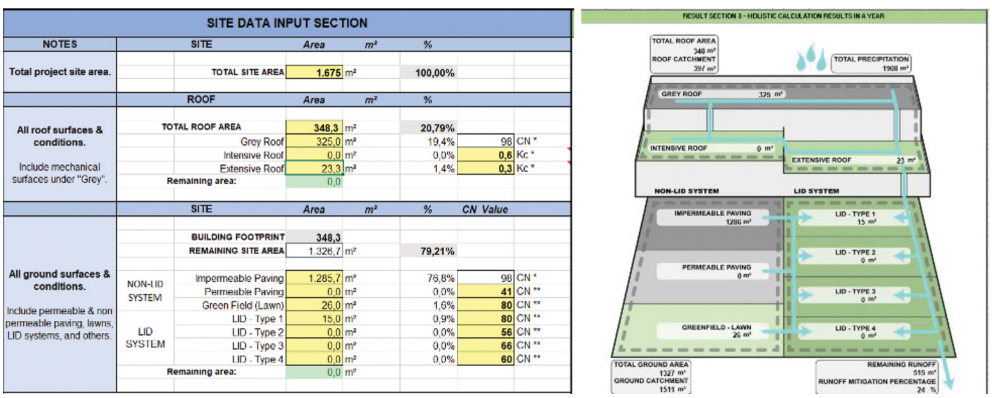

Figure 9: Results from the LID application in Legazpi (image by greenskinslab [37]).

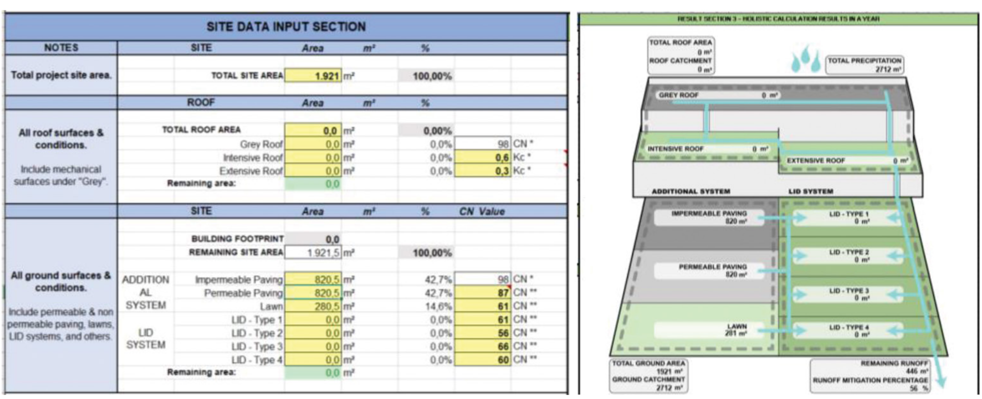

Figure 10: Results from the LID application in Muxika (image by greenskinslab [37]).

ESTIMATION OF THE CO_2 SEQUESTRATION IN THE MUXIKA PROJECT				
MUXIKA		surface (m2)	sequestration (kg/m2) [19]	CO_2 sequestration (kg/year)
	Grassy plants	124,71	4,38	546,2298
		number (ud)	sequestration (kg/year) [20]	
	Young trees	10	0,02	0,2
	TOTAL			**546,4298**

Figure 11: CO_2 sequestration by the GUIS of the Muxika's project (figure by the authors).

3.4 Contribution to the reduction of CO_2 emissions

In both pilot projects, the proposed urban greenery does not significantly affect nearby buildings. Thus, this paper estimates the reduction of CO_2 emissions solely through the capacity of the greenery to sequester CO_2 (not including the reduction of buildings' energy demand). The CO_2 reduction estimate is based on the data from Schaefer et al. [38].

In the case of Legazpi's pilot project the specific research estimates that grassy plants from the bio-retention areas and vegetated canopy would trap 281.63 kg of CO_2/per year; and climber plants from the canopy would trap around 153.1 kg of CO_2 per year. Additionally, according to McPherson et al. [39] the proposed nine trees, with a diameter less than 7 cm, would trap around 0.18 kg of CO_2 per year. Therefore, the combined contribution of the proposed GUIS to the sequestration of CO_2 is 434.89 kg of CO_2 per year, which is the 7% of the CO_2 emissions assignable to the site area.

Similarly, in the case of Muxika's pilot project, grassy plants from the bio-retention areas would trap 546.23 kg of CO_2 per year; and the proposed 10 young trees would trap around 0.20 kg of CO_2 per year. The sum of the sequestration of CO_2 is 546.43 kg of CO_2 per year (Fig. 11).

Thus, the overall results show that GUIS are effective to reduce the stormwater runoff and the urban heat island effect of a specific site. They achieve more modest results to significantly reduce CO_2 emissions by sequestering it.

This means that more ambitious green urban interventions should be addressed in order to achieve better climate change adaptation results.

3.5 Regulation

Green urban regulations are essential to broadly promote GUIS. Green urban ordinances are developed in both pilot projects. They are by-law urban tools, based on excel spreadsheets, in order to facilitate and require the implementation of climate change adaptation solutions. In addition, in the case of Legazpi, a green tender was applied for the selection of the construction company. A similar process is currently developing for the case of Muxika's project. These urban instruments pretend to provide effective tools to local governments and policy makers in order to easier implement GUIS into planning strategies.

4 CONCLUSION AND DISCUSSION

This paper proposes a design methodology (PRRM) to better and broadly implement GUIS. It applies this method and the selected GUIS in two pilot projects in the Basque Country (Legazpi and Muxika). It also highlights the potential of GUIS as effective climate change adaptation solutions, as well as the community engagement process, which is crucial to both select the GUIS applicable to the site and to raise awareness regarding the consequences of climate change at a local level.

A series of findings on how these green urban interventions contribute to climate change adaptation is provided in terms of reducing the urban stormwater runoff and the risk of floods, as well as the influence on the urban heat island effect and CO_2 sequestration. These pilot projects show that GUIS are effective for climate change adaptation, especially to reduce runoff and urban heat island effect and in a more modest way to reduce CO_2 emissions. However, further research is needed to also study the economic and social impact of GUIS in urban projects.

Furthermore, the paper identifies the main barriers encountered when implementing GUIS, and it shows that there are still many challenges which are summarized below:

1. The little experience in implementing GUIS from all stakeholders involved in the project: the design team, the construction company and the municipal technicians.
2. The skepticism and distrust toward new urban solutions (GUIS), which reflect the need to continue working and promoting them to increase the experiences of all the agents involved. This would generate more confidence in GUIS.

As a response to these challenges, the authors include in the methodology new green urban regulations to broadly implement these solutions. These urban regulations are key to move from pilot projects to common practice. This should be accompanied by training courses on green solutions for all the stakeholders involved in these types of projects from designers and developers to builders, planners, municipal technicians and decision-makers.

The paper emphasizes that this type of green urban infrastructure design process is effective for adapting to climate change, creating consensus within the community and developing a more resilient urban space. It advocates following this kind of methodology (PRRM) in order to promote this type of GUIS in larger-scale projects and to meet the international urgent commitments of the Paris Agreement.

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