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Realization of Vitality Optimization in Traditional Village Human Settlement Environment Supported by Intelligent Sensor Technology

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Abstract

The vitality of traditional villages (VTV) is a reference indicator for measuring the hollowing out of traditional villages. Human settlements in the world are based on the access and availability to the chief vitality factors of the geographical region. The traditional villages of China are the potential candidates for improving vitality optimization, as their development is still in the stage of infancy. This work proposes a framework that integrates complex subsystems of the traditional village human settlements with the vitality factors. The issues in these traditional villages are analyzed under the umbrella of social life, domestic life and agriculture, which is the primary occupation of people in traditional villages. Further, the work identifies the contemporary computing technologies and communication technologies used in various applications of intelligent sensor technology. This work associates the various subsystems of the villages, namely strategic, social, economic, resource and environment subsystem, and information subsystem, with the factors influencing dimensions of development, namely resources, service chain, sustainability, technology and institution. This framework can be further extended to include more elements of vitality factors.

Keywords: Communication Technology, LPWAN, Intelligent Sensor Technology, Subsystems, Human Settlements, Villages

1. Introduction

The notion of human settlements was initially defined by the famous scholar Doxiadis of Greece as the science behind the development and formation of human settlements [1]. The human settlements are viewed as rudimentary challenges to basic survival and further human development. In the early 1970s, the United Nations recorded the human settlements whilst the Vancouver Declaration states that Human Settlements (HS) are defined as the collection of humans in multiple dimensions, namely social, organizational, material, cultural and spiritual elements in cities, towns, villages and in rural areas. They focus on physical elements as well as on the delivery of service compositions [2]. It shows that efforts must be taken by the governments to provide basic facilities such as infrastructure, employment and public services to the sso-formedrural areas [3]. The traditional settlements expand the scope of the public sector services for rural areas by creating

industrial nodes and thereby improving the township [4]. Because of the intensive urbanization that increased the urban construction, the traditional HS are facing intense impacts, which leads to the deterioration of the classical landscape, lack of investment, mismanagement, and migration of longer-term [5], [6]. As a method to handle these challenges, the HS policies and planning methodologies are focused towards sustainable development [7], [8].

Many researchers have explored these traditional settlements from the perspective of environmental creation as well as intervention by integrating bioclimatic characteristics, attempting to protect and upgrade the traditional settlements, which improves energy efficiency [9]. The nature of rural and urban HS in China significantly differs from the rest of the world as they are highly unbalanced [10]. In addition to this, issues like pollution, underdevelopment of public sector facilities, clumsy construction, etc, further aggravate urbanization and industrialization [11]. These issues are actually blessings in disguise, which depicts a multidisciplinary research trend that attracts more scholars to investigate urban and rural town planning based on geography, ecology, sociology, etc [12].

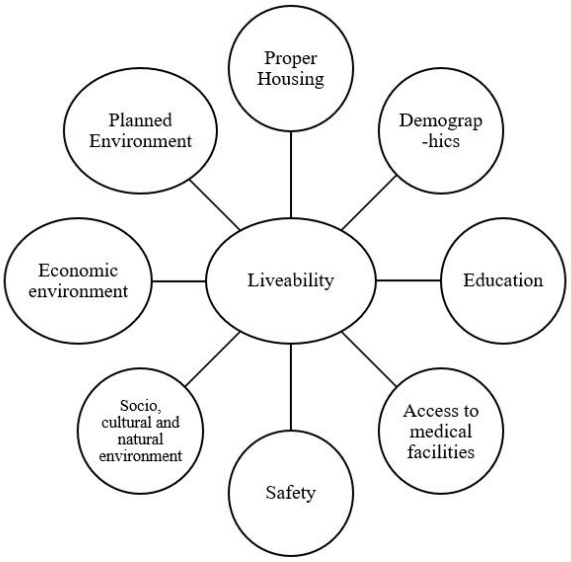

Figure 1. Factors Influencing Liveability

Liveability is the aggregation of factors that fosters quality of life. It encompasses built, as well as natural environments, economic sufficiency, equity, social stability, education, culture, recreation and entertainment [13]. The major focusing dimensions of liveability are listed as environmental quality, life, and sustainability, with some models presented in many types of research [14]. The constitution of the liveability index may include natural environment data like meteorological, terrain, land cover, natural disaster data, public services available, traffic, population, and social well as economic data. In all these systems, the data is used as indicators which are applied to discriminate the HS with a special focus on regional differentiation.

The word vitality has its etymology from biology, which indicates an abstract concept that refers to capability of the things to develop, overcome, and sustain [15]. The previous studies indicate that there has not been a universally acclaimed definition or concept for the vitality of village HS. It is viewed that the intensity of geographical spatial agglomeration facilitates the concept of urban vitality [16]. This concentrates on the transaction and activity, as well as on the diversity of the human population. These diversified activities of the village people and their interaction with social networks bring in region vibrancy. It is evident that urban vitality has an influential effect on sustainable development. It can be observed that village HS has shifted from single-issue research that centres only on the natural environment to more comprehensive and collective research that considers various factors like economy, culture and society and also involves multiple stakeholders. Figure 2 shows the various dimensions of vitality factors in HS in villages. These factors can be categorized under the umbrella of built structures like transportation structures, medical infrastructure, etc; habitat activities like population density sanitation, etc. and environmental interaction like road density, metro density, etc.

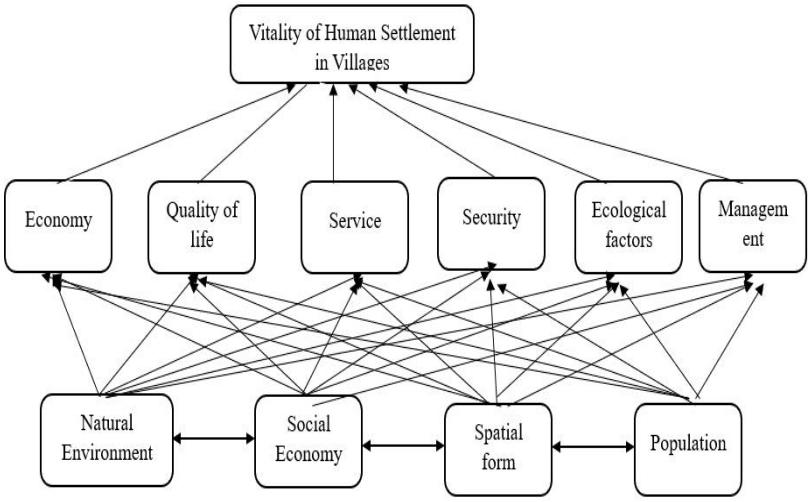

Figure 2. Vitality Factors in Villages

In addition to the primary vitality factors, certain other reasons also influence HS in any area. For instance, Figure 3 shows the vitality index of Zhejiang province of China, which includes the secondary influencing factors like catering, accommodation, shopping, tourism, fitness, etc., which are also important for assessing the quality of modern life.

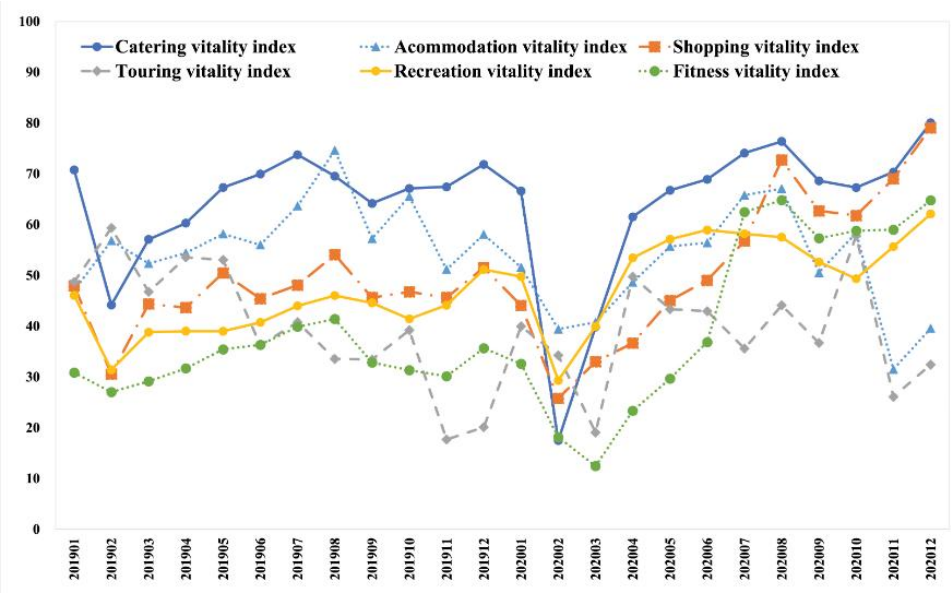

Figure 3. Change in Monthly Trends of Vitality Index in Chinese Zhejiang Province [17]

1.1 Human Settlement in Villages of China

The status quo of the optimization strategies adopted in the HS in Chinese villages is discussed here. The opening of Rural Anthropology as well as Sociology sticks to the early 20s of the 20th Century, which is marked as the golden era of rural construction in China. During this period, the development focused on the life quality of farmers, land structure, and agricultural prosperity. This rural construction movement is more concerned with reviving the nation through societal transformation, which is generally viewed as a subsidiary product of this revolution. China's national conditions imposed new ideas and rules for village construction. These activities integrated the intellectuals with the village farmers through technological promotion, imparting quality education with a special focus on agricultural economic development. It advocated the involvement of the whole people as well as an in-depth study of the villages with a mention of the complex development exploration of the local needs.

For instance, the research made on the village autonomy of Wanxi, Henan, around the early 30s, reveals that weak or strong change within the state or local has occurred due to the difference in the existing village or local management structure along with social conditions of the state. This autonomy represents the spontaneous action of the locales and also indicates the existence of endogenous endemicity. This active village elite promotes rural stability as the locality does not turn against the development. Figure 4 represents the association between the exploration and transformation in villages.

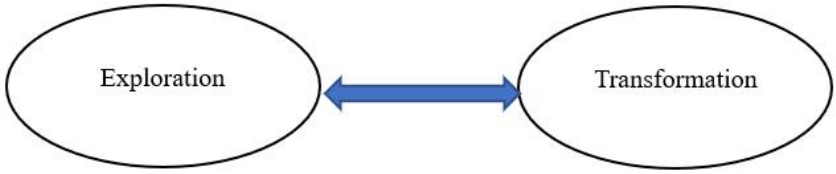

Figure 4. Exploration and Transformation Cycle

1.2 Exploration in Villages

The village development in the early 80s greatly reflects the rural construction in the rudimentary stage, and the transition of the behaviour of local government positively influenced the development of autonomous innovation in villages. All the countries began to explore their own development model, thus accelerating the collective development of the economy as well as HS in villages. The development of non-agricultural industries enabled the creation of resources with imbibed local characteristics. Numerous distinctive villages like Nanjie, Wan Feng and Huaxi have emerged with unique economic-oriented conceptual models. They have further stimulated the development of the villages and played a positive role in fostering local development. Industrial development is tightly coupled to the economy and causes serious damage to the village's natural ecological environment, which hampers the traditional aspects. On the other hand, in most villages, where there is a scarcity of resources and manpower, the primary occupation is agriculture. So, any non-agricultural development is not achievable in many rural areas. Figure 5 shows the distribution of the Chinese population in urban and rural areas.

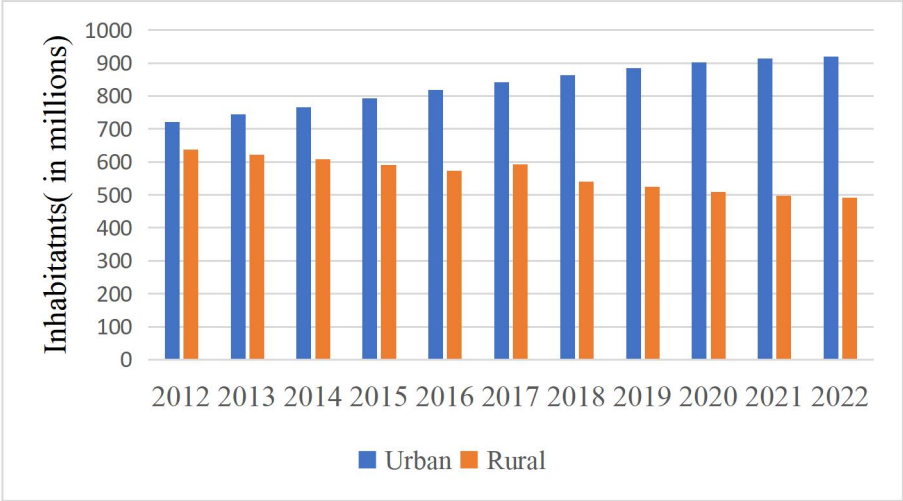

Figure 5. Distribution of Population in China (Data Source: Statista)

1.3 Transformation Phase of Villages

The exploration led to the development of thousands of the same kinds of villages with varied degrees of urbanization, construction strategies, natural environment and human culture. The regional and social aspects face a lot of differences in the excessive practice of uniqueness. Hence, these villages appear to exercise vague positioning that is totally divorced from reality. They also tend to produce symbol which is against reality, like wall paintings and making up local and regional historical stories. This has further been accelerated by the involvement of non-governmental organizations. These practices are affected by the participation of the external forces

as well as the spontaneity. The experience gained in the construction of the villages can be studied from the rural construction, which has gradually transformed a single force into multiple forces with internal and external pressure.

1.4 Role of Sensory Technology in Vitality Optimization of Traditional Villages

Leveraging Sensor Technology (ST) in optimizing the vitality of villages is not recent. The world has witnessed a large number of intelligence-enabled cities, townships and villages. This employs smart village design by deploying smart technology to construct viable services to benefit the village community for the sustenance of the social ecosystem, which fosters economic growth. The construction of intelligent villages using ST demands the involvement of many hierarchical structures. This should consider the fact that most of the resources are shared, and hence, a comprehensive and holistic approach is the need of the hour. Figure 6 shows the phases for the design and development of a smart village, which involves essential components like mapping, identification, decision making, development of prototype, and evaluation. And scale-up. It has to be noted that the primary deciding factor of ST is the coverage area, data rate, cost and power [18].

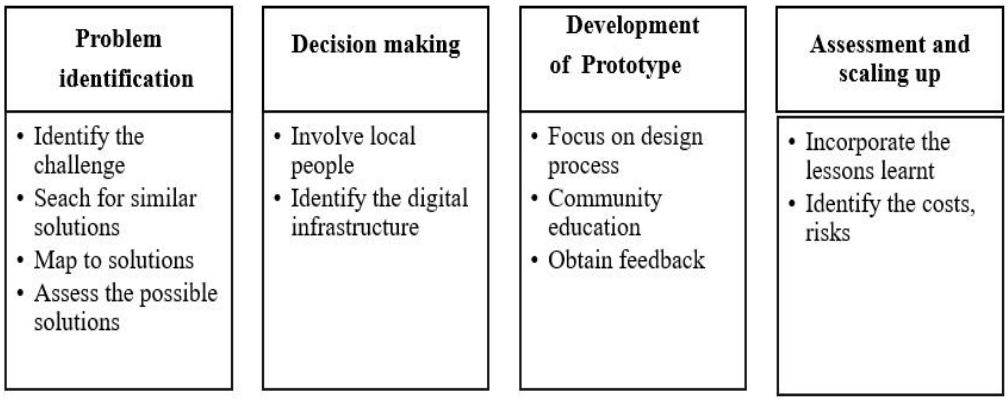

Figure 6. Phases of Design and Development of Smart Villages

This work focuses on the design of a novel framework by leveraging the ST to optimize the vitality of traditional village HS.

2. Related Works

This section focuses on a few important works that discuss the vitality enhancement of HS in villages and other forms of HS. A hybrid Galactic Swarm Optimization is developed that utilizes renewable resources for managing energy [19]. The work uses the point estimation method, which is used to model the inherent uncertainties of the power resources to render optimal power supply. This algorithm manages the power distribution system with better power stability. Formulating a comprehensive evaluation index system focussing on HS's vitality using projection models, spatial correlation, measurement models, spatial pattern and its influencing factors are studied [10]. The results indicate that spatial differentiation characteristics focusing on the vitality of HS in Dalian are encouraging, and it declines from the centre to the border.

Another work that focuses on constructing an evaluation index to evaluate the suitability of HS that depends on the ecological environment, economic development as well as on public services is done by Yi Wang [20]. These are integrated with resident's preferences, spatial patterns, spatial relationships and population distribution in the famous Zhejiang Province. It has been observed that from the perspective of ecology, the HS declines from south to north. The entropy method integrated with cluster analysis is employed to assess the HS by segregating the regions into 31 provinces [21]. The findings show that the regions can be divided into demonstration regions, potentials for development, weak points, satisfying basic needs, and further backward regions.

The vitality study of Shanghai is done using urban vitality from the multi-sourced data, and the outcomes are a monocentric vital pattern [22]. The empirical analysis identifies three main clusters, namely the old urban region, Lujiazui and the residential agglomeration region. The results showed a positive correlation, which indicates high accuracy. A framework exhibiting the impact of HS on rural development based on the structural equation model is proposed [23]. This is used to

study the vitality across China, and its effects include scale effects, health effects, mobility effects, etc. The aspects include infrastructure, natural environment, public service levels, housing conditions and human social amenities [24].

The HS areas based on natural factors such as relief degree, land cover, average land surface temperature, water resource index and frontal area index are studied using the GIS [25]. The study reveals that unsuitable HS are distributed in mountainous regions with problems like scarce water resources, inadequate vegetation cover, etc. A deep learning-based analysis was done to study the street-view images and form a composite indicator developed by analyzing the data from social media [26]. The investigation is done using factors such as neighbourhood attributes, urban function, location, street configuration and landscape. The results indicate that population density, age, open space, ratio of sidewalk, shopping, streetlights, and leisure density.

An extensive empirical study that explores the relationship between the HS and livelihood capitals on the village-based agricultural land transfer is done [27]. This analyses the regional differences in decision-making of land transfer behaviours. The results showed that capital accumulation directly increases the agricultural land inflow. The ecological function of the Sichuan Tibetan areas is studied to understand the vitality index [28]. The analysis of cultural elements in the aspects of folklore, traditions and legends are primary factors that affected the HS. The interactive relationship between the evolution of HS and its limitations was clarified. The relationship between HS and health factors is done in three dimensions, including human activities and the physical and natural environment. The correlation and multiple linear regression methods are used to analyze the relationship between the factors and human health [29]. To foster the living environment in villages and improve the quality of life among the HS emanates from the human settlement theory [30]. The deployment of BIM technology in the process of collaboration, visualization, and optimization of environmental protection in villages amidst industrial development is done.

The detailed literature indicates that works are done in the genre of vitality optimization in traditional village HS. However, not many works focus on the development of intelligent solutions leveraging the ST to improve the quality of life. Hence, this work focuses on the development of a framework that provisions the possible inclusion of contemporary computing technological solutions to help the HS in traditional villages.

3. Methodology

Detailed analysis using scientific methods is deployed to investigate the subsystems, their relationships, and the dimensions of ST-enabled intelligence villages. This system is very complex, with many inter and intra-related aspects. As the villages are holistic multibody systems, many factors with many versatile dimensions should be considered for designing the framework. This work describes the association between the various subsystems of the villages, namely strategic, social, economic, resource environment subsystem, and information subsystem and the factors influencing dimensions of development, namely resources, service chain, sustainability, technology and institution [31], [32]. Figure 7 shows the proposed framework that maps the subsystems with the components of development using sensor technology.

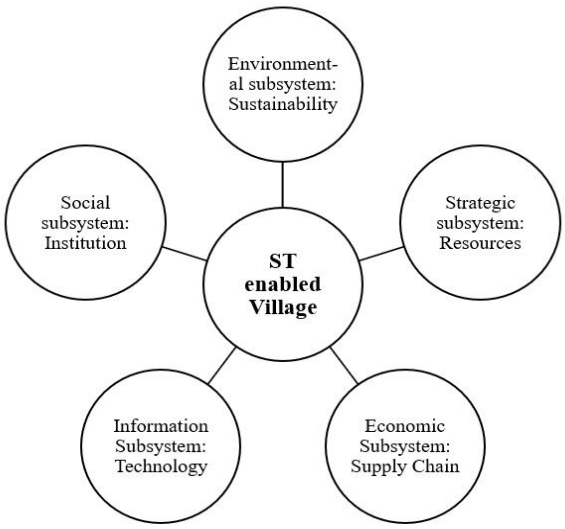

Figure 7. Framework Mapping Subsystems of Villages and its Vitality Components

The micro-level analysis of the vitality components mentioned in the proposed framework is presented in Table 1. The effective management of these dimensions must be aligned with the subsystems such that they can be independently employed by the villagers to optimize their vitality. These vitality elements can be outsourced to the people and stakeholders outside the HS of the village. The following are the major indicators that evolve the vitality of the HS in traditional settlements:

- Natural resources: supply of water, energy, provisioning education, promoting public health, management of village fund and other fundamental infrastructures.
- Technology: This is used by the community. The technology encompasses ICT tools, ST, and agricultural technology, which imbibe the economic prosperity of the HS in the traditional villages.
- Services: This included essential services as well as economy-based services.
- Institution: It is the governance of the village through local bodies.
- Environmental ecosystem: This is the behaviour and actions of people maintaining the sustainability of the available natural resources.

Table 1. Indicators of Vitality Dimension

Vitality Dimension	**Micro level indicators**
Resources	Natural resources, water supply, power supply, Human resources, proper infrastructure, economic resources
Technology	ICT, ST, IoT, ML, DL, [33]
Services	Essential services, medical facilities, economic facilities
Institution	Governance of villages, community, central government, local bodies, NGOs, research agencies, educational institutions,
Sustainability	Air quality, pollution control, increase of greeneries, soil and land usage, water contamination, etc.

The proposed framework maps the village subsystems with the vitality dimensions to achieve the specific goals using the ST. Table 2 summarises the goals and the specific issues that have to be addressed to optimize the vitality of the traditional HS in Chinese villages. As most of the villager's life centres around mainly three dimensions, namely agriculture, domestic purpose and social life, the development in the vitality factor must consider these factors as primary concerns. The realization of the solutions for these issues is done by choosing appropriate sensors along

with a communication medium which focuses on connectivity among the devices that are leveraged at various levels of the villages to improve the vitality factor of the HS.

Table 2. Primary Issues in Traditional Villages

Dimensions	Issues prevailing
Agriculture	Weather forecasting, climate monitoring, water management, irrigation control, pesticide management, fertilizer management, health and growth monitoring, autonomous disease monitoring, cattle management, recycling agricultural waste, market analysis, soil temperature and moisture level measurement etc.
Domestic life	Energy and water management, Monitoring and surveillance, Gas and smote detection, medical facilities, psychological help, access to treatment for chronic illness, home and farmland security, water quality management, temperature measurement, sound and pressure monitoring, electrical equipment control, human detection etc
Social life	Pollution level monitoring, educational facilities, health care facilities, higher education, crime prevention, recreational facilities, transportation and other logistics, infrastructure, etc

The framework addresses the above-mentioned problems using ST, which includes end devices, i.e., the sensors and their communication protocols. The integration of these two elements is quintessential for the implementation of any smart applications in the geographical land area [34]. The ST depends on the following types of connections for effective communication and control of sensor devices:

- Device-Device
- Device-Gateway
- Gateway – Data source
- Data systems- Data System

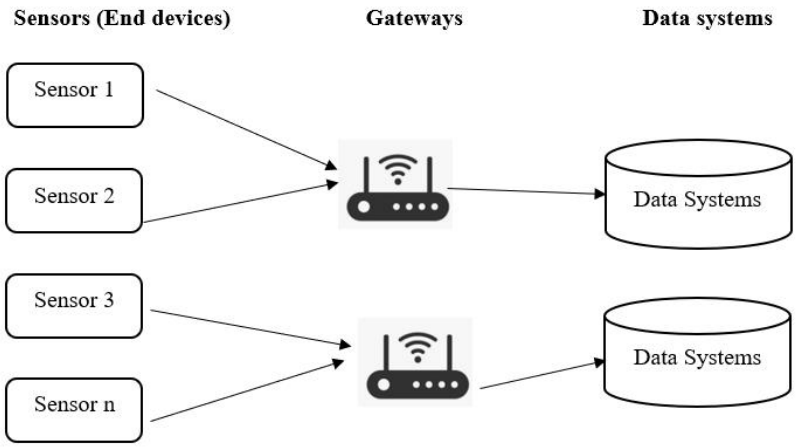

Figure 8. Sensors and their Connectivity

Any sensor that is deployed in the field of the village needs to follow the sequence of activities as mentioned in Figure 9. The data from the physical sensor devices are captured, which represents any physical phenomena [35], [36]. The environment of the village is learnt or observed by the sensor devices. This data is used for computing the field aspects and characteristics. The communication protocols are specific to the application that is deployed [37].

This is then processed by the controllers or decision support system. The data, along with its decisions, are archived for future use. Figure 9 shows the complete sequence of processes in implementing ST in the village HS to improve the vitality.

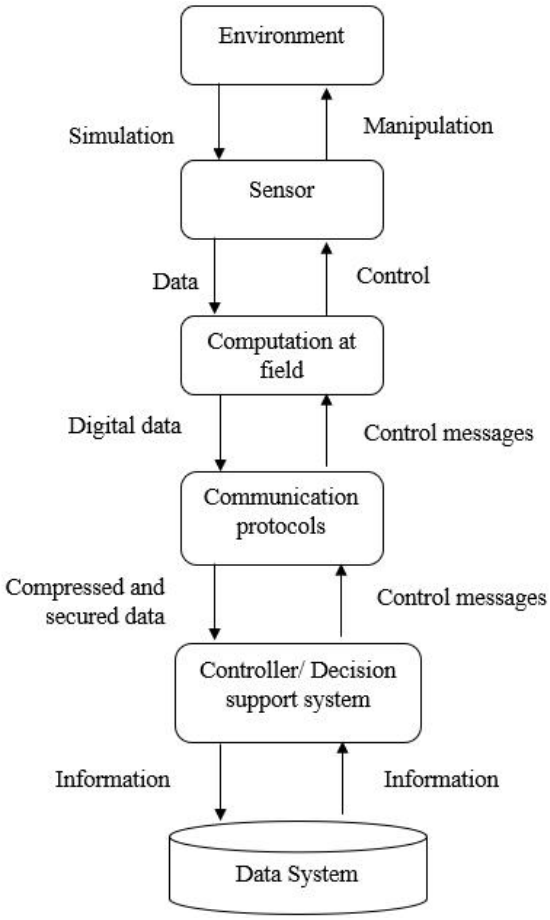

Figure 9. Sequence of Activities in the Implementation of ST in Villages

In addition to this, each specific application demands the usage of a specific communication protocol and the sensor. As technology is always evolving, more and more complex and advanced sensors flood into the field of ST [38], [39]. It is important to deploy the right sensor for the right application [40]. The integration of sensors, computing devices and actuators through communication protocol paves the way for digital transformation. The ST is enabled by means of these devices and by contemporary computing technologies as follows:

IoT Enabled systems: This fosters machine-to-machine connections, which encompasses the sensors, interfaces, microcontrollers, Low Power Wide Area Networks, Nera field communication, energy-saving mechanisms, localization technology, Radio Frequency Identification, Bluetooth, Zig-Bee, Z-wave, etc.

Computing technologies: These add values that help in decision-making while improving security from a holistic perspective [41]. The technologies like cloud computing, fog computing, Big data analytics, artificial intelligence, IoT, Machine Learning, blockchains, deep learning and virtual reality are some technologies that can be thrived upon. Table 3 lists the communication protocols that can be leveraged for different ST applications.

Table 3. Communication Protocols for Applications Leveraging ST in Villages

Application	**Protocol**
Weather Forecasting	LPWAN
Water Management	LPWAN
Animal Husbandry	LPWAN, RFID
Livestock Management	LPWAN, RFID
Dairy Management	RFID, Zig Bee, NFC, LPWAN

Health Care	RFID, Zig Bee, NFC, Bluetooth, Wi-Fi, LPWAN, Cellular
Energy Management	LPWAN
Smart Street Lights	LPWAN
Smart Home	RFID, Zig Bee, LPWAN, Z-wave, Bluetooth, Cellular, Wi-Fi
Monitoring	Zig bee, RFID, LPWAN, Cellular
Waste Management	RFID, Zig bee, RFID, LPWAN

The implementation of these technologies in improving human settlements is guided by the activities mentioned in Figure 6. Detailed analysis is made before leveraging the technologies, and the existence of similar types of social structures must be made. The decisions should be made based on a detailed investigation of the locales, geography, demography and the compliances in that locality. The next phase is the design, where the communication and infrastructure design of the sensors must be decided. The last phase is similar to the feedback phase, where the established sensor devices and networks are analyzed for their efficiency and usability. However, the proposed framework is very generic and demands customizations based on the requirements of the locals. This involves a more detailed analysis of the factors enumerated in section 1, which is a tedious process.

Thus, the proposed framework focuses on improving the lifestyle of the village habitants in Chinese villages by leveraging sensor technology. The HS in the villages will benefit from the deployment and realization of the framework.

4. Conclusions and Future Work

Liveability or vitality in any geographical area is a primary factor of concern for HS. As the technologies and government policies take a long way to reach the stakeholders of the traditional villages, it is essential to throw more focus on these villages as their development and quality of life are important for the country's economy. In this work, a detailed analysis of the vitality factors in Chinese villages is identified. The limitations of the HS vitality factors are studied from the literature. The proposed framework integrates the village sub-systems along with the vitality factors of the traditional HS of China. Then, the dimensions of focus for the development of the villages in three aspects, namely agriculture, social life and domestic life, are done. In addition to this, the issues in the villages and the probable solutions, along with the communication and ST, are also mentioned in this work. In the near future, the implementable systems shall be proposed and realized.

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