TOWARDS THE ENVIRONMENTALLY SUSTAINABLE
SMART VILLAGE

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Abstract: Environmental sustainability is a critical global challenge. Housing and infrastructure demand huge quantities of resources and result in significant environmental effects. The creation of ‘smart villages’ offers a unique opportunity to redefine how housing and infrastructure systems interact with the natural environment and explore solutions for improving their environmental sustainability. The concept of the Smart Village has a heavy focus on using technological solutions to enhance the existing networks and services available within a village community. This inevitably leads to an increase in resource use (both for construction and operation) which can be counter-productive to improving the environmental sustainability of villages. With environmental concerns becoming increasingly integral to decision-making, the design and implementation of Smart Villages must consider the potential environmental implications and performance of Smart Village solutions if they are to be considered truly ‘smart’. This paper introduces a four-step process for identifying, analysing and implementing solutions for achieving an environmentally sustainable Smart Village. This involves an integrated design process where the current environmental performance of a village is assessed (step 1), the local context is analysed to determine what resources, skills and expertise are locally available (step 2), potential Smart Village solutions are identified and analysed (step 3), and the Smart Village is designed and implemented, with the assistance of trained professionals and village communities (step 4). A village community located in Assam, India is used as a case study to demonstrate the application of step 1. By using this process in the design and implementation of Smart Villages, greater confidence is able to be placed in ensuring that potential solutions, both technological and non-technological are not creating greater environmental issues than already exist within villages. It can also be used to provide a better understanding of current village performance and that of potential Smart Village solutions so that opportunities for further environmental improvements are able to be identified and prioritised.

Keywords: Smart villages, Environmental sustainability, Housing, Assam.
1 Introduction

While there is a global trend towards urbanisation, over-population of cities, especially without appropriate supporting infrastructure, has been shown to have serious consequences on resource availability (for example, the 2018 water crisis in Cape Town, South Africa (Maxmen, 2018)) and the health and wellbeing of their inhabitants (for example, due to the high levels of air pollution in Delhi, India (Rizwan et al., 2013)). As population increases so does the demand for housing and infrastructure, further increasing the demand for resources and the waste and pollution produced as part of construction and other associated activities. For example, it is predicted that at least 200 million new houses will be required in India alone by 2030 (Planning Commission (Government of India), 2008). This is driving exponential growth in global resource demands. For example, the demand for minerals, ores, fossil fuels and biomass is predicted to be 2.5 times greater in 2050 than it was in 2010 (UNEP, 2016). Demand for energy is on a similar trajectory, also expected to be 2.5 times greater in 2040 compared to 2013 (IEA, 2015). Demand for fossil fuels has seen a rapid increase in global carbon dioxide levels, contributing significantly to climate change (IPCC, 2014), and reduced air quality (with half of the world’s population living in countries with unsafe air quality (Yale University, 2018)).

Evidence shows that the built environment (buildings, in particular) is responsible for a significant proportion of human induced resource demands and environmental effects. This includes 36% of global energy use and 39% of carbon dioxide emissions (UN Environment and International Energy Agency, 2017). Increasing demand for housing, lifestyle changes and rising expectations, especially in developing countries, will only further exacerbate the demand for materials, changes to land-use and increases in greenhouse gas emissions and pollutants emitted into the environment. The most critical issue with this is that not only are the Earth’s resources finite and being rapidly depleted, but the ability for it and humans to cope with the damage that is already being done is also limited.

Much has, and is being done to address the broad challenges being faced by the world’s cities, including work on developing ‘Smart Cities’ and improving their environmental performance. However, a significant proportion of the world’s population still live in regional and remote communities (often referred to as towns or villages). Living standards, access to infrastructure, housing, healthcare and education, and environmental sustainability are equally important to the people living in these typically less urbanised areas. The decentralisation of human populations is also seen as an important element in dealing with future population growth. This can help balance out and better manage the resource, pollution and other challenges facing many of the world’s expanding cities, but can also provide a better quality and more equal living standard to those living in villages, unable or unwilling to move from village communities. It can also encourage village communities to build upon their existing strengths and develop new opportunities, facilitated by smart solutions.

Figure 1 shows the relatively primitive nature of some villages.
1.1 Smart Villages

The idea of Smart Villages is a relatively new phenomenon, taking learnings from the Smart Cities movement and contextualising them in relation to the challenges and characteristics unique to typically smaller, more remote, less populated and less developed communities. The European Commission (2016) defines a Smart Village as a village who’s ‘traditional and new networks and services are enhanced by means of digital, telecommunication technologies, innovations and the better use of knowledge, for the benefit of inhabitants and businesses’. This definition of ‘smart’ tends to imply a technological solution to aspects such as healthcare, education, housing etc..

Access to critical services, such as healthcare and education are often much more difficult in villages due to their remoteness and lack of infrastructure and investment. Important elements of what makes a village ‘smart’ may include: education and training in e-literacy skills, e-health and other basic services, circular economy approaches to agricultural waste, using technology to promote local products, and specialisation for agri-food projects, tourism and cultural activities (European Commission, 2016).

This definition of Smart Villages lacks a consideration of the sustainability dimension, particularly from an environmental perspective. While digital and telecommunication technologies can play an integral part in improving amenity, access to services and quality of life for people living in village communities, the environmental sustainability of these communities should be considered equally important.

1.2 Villages and the Environment

In some ways, villages are no different than cities. They require natural resources to support the livelihoods of their inhabitants and produce waste that must be managed. One of the main differences is the scale of these and the ability to manage them. There are
three main natural resource inputs required for the various aspects of a village to function (from the initial construction of its buildings, roads, bridges and essential services infrastructure, to its operation, and ongoing repair and maintenance). These include energy, water and raw materials (Figure 2). The use of these resources results in the production of waste, that must be managed, and the release of pollutants into the environment. These resource demands and outputs of waste and pollutants are having a detrimental effect on the environment and human health.

![Figure 2: Inputs and outputs associated with a village](image)

As is the case with Smart Cities, the development of Smart Villages must not be treated in isolation of their longer-term environmental consequences. Smart Village solutions must consider the context of resource availability, waste and pollution management and human health and wellbeing to ensure long-term sustainability. For example, there is little point in a technological solution for better communication, education and healthcare services if the natural resources used for the provision of these technologies (e.g. energy and minerals) are easily depleted or cause indirect environmental or human health concerns, resulting from the release of greenhouse gas emissions or pollutants, for example. What is needed is a model for Smart Villages that not only enhances the services and networks within villages but that also ensures that these villages are environmentally (as well as financially and socially) sustainable. Surely a village cannot be considered ‘smart’ if it ignores or pays mere lip-service to the ever-increasing global environmental concerns.

The aim of this paper is to present a framework for achieving environmentally sustainable Smart Villages and to demonstrate its application using a case study village in Assam, India.

2 A Pathway Towards the Environmentally Sustainable Smart Village

Environmental sustainability is often considered using a retrospective approach (Figure 3). The problem with this is that decisions (material choices, and solution design and selection, for example) are often locked in and difficult to change. This often means that a compromise is necessary and decisions are modified or solutions 'retrofitted' to address environmental sustainability goals for particular housing or infrastructure projects. This leads to sub-optimal solutions that can potentially be even more wasteful and inefficient than business-as-usual options. The more preferred approach for designing Smart Village solutions that address environmental sustainability concerns is an integrated approach (Figure 3), where environmental criteria are a key driver in the development of Smart Village solutions from the outset. This approach enables maximum potential environmental benefits from the optimisation of resource use and minimisation of waste and other environmental effects. It can also provide opportunities for better cost
optimisation as a reduction in resource demands and waste production often leads to reduced costs.

In order to facilitate this integrated approach to the development of Smart Village solutions, a four-step process is proposed. This includes Step 1: Understand current performance, Step 2: Understand local context, Step 3: Identify and analyse potential Smart Village solutions, and Step 4: Design and implement ‘sustainable’ Smart Villages.

**Step 1: Understand current performance**
It is important to understand how a particular region, country or village currently performs from an environmental perspective in order to identify opportunities for improvement and to provide a benchmark for the performance of potential Smart Village solutions. Depending on the scale of the information required, various sources of this information exist. For example, the Environmental Performance Index (Yale University, 2018) provides environmental performance data at the country scale across a total of 24 environmental performance indicators.

Other tools and frameworks can also be used to provide an understanding of a region’s current environmental performance, such as the UN Sustainable Development Goals (UN, 2018). A survey of community members and observation of specific village communities can also provide the empirical evidence needed to better understand the current performance and issues being faced within a village. Bottom-up data like this is typically preferred, due to its greater specificity and reliability.

**Step 2: Understand local context**
A critical element of improving the environmental performance of a village is to understand its current characteristics and context. This step involves exploring the local resources available, such as materials, energy and water, and determining the ability for these local resources to be more widely used in the construction and operation of a village. An understanding of locally available skills and expertise is also essential, especially as maximising the use of these to meet specific village community needs is a key component of creating a sustainable Smart Village.

By closely aligning the selection of construction methods and materials with community needs, expertise and skills it is also possible to meet social sustainability goals. While the
ultimate goals may be to improve the environmental performance of a village, current community expertise may not be conducive to maximising this environmental performance. If new construction techniques or better performing construction materials are shown to perform better from an environmental perspective than current practice, then further training and education of villagers may be necessary. This can then be supported by other Smart Village solutions, such as e-learning.

**Step 3: Identify and analyse potential Smart Village solutions**

This step involves identifying potential Smart Village solutions considering the contextual information gathered in Step 2. Appropriate solutions for one village may not be the best solution for the next village. It is important that each potential Smart Village solution for improving environmental performance is assessed in the context of each village. In addition to considering the contextual aspects of potential alternative construction methods, materials or systems and their appropriateness (Step 2), each potential solution for improving the environmental performance of a village must be analysed from a life cycle perspective. This involves quantifying the total input flows (energy, water and resources) and output flows (waste, emissions and pollutants) over time, to determine whether net environmental benefits are able to be realised and ultimately whether or not a potential solution is environmentally sustainable. This should also be used as an opportunity to identify areas for further improvement in the way things are currently done and in the proposed alternative solutions, in the interests of striving towards achieving an environmentally sustainable Smart Village.

A number of approaches exist for analysing the environmental performance of Smart Village solutions, such as Bioregional's One Planet Living (Bioregional, 2018) (Figure 4) and The Living Future Institute’s Living Building Challenge (Living Future, 2017). More in-depth analysis is also possible using sophisticated life cycle assessment data and techniques, as outlined by Crawford (2011).

![Figure 4: Bioregional's One Planet Living assessment criteria](source: Bioregional, 2018)

As part of identifying and analysing potential solutions for achieving an environmentally sustainable Smart Village it is important to identify the associated training and education...
needs for their implementation. This capacity building could take the form of higher education or on-the-job training for villagers.

**Step 4: Design and implement 'sustainable' Smart Villages**
The final step in the proposed process for identifying and implementing sustainable Smart Village solutions is to design and implement the selected solutions. This should involve the village community as well as trained professionals (designers, engineers, contractors etc.). This will not only help ensure that certain construction standards are met, but will also help to maximise the opportunity for villagers to be trained in any aspects of this process that may be appropriate, and develop skills and capabilities that will enable them to modify and maintain buildings and infrastructure systems into the future. This will provide an element of ownership and promote a greater feeling of engagement in the Smart Village upgrade process.

3 Case Study - Step 1: Understand Current Performance
This section describes one approach to step 1 of the proposed framework - understanding the current environmental performance of a village. As mentioned previously, a range of tools can be used to assess the current environmental performance of a village, including Yale’s Environmental Performance Index and the UN Sustainable Development Goals. While these tools are able to provide a very broad and high level overview of the performance of a country or region, which may help to prioritise areas for improvement, they don’t provide the level of detail necessary for community or village specific decision-making. For this, a bottom-up approach is needed. This involves collecting data from a specific village, or group of villages. The environmental performance of a village is based on a broad range of criteria, as shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Environmental performance criteria</th>
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<tr>
<td>Global warming (greenhouse gas emissions)</td>
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<td>Resource depletion (non-renewable materials and fossil fuels)</td>
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<td>Ozone depletion</td>
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3.1 Approach
A holistic understanding of the environmental performance of a village would ideally consider all of the criteria in Table 1. However, capturing data on each of these criteria in a remote location is challenging, not only for logistical reasons (distance, time, cost), but also as much of this data is not routinely captured by homeowners or authorities.

3.1.1 Location
The state of Assam in India is used as a case study to demonstrate step 1 of the proposed framework. Assam has a very high proportion of its population living in villages, many of which are characterised by poor quality housing and insufficient infrastructure. A significant opportunity and need exists for improving village living standards, with the challenge being to achieve this while also improving environmental performance. A total of 2,153 houses across 37 local villages on the island of Majuli were surveyed in 2017-8 as part of a larger project with the Government of Assam. This survey covered population demographics and housing characteristics, from which some environmental-related data can be extracted (see Table 2).

| Table 2: Environmental-related data collected |
3.2 Findings

The data collected highlights the relatively primitive nature of village housing and lifestyles compared to that which is more prevalent in cities or more developed countries. For example, air conditioners, heaters, hot water systems, televisions, computers, washing machines and refrigerators are not universally owned. This section presents a sample of village characteristics and the associated environmental sustainability considerations.

3.2.1 Housing construction

In relation to housing construction, a variety of materials are used, ranging from more primitive earth and timber elements to brick and plastic (Figure 5). There are two key considerations in determining the environmental sustainability of the use of each of these materials: 1) is the material renewable? and 2) is it being used sustainably? Both questions are important to answer as a material may be renewable (e.g. timber), but it may be used at a rate faster than which it is able to be renewed (i.e. not sustainable). Various factors need to be considered, such as harvesting/extraction rates and processing practices, and rates of replenishment. Figure 5 indicates that the majority of existing houses use quite primitive, often renewable materials. The risk associated with improving housing in these villages is that materials that are non-renewable (e.g. concrete and plastic) may become more desired and prevalent, diminishing, rather than enhancing the sustainability of villages, in relation to housing construction at least.

![Table of housing materials of surveyed Majuli villages (no. of houses)](Figure 5)
3.2.2 Cooking

Data collected on cooking fuels (Figure 6) shows that households use a mix of renewable and non-renewable fuels. However, in this case, renewable fuels (e.g. firewood) can lead to negative health consequences due to reduced air quality. This shows the importance of a more holistic approach than a sole focus on environmental sustainability (for which burning timber may be a reasonable solution). As with housing materials, improving the environmental sustainability of cooking will involve shifting to more renewable fuel sources but will also need to consider the context of changing expectations and lifestyles, where existing cooking technologies and methods may be progressively replaced with more advanced technologies.

![Figure 6: Cooking fuels used in surveyed Majuli village houses (no. of houses)](image)

3.2.3 Technology

Technological solutions for Smart Villages will inevitably increase the demand for connected devices, such as smart phones and computers. According to the survey data, 77% of households do not currently have access to either of these devices. The uptake of devices needed to take advantage of Smart Village solutions (such as e-health and e-learning) will not only demand resources in their manufacture, but also electricity for powering them. This will create an increase in energy use within villages, potentially negatively effecting the ability for a village to perform sustainably, unless renewable energy sources form part of the Smart Village solution.

This case study uses only a sample of the data that is required to understand the environmental performance of a village, but it does give some insight into the process involved and the type of data that is required. It is important to note that the survey was not designed with the primary purpose of understanding the environmental performance of the villages surveyed. A more targeted survey would thus be more useful in understanding the resource inputs and waste and pollutant outputs associated with a village. This would include developing an understanding of the environmental flows occurring both within and outside of the village. The data collected should give an indication of the types of resources, wastes and pollutants associated with a village as well as their scale. The collection of this data provides a benchmark for Smart Village performance so that potential Smart Village solutions can be assessed against the existing performance of a village to ensure environmental sustainability improvements and targets are able to be achieved (step 3). It also provides an indication of the extent of intervention that is needed to deal with the scale of the issues for a specific village.
4 Conclusions
Smart Villages must go beyond a purely technological solution to enhancing the existing networks and services of village communities. At a time when environmental issues are of utmost concern, promoting the utilisation of more of the very resources that have been responsible for these current issues is unsustainable and outright negligent.

This paper proposes a four step process for identifying and implementing sustainable Smart Village solutions. This involves a holistic and integrated approach to identifying appropriate solutions for improving the environmental performance of villages. It goes beyond a purely technological approach and relies on community engagement and an understanding of the local context, particularly in relation to available skills and resources, and local issues. The importance of a bottom-up approach to understanding the current environmental performance of villages was highlighted. The ability to understand and address specific village issues and characteristics using this approach was demonstrated through a preliminary study of data collected from a number of villages in Assam, India.

While environmental concerns are of utmost importance, the other aspects of sustainability – social and economic – should not be forgotten. These should also be considered when assessing any potential solutions for Smart Villages that might be proposed. Solutions that enhance all three aspects of sustainability should be prioritised, as these are likely to not only improve the environmental performance of a village but also provide health, education, employment and equity benefits.

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