Department of Civil Engineering

Indian Institute of Technology, Ropar

Ropar – 140001

Development Engineering Project Report

On

“Revitalizing Rural Life: A Smart Village Initiative”

Submitted in B. Tech Third Year Core Course on Development Engineering Project (CP301)

Under the Guidance of **Dr. Naveen James**

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<u>CERTIFICATE</u>

This is to certify that the project entitled, "**Revitalizing Rural Life – A Smart Village Initiative**" has been done by: - **Akash, Neeraj Kumar, Nikunj Mahajan and Tayyab Choudhary** of Bachelor of Technology in Civil Engineering from **IIT Ropar** under the supervision of **Dr. Naveen James.**

Dr. Naveen James

DECLARATION

We hereby declare that the project entitled “**Revitalizing Rural Life – A Smart Village Initiative**” is being submitted as a Development Engineering project for the course CP301 in the third year of the B. Tech programme at IIT Ropar under the guidance of Dr. Naveen James, Assistant Professor, Department of Civil Engineering. We further declare that this written submission contains both our thoughts and those of others, if any. In the event that we have used someone else's thoughts or words, we have properly cited and referenced the sources. To the best of our knowledge, we have not distorted any concept, information, fact, or source. As a result, we declare that our team has upheld all standards of academic integrity and honesty.

Date: 23-April-2023

Signature of Group members

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Acknowledgement

This project combines theoretical and practical work. We would like to express our sincere gratitude to Dr. Naveen James for their guidance and corrections throughout the course, without which this project would not have been possible.

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We are grateful to IIT Ropar for providing us with this opportunity. We also acknowledge our parents and family members for their unwavering moral and economic support.

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Finally, we would like to emphasize that any omission in this acknowledgement does not imply a lack of gratitude.

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1. Introduction

The research and development of the village as a smart village is the subject of this project report. A "smart village" is a collection of services that are effectively and efficiently provided to its residents and companies. The idea behind a "Smart Village" is that improved energy access catalyzes advancements in infrastructure, including roads, buildings, bridges, canals, ponds, sewage systems, schools, colleges, hospitals, etc., that in turn support further advancements in energy access. This paper focuses on more responsible individual and group behaviors to create a happy society, access to ensure basic facilities, and increased resource usage efficiency.

By using smart technologies and services, we are creating a smart village. A "Smart Village" will provide the community of the village with long-term social, economic, and environmental welfare actions while also ensuring good education, better infrastructure, proper sanitation, health facilities, waste management, renewable energy, environment protection, clean drinking water, resource use efficiency, etc. A "Smart Village" that is independent in its provision of services and employment and is nonetheless well-connected to the rest of the world is urgently needed to be designed and developed.

The Smart Village can achieve SMART infrastructure, SMART service delivery, SMART technology and innovation, and SMART institutions, along with optimal mobilization and utilization of available resources, leading to faster and more inclusive growth. This is based on various programs taken by Central and state governments and further technological Initiatives.

The adoption of technologies like Geographical Information Systems (GIS), IoT, Remote Sensing, Cloud Technology, etc. is fundamental to the transformation of an existing village into a smart village. These technologies comprise many levels in the fundamental framework of the smart solutions for the smart village, which are further integrated through secure interfaces to global applications like smart agriculture, smart transportation, smart health, smart education, etc.

2. Objectives

The objective of achieving 'Smart Village/Ward' status is to empower the community, both individually and collectively, to make informed decisions using smart technologies supported by skilled manpower. The key goals of a Smart village are as follows:

- Accelerating connection and information/knowledge exchange to boost productivity to drive economic growth.
- Enhancing the quality of life in a safe and secure environment for residents to live, work, learn, and play.
- Promoting a greener environment through better resource planning for social and economic sustainability.
- Organizing settlements more efficiently, the population of the village is dispersed unevenly, and it has poor access to the local roads. These might be redistributed while maintaining appropriate zones for residential areas, playgrounds, agricultural space, and locations to build different infrastructures like a biofuel production facility and overhead water tanks.
- To enhance the quality and quantity of agricultural production, 'Sensor' technology is being utilized to make farms smarter and more connected through a farming approach known as "Precision Agriculture" or "Smart Farming". This involves incorporating sensor technology to make agricultural practices more intelligent and efficient.
- To ensure efficient and sustainable utilization of surface and groundwater, it is important to establish provisions for water supply that cater to agricultural, household, and drinking water needs. This approach, referred to as "Smart Water Supply", aims to facilitate effective and judicious use of water resources in various sectors.
- Smart Sanitization involves utilizing advanced technologies and equipment to ensure proper sanitation practices, leading to healthier and disease-free villages.
- Smart Education involves the incorporation of advanced technologies and innovative approaches to enhance the quality and effectiveness of education in various settings. This may include leveraging digital tools, online resources, interactive learning methods, and personalized learning techniques to create a more engaging and dynamic learning experience.

3. Theoretical Aspects of the Problems

3.1 Roads and Connectivity

- Lack of planned infrastructure leads to inconsistent road building and varying road widths, resulting in unsafe road conditions and a high number of accidents.
- Rural connectivity is essential for the socioeconomic development of rural communities, providing access to education, and healthcare, and lifting residents out of poverty.
- Improved road connectivity has been shown to decrease rural poverty levels, highlighting its significance in reducing economic disparities.
- Better roads contribute to economic growth and poverty eradication by reducing transit, consumption, and production costs, enabling efficient movement of goods and people.
- Enhanced road infrastructure benefits various aspects of rural life, including improved access to schools, healthcare facilities, and markets for farmers, strengthening the supply chain and fostering economic growth between urban and rural areas.

3.2 Sanitation

Wastewater is not properly disposed of by people. It gathers near their hutments and spreads numerous diseases. Even if there are bathrooms available, many still use them as storage spaces and urinate in public. It gets confusing during the monsoon since the fields are muddy. It's nasty to pass close by as they faeces by the side of the road, walkway or railway line. Every celebration includes a meal for the town or neighborhood feeding produces a lot of thermocol or plastic trash. And it never disintegrates. The village lacks suitable landfills, which causes the rubbish to accumulate. Stunting is made worse by poor sanitation, which is connected to the spread of diseases like cholera, diarrhoea, dysentery, hepatitis A, typhoid, and polio. Poor sanitation lowers societal and human well-being.

3.3 Pure Drinking Water

The primary challenge faced by the people of Bhalian is the lack of clean drinking water. Water contamination affects 95% of our water supplies, making it the most impacted of the top three human requirements of food, water, and shelter.

At least 35% of all diseases impacting rural India are caused by drinking water. The availability of sufficient amounts of high-quality water as well as safe sanitation practices in rural areas is related to the population's health and economic prosperity. Water is necessary for maintaining cleanliness as well as for drinking and cooking. Every year, millions of people suffer from waterborne infections that can be fatal due to the lack of access to clean drinking water and the usage of contaminated water.

3.4 Agricultural

The main business in Bhalian Village is agriculture, poultry, dairy products, animal conservation, and nursery. Farmers face infrastructural and economic problems, mainly due to the lack of technological resources and education. Irrigation is crucial for agriculture in India, as the country's rainfall is uncertain and erratic. Assured irrigation is necessary for sustained progress in agriculture. Organic farming with modern techniques and equipment can increase productivity and reduce work time

3.5 Electricity

Electricity plays a crucial role in rural areas by supporting economic development by providing power for machinery and equipment, enabling education through the use of computers and internet access in schools, facilitating healthcare by powering medical instrumentation and refrigeration, improving quality of life through lighting and appliances, and enhancing agriculture by providing power for irrigation systems and farming equipment.

4. Findings

4.1 Roads and Connectivity

The majority of the roads in the village networks are made of gravel or dirt. Gravel roads have a problem in that they typically deteriorate fast, especially during the rainy season, impeding access to markets and healthcare facilities during critical periods and disrupting transportation services.

The provision of gravel roads at a minimal initial cost is fraught with problems. These consist of:

- Road surface causes damage to vehicles and equipment.
- Insufficient drainage and watercourse crossings.
- Short expected road life owing to erosion and wear.
- health risks and reduced farming production from dust.

Rural people now expect the government to create and maintain roads that provide for all-weather access and regular transport services.

The rates of gravel road deterioration and the issues related to maintaining gravel roads are projected to worsen as economies develop and traffic volumes rise. Consideration must be given to strategies that raise the attraction of investing in sealed roads through technological advancement and the monetization of the advantages of upgrading to a sealed road standard on the economic, social, and environmental fronts.

4.2 Pure drinking water

Since life cannot exist without water, water is properly equated with life. It is crucial to our survival more than anything else. Humans can go without food for a few weeks, but they cannot go even a few days without water. It is necessary in every aspect of life. In comparison to surface water, groundwater is typically less prone to contamination and pollution. A village's population of about 95% relies entirely on groundwater which is quickly running out. A wide range of land- and water-based human activities are polluting this priceless resource in Bhalian, where groundwater is used heavily for irrigation and industrial uses including chimneys.

4.2.1 Groundwater analysis

Groundwater development refers to the percentage of the available groundwater that is being withdrawn for various uses like irrigation, domestic, and industrial purposes. In the case of Ropar, the fact that the groundwater development percentage is only 38% indicates that a significant amount of available groundwater is still untapped.

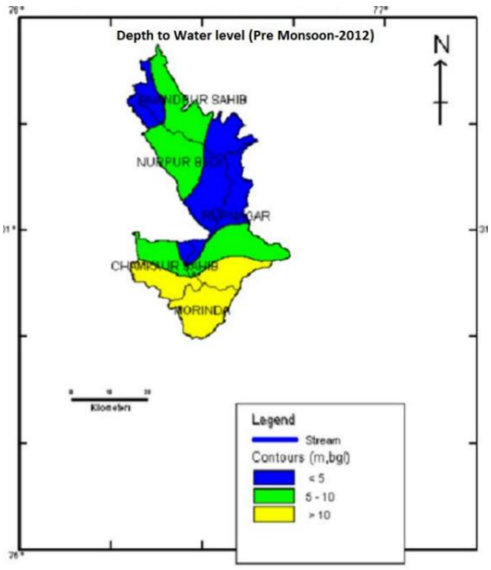


Fig 1– Depth of water table
(*Source: cgwb.gov.in*)

Block Name	Net Annual Ground Water Availability (MCM)	Existing Gross Ground Water Draft for irrigation (MCM)	Existing Gross Ground Water Draft for all uses (MCM)	Allocation for domestic and industrial requirement supply upto next 25 years (MCM)	Net Ground Water Availability for future irrigation development (MCM)	Stage Ground Water Development (%)	Category
ROPAR	143.85	42.75	54.10	13.46	87.64	38	SAFE

Table 1- Groundwater development percentage
(Source: cgwb.gov.in)

4.2.2 Chemical constituent in Groundwater

The shallow and deep aquifer chemical quality data show that all major cations (Ca, Mg, Na, K) and anions (CO_3, HCO_3, Cl, SO_4) are within the

BIS, 2012. K. permitted limits. A water sample has slightly more iron than the allowed limit of 1.0 mg/l. Well, waters in Bhalian have arsenic levels that are higher than the BIS-recommended allowable limit of 0.05 mg/L (0.096 mg/L).

4.3 <u>Sanitation</u>

Improper waste management systems can lead to the accumulation of garbage and waste in the community, which can pose a threat to public health and the environment. In addition, a poor outlet for wastewater is a common problem in some areas, resulting in unpleasant odors and potentially harmful effects on plants and animals. This can negatively impact the quality of life of people in the community. Another issue is the practice of defecating by the side of the road or pathway, which can create an unpleasant atmosphere for passersby. During the rainy season, this becomes even more problematic as it can turn into a muddy field and create a nuisance for everyone. Therefore, it is essential to prioritize hygienic disposal or recycling of waste and improve wastewater management to create a safer and healthier environment for all.

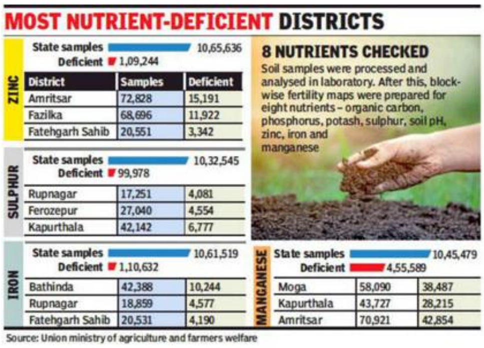
- According to our study and calculation using the sample size of 40 houses, we conclude that the availability of private toilet facilities in the village was only about 65% and 73.07% of them were using it appropriately with 84.21% of the toilets connected to septic tank.
- A high prevalence of outdoor defecation has been noted. When asked for the reasons for not using, the majority expressed that they were comfortable with outdoor defecation.

4.4 <u>Agricultural Issues</u>

In Bhalian, Farming is the main source of income. So, it is an important area that needs to be covered in the development plan. Some of the issues that we found there are:

- Crop Residue Burning: Burning crop residues is a common practice there, which contributes significantly to air pollution. It also leads to soil degradation, as the nutrients from the crop residues are lost.

- Soil Degradation: Overuse of chemical fertilizers and pesticides has led to soil degradation. This has resulted in decreased soil fertility, decreased crop yield, and loss of biodiversity.



MOST NUTRIENT-DEFICIENT DISTRICTS

ZINC

State samples 10,65,636
Deficient 1,09,244

District	Samples	Deficient
Amritsar	72,828	15,191
Fazilka	68,696	11,922
Fatehgarh Sahib	20,551	3,342

SULPHUR

State samples 10,32,545
Deficient 99,978

District	Samples	Deficient
Rupnagar	17,251	4,081
Ferozepur	27,040	4,554
Kapurthala	42,142	6,777

IRON

State samples 10,61,519
Deficient 1,10,632

District	Samples	Deficient
Bathinda	42,388	10,244
Rupnagar	18,859	4,577
Fatehgarh Sahib	20,531	4,190

8 NUTRIENTS CHECKED

Soil samples were processed and analysed in laboratory. After this, block-wise fertility maps were prepared for eight nutrients – organic carbon, phosphorus, potash, sulphur, soil pH, zinc, iron and manganese

MANGANESE

State samples 10,45,479
Deficient 4,55,589

District	Samples	Deficient
Moga	58,090	38,487
Kapurthala	43,727	28,215
Amritsar	70,921	42,854

Source: Union ministry of agriculture and farmers welfare

Fig 2- Soil fertility map
(Source: timesofindia.com)

Parameters	values	Ideal range
pH	7.88	6-7.5
EC	0.48 dS/m	0.5-3 dS/m
Organic carbon	5.4 g/kg	10g/kg<
Nitrogen	270 kg/ha	240-480 kg/ha
phosphorus	18.5 kg/ha	11-22 kg/ha

Table 2- soil chemical properties
(Source: researchgate.net)

Significantly low levels of Organic carbon and nutrients like iron and Sulphur

- Lack of Crop Diversification: Farmers predominantly grow wheat and paddy, which are water-intensive crops. There is a need to diversify crops and promote the cultivation of crops that require less water and are more suited to the local agroclimatic conditions.

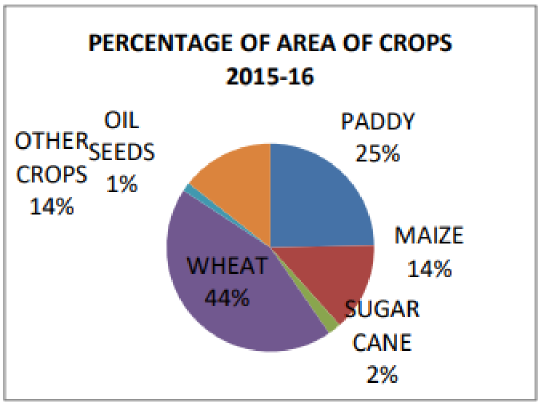


Fig 3- Analysis of crop diversification
(Source: ijrte.org)

Our team also took a survey of some farmers there to find out about the real problems faced by farmers. The major problem faced by farmers is inadequate infrastructure and transportation facilities.

4.5 Improper waste management

While surveying the village we noticed that there is a major problem with open disposal of waste. We asked people about it and they told us that there are no proper waste collection facilities. Some major problems are:

- Improper disposal of solid waste in Bhalian is a major problem that leads to environmental and health hazards.

Fig 4- open disposal of waste in Bhalian

- Waste is often burnt, causing air pollution and respiratory problems.
- The lack of proper waste segregation and recycling facilities makes it difficult to recycle and reuse waste.
- Inefficient infrastructure for waste collection and transportation leads to the accumulation of waste in the streets.

4.6 Electricity

There has been continuous power cut in Bhalian village due to the following reasons:

- **Insufficient power generation**: The state's limited power-producing capability may be one of the key causes of the electrical issue in Punjab's rural areas. Power shortages could result from the state's need for electricity being greater than its capacity to produce it.
- **Electricity theft in rural areas**: It came to know that people bypass the metres and directly pull wires on the transmission line which led to financial loss of power generating companies.
- **Low priority to the rural area**: Power generating companies prioritize cities over rural areas to provide electricity as they have more industrial areas as compared to villages.
- **Lack of awareness among people**: People generally waste power as they do not turn off the switches when the need is fulfilled. So, there is a lack of awareness among them.

5. Discussion

5.1 Roads and Connectivity

When recommending a new road, there are fundamentally three key factors that must be considered:

1. Economics

- Saving the cost of road maintenance.
- Less travelling time.
- Present transportation cost per km is higher with the improvements in roads it will decrease.

2. Technical viability

- The road should join another well-maintained road, extending the village's already functional network of roads.
- Building supplies including gravel, aggregate, and water should be close to the construction sites.

3. Social Factors

- The accessibility of economic and social services. Most social and economic activities (such as health, education, and agriculture) come to an end where the Road that can be travelled on comes to an end.

The methodology adopted would be to research and become familiar with the current circumstances. After studying maps, an auto level survey, and a traffic analysis will be done, also we will test the soil both in a lab and on the ground before designing the road's pavement.

Surveys of traffic are undertaken to determine the width, number of lanes, pavement design, and economic analysis. To design the geometric features of the road, the primary goal of a traffic survey is to identify the composition of the vehicles in the flow of traffic.

The concept of ESAL (Equivalent Single Axle Load), which establishes a correlation between axle loads and their impacts, was developed based on the findings of the Road Test conducted by the American Association of State Highway Officials (AASHO). This correlation allows for the comparison of the damage caused by axles carrying different loads.

The design traffic for a road, which represents the total number of standard axles expected to be transported during its design period, can be determined by the following equation:

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

N = cumulative number of standard axles to be catered for during the design period of 'n' years.

A = initial traffic (commercial vehicles per day) in the year of completion of construction

D = lateral distribution factor

F = vehicle damage factor (VDF)

n = design period, in years

r = annual growth rate of commercial vehicles in decimal (e.g., for 6 per cent annual growth rate, r = 0.06). Variation of the rate of growth over different periods of the design period, if available, may be considered for estimating the design traffic.

5.1.1 <u>Methodology</u>

1. **<u>Earthwork</u>**

   The subgrade soil is ready by being brought to the necessary grade and camber and being sufficiently compacted. The subgrade may be in an excavation or an embankment. The limit of economical haul and lift must be decided.

2. **<u>Subgrade Preparation</u>**

   It is done by Sprinkling the necessary amount of water onto the subgrade to maintain the Optimum moisture content and preserve it in the predetermined state. The subgrade can become dry and disintegrate due to lack of cohesiveness. The final sectioning should be finished to the correct camber, gradient, and super elevation using a template and strings.

3. <u>Pavement construction</u>

- **Sub-base/ base preparation**

  The subbase/base surface that will receive the WMM course must be cleaned of all debris and prepared to the necessary lines and camber. In order to establish a solid surface, any ruts or soft yielding areas must be thoroughly filled in, rolled, and, if required, sprinkle with water. It is not allowed to lay WMM on top of an existing bituminous surface.

- **Material**

  Coarse aggregate (Must be crusher run or crushed stone as per IRC 109) The aggregate must meet the specifications listed in table 400-10 of MORTH and Technical Specifications for Wet Mix Macadam.

Sl. no	Test	Test method to be followed as per	Requirement
1.	Los Angeles Abrasion Value or, Aggregate Impact Value	IS 2386 (Part -4) IS 2386 (Part -4) or IS :5640	40 % (Max.) 30% (Max
2.	Combined Flakiness and Elongation indices (Total)	IS : 2386 (Part -1)	30% (Max.)

Table 3: Specification Limits for Aggregates
(Source: www.constructioncivil.com)

Grading Requirement

Sieve Size	Percentage Passing
53.00	100
45.00	95-100
26.50	-
22.40	60-80
11.20	40-60
4.75	25-40
2.36	15-30
600 micron	8-22
75 micron	0-5

Table 4: Aggregates Retained for WMM
(Source: www.constructioncivil.com)

- **Laying Down Coarse Aggregates**
  The aggregate should be evenly and appropriately spread over the GSB (Granular Sub-Base) layer immediately after mixing. It should not be stacked or placed on a partially completed section. The second layer mix should be dispersed by a WMM paver finisher with a minimum paving width of 4.5m to 9.0m after the first layer is placed by a motor grader. There is no room for material separation. The aggregates should not contain any fine elements and should be of uniform size.

- **Compaction**
  Once the coarse aggregate has been evenly spread, it should be compacted using a vibratory roller equipped with static weights ranging from 80 to 100 KN, a simple drum roller, or a roller with a similar capacity. If the WMM (Wet Mix Macadam) layer is soft or yielding, or if rolling causes a wave-like action, rolling should be stopped. To check for level differences or irregularities exceeding 12 mm, a three-meter straight edge can be used for testing. If any issues are found, the surface should be loosened promptly, and premixed ingredients should be added or subtracted as needed before rolling again.

- **Sprinkling of water**
  After applying the screening, it is important to sprinkle the surface with water, clean it, and then roll it. The wet screens must be equally distributed across voids and brushed into them using hand brooms. During the rolling process, water must be applied to the roller wheels as needed to remove any adhering binding material.

- **Drying and setting**
  The water-bound macadam course should be thoroughly compacted before allowing the pavement to dry overnight. The following morning, any voids or depressions should be filled with screens or bending materials as per instructions, lightly watered, and then rolled. No traffic should be allowed on the road until the macadam has set.

5.1.2 Calculations for Designing Pavement:

- **CBR**

  According to IRC:37-2018 subgrade will have CBR of subgrade values ranges from 2% to 10%. We assume it as 6% [1].

- **Cumulative Vehicles Per Day (CVPD)**

  So, we have divided the vehicles in different classes as per their Weight. There are a total number of 8 classes and out pf which we took last 7 classes and ignored the class 1 as the vehicles coming in this class has weight less than 3 tonnes.

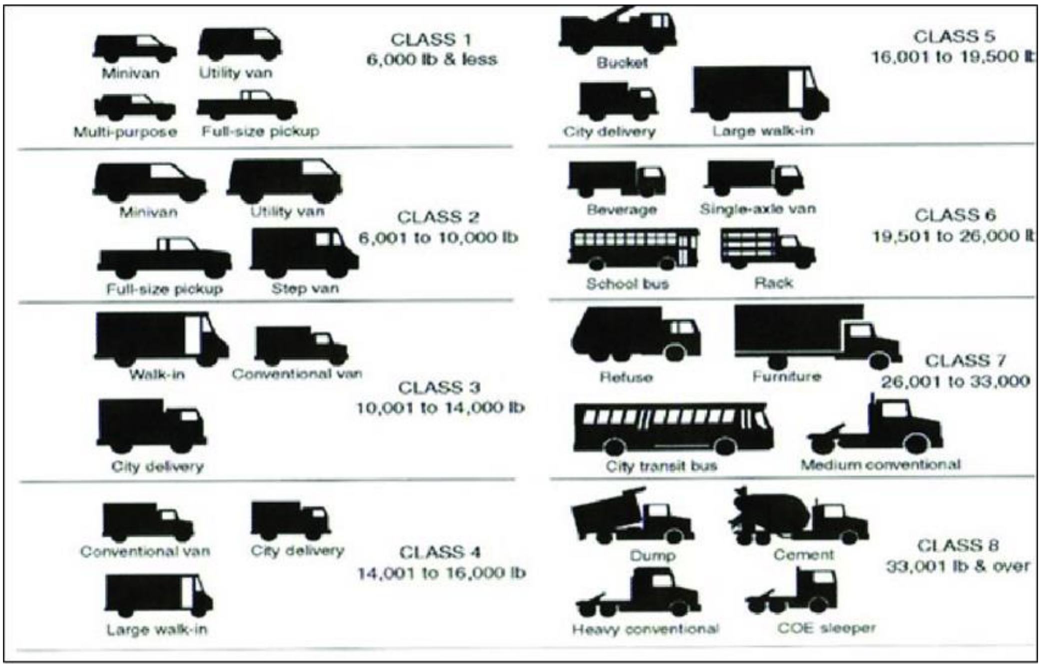


Fig 5: Various Classes of Vehicle Based on Gross Vehicle Weight Rating (GVWR)
(Source: https://www.researchgate.net)

We conducted a survey in the Bhalian village and asked a total of 10 shopkeepers, Vendors and the villagers who usually spent their most of the time near roads or subconsciously observing the vehicles on the roads as they have that kind of a job, about the total number of vehicles travelling on the road per day of different classes. So, we divided these 7 classes again into 4 classes of vehicles as the villagers cannot distinguish between classes 3, 4 & 5 and classes 6 & 7. So, we took classes 3, 4 & 5 as one class and class 6 & 7 as one.

S. No.	Class 2 (CVPD)	Class 3, 4 & 5 (CVPD)	Class 6 & 7 (CVPD)	Class 8 (CVPD)
1	30	50	50	1
2	45	50	60	0
3	40	40	80	0
4	50	60	60	2
5	45	60	55	1
6	40	50	70	1
7	35	60	60	2
8	35	70	70	2
9	50	50	60	2
10	45	50	75	2
Mean($\bar{x}$)	41.5	54	64	1.3
Standard Deviation(σ)	6.687	8.433	9.367	0.823
UCL	54.874	70.866	82.734	2.946
LCL	28.126	37.134	45.266	0

Table 5: Vehicle Classes

Here UCL is Upper Control Limit and LCL is Lower Control Limit which are calculated by normal distribution curve by taking 95.44% as the confidence interval.

So, for calculation we take the Upper Control Limit to be safe.

- **Traffic Growth Rate (r)**
  According to IRC:37-2018 take minimum Traffic Growth Rate of 5%, So we assume it as 7.5% for design life of 15 years for flexible pavement[1].

- **Projected Traffic before completion of construction (A)**

A = $P(1 + r)^x$

P = Number of commercial vehicles per day as per last count.

x = Number of years between the last count and the year of completion of construction.

Let us assume x = 2 years

Vehicle Classes	P (CVPD) = UCL*10	A (CVPD)
2	549	635
3, 4 & 5	709	820
6 & 7	827	956
8	30	35
		ΣA = 2446

Table 6: Various Classes of Vehicle Based on Gross Vehicle Weight Rating (GVWR)

- **Weight of different classes and load distribution on axles**

Vehicle Classes	Type of Axle and Wheel	Weight (KN)	LDR (FA:RA)	FA Load (KN)	RA Load (KN)	EF
2	FA- SA & SW RA- SA &SW	44.5	1:1	22.25	22.25	0.0274
3, 4 & 5	FA- SA & SW RA- SA & DW	71.2	2:3	28.48	42.72	0.1181
6 & 7	FA- SA & SW RA-SA & DW	133.5	2:3	42.72	80.1	1.46
8	FA- SA & SW RA- DA & DW	178	1:4	44.5	133.5	0.882

Table 7: Weight and Load distribution on axles

FA – Front Axle
RA – Rear Axle
LDR – Load Distribution Ratio
EF – Equivalency Factor

SA – Single Axle
DA – Dual Axle
SW – Single Wheel
DW – Dual Wheel

- **Vehicle Damaging Factor (F)**

$$F=\frac{A1*EF1+A2*EF2+A3*EF3+A4*EF4}{A1+A2+A3+A4}$$

$$F=\frac{635*0.0274+820*0.1181+956*1.46+35*0.882}{635+820+956+35}$$

F=0.63

- **Lane Distribution Factor (D)**
  For our specific road, which is a two-lane single-carriageway road, we consider the Lane Distribution Factor as 0.5[1].

- **Cumulative number of standard axles (N)**

$$N = \frac{365 \times [(1+r)^n - 1]}{r} \times A \times D \times F$$

$$N = \frac{365 \times [(1+0.075)^{15} - 1]}{r} \times 2446 \times 0.5 \times 0.63$$

$$N = 7.34\, msa$$

- **Pavement Layers**

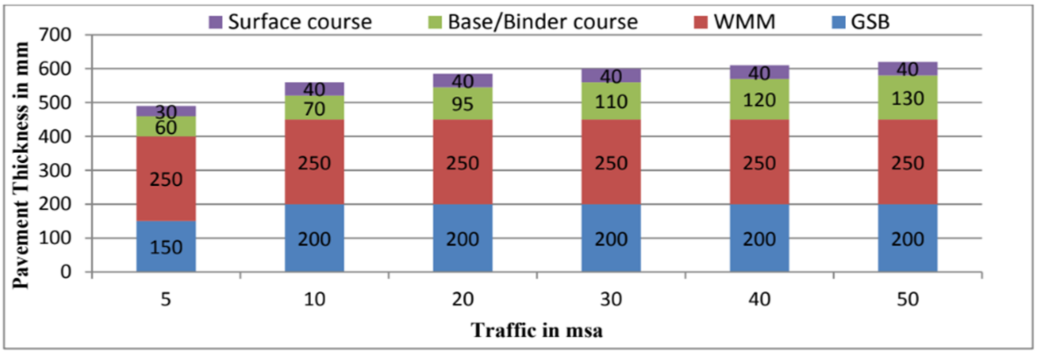


Fig 6: Catalogue for pavement with bituminous surface course with granular base and sub-base - Effective CBR 6%
(Source: http://www.irc.nic.in/)

Take $N = 10$ msa

Therefore, from the Catalogue for pavement the thickness of the different layers are as follows:

Granular Subbase (GSB) = 200 mm

Wet Mix Macadam (WMM) = 250 mm

Base/ Binder Course = 70 mm

Surface Course = 40 mm

- **Determination of Allowable Compressive Strain**

  According to IRC:37-2018 equations that evaluate the subgrade rutting and fatigue cracking of the lower asphalt layer with 80% reliability are utilized for designing traffic volumes below 20 million standard axles (msa). Therefore, for subgrade rutting the equation is[1]:

  N = $4.1656*10^{-8}\left[\frac{1}{\varepsilon_v}\right]^{4.5337}$

  where,

  N = Number of cumulative standard axles = $7.43*10^{6}$sa

  ε_v= Vertical strain in subgrade

  ε_v = 7.2* 10^{-4} (Allowable compressive strain)

- **Determination of Allowable Tensile Strain:**

  The equation for fatigue cracking of bottom bituminous layer with 80% reliability is[1]:

  N_f = 1.6064*C* $10^{-4}[\frac{1}{\varepsilon_t}]^{3.89} * \left[\frac{1}{M_{Rm}}\right]^{0.854}$

  Where,

  C = 10^{M} and M = $4.84(\frac{Vbe}{Va+Vbe} - 0.69)$

  Va = Percent volume of air void in the mix used in the bottom bituminous layer

  Vbe = Percent volume of effective bitumen in the mix used in the bottom bituminous layer

  N_f = Fatigue life of bituminous layer

  ε_t = Maximum horizontal tensile strain at the bottom of the bottom bituminous layer

  M_{Rm} = Resilient modulus (MPa) of the bituminous mix used in the bottom bituminous layer, selected as per the recommendations made in these guidelines.

  Let us assume,

  Voids Filled with Bitumen = 80%

M = $4.84(\frac{Vbe}{Va+Vbe} - 0.69)$

M = 4.84(0.8-0.69)

M = 0.5324

C = 10^{M}

C = 3.407

$M_{RM} =$ 2000 Mpa (Here we are using Bituminous Concrete and Dense Bituminous Macadam for VG30 bitumen VG30 at 35°C Average Annual Pavement Temperature)

Therefore,

ε_t = 4.7*10^{-4} (Allowable tensile strain)

Now, we will find actual compressive and tensile strain by using IITPAVE Software.

And then check whether allowable strains >= actual strains

If yes, then our Design is safe.

If not, then go for design by increasing the thickness of bituminous layer till actual strains are less than allowable strains. We can also Review Design Assumptions that verify the input parameters used in the pavement design, such as traffic loads, material properties, and environmental conditions.

5.2 Pure drinking water

The primary source of drinkable water is groundwater. Groundwater is used because it is of a better quality and needs only disinfection (chlorination) and arsenic treatment, therefore it is more cost-effective. Water is pumped from bore wells to the above tank. The supplied water from the storage is given according to need and schedule. Open wells are also constructed for other reasons. In case of deficiency, hand pumps are put at several sites.

Purification Suggested:

- **Sedimentation** - For particles smaller than 0.05 mm to settle, the water must be allowed to stand in peace for at least 6 hours. settling time, or depth / settling speed.
- **Chlorination-based disinfection** is sufficient because all of the evaluated parameters are within the Indian Standard's permissible range for drinking water.

Disinfection is done by Chlorination in two ways:

- Using 0.5g of halogen (chlorine) tablets per 20 liters of water. The National Environmental Research Institute in Nagpur has produced these halogen tablets, which are inexpensive and readily available throughout India.
- Using bleaching powder with a chlorine content of 30–35%. Strength is 30% of 1 kg. According to Indian Standard, 0.3 mg/l of chlorine is the maximum dosage when 1 kilogram is put to 1 ml. As a result, it can be dosed at 5 mg/l for 30 minutes of contact time.

Two essential subfields of civil engineering—environmental and water resource engineering—are successful in providing millions of people with dependable sources of clean water on a global scale. So, we came up with the idea of **Small Decentralized Distillation Units.**

Piped connections from a central water source are commonly used to provide clean drinking water to large communities. However, in areas where it is not possible to connect to a centralized water supply due to physical or economic constraints, decentralized water distillation systems can be used. These systems come in various forms and utilize different methods to filter and distill contaminated groundwater. The capacity of the system determines how much clean water it can produce. By implementing decentralized distillation systems, clean and reliable drinking water can be made available to areas that lack a centralized water supply.

- Point-of-use supply systems: Each home can utilize 25–30 litres of treated water per day.
- Point-of-entry supply systems: They have the ability to treat all water entering a home.
- Small-scale systems: They can deliver 1,000–10,000 litres of water per day to entire communities.

Distillation unit

1. **Where should the distillation unit be installed in our village?**

   At the point-of-use, distillation units can be installed to treat water. This indicates that the treatment system is set up at the particular faucet where water will be utilized for drinking, cooking and personal hygiene. Water from other taps should not be used for these uses without treatment as only the water used from this specific tap will be treated.

2. **How effective is distillation?**

   Almost all of the arsenic in the raw water can be eliminated by distillation units.

3. **Does the distillation system also get rid of other things?**

   Nearly all dissolved contaminants that you might anticipate to find in drinking water are removed by the distillation unit.

There are several effective methods for destroying pathogens in water, including heat, radiation, and chemicals. Physical removal processes can also be used to separate contaminants from water. These techniques include sedimentation, filtration, and aeration. Advanced decentralized distillation units are being developed to provide clean water to communities at a sustainable cost, and civil engineers are working to improve the efficiency and range of these units. Different purification and disinfection procedures such chemical disinfection, coagulation, flocculation, precipitation, adsorption, and ion exchange, and various types of filtrations are used to ensure water quality. In Bhalian village, these methods can be used to provide clean water to the community.

5.3 Sanitation

5.3.1 Biogas plant

Biogas is a gas mixture that is generated when organic matter decomposes without the presence of oxygen. This biogas can be utilized for cooking, heating, and lighting purposes, making it an eco-friendly alternative to fossil fuels. Additionally, the organic fertilizer produced as a by-product can be utilized to enrich the soil and improve crop yields. By setting up biogas plants, we can reduce the amount of organic waste sent to landfills, which can have adverse environmental impacts.

Calculating Biogas Energy Production

- Everyday 50 kg of cow dung and 5 kg of food waste are collected from a rural household.
- The collected cow dung and waste are mixed with water in a ratio of 1:1 (by weight) to create a slurry. Therefore, the total slurry weight is 110 kg.
- During the anaerobic digestion process, biogas is produced as a byproduct of the decomposition process. Assuming a yield of 0.03 cubic meters of biogas per kg of slurry, the total biogas production would be 3.3 cubic meters.
- If typical household biogas stove burns 0.2 cubic meters of biogas per hour, the total cooking time that can be achieved with the 3.3 cubic meters of biogas would be 18 hours

5.3.2 Integrated Decentralized Treatment

Most of the wastewater in rural areas is directly dumped into neighboring fields and aquatic bodies after only partial treatment via a septic tank. Serious health problems, financial losses, and the deterioration of land and aquatic bodies are all results of this discharge. Integrated decentralized wastewater systems can improve water quality and turn wastewater into a source of essential nutrients for use by plants, resulting in landscape restoration and conservation. These systems process and dispose of modest quantities of wastewater from individual homes or dwellings.

Fig 7- Decentralized system
(Source: RUVIVAL)

Working of decentralized tank

- For rural homes, a decentralized wastewater system should be easy to operate, economical, and energy efficient.

- The recommended system involves separating and treating wastewater into three types: brown water (containing mainly faeces), grey water (from sinks, showers, washing machines, and dishwashers), and yellow water (containing urine) using **smart sanitation tank**.

- Prior to being released for irrigation on non-food agricultural fields, grey water is first treated in a septic tank to remove the majority of the solids, followed by additional treatment in a small horizontal flow-built wetland.

- Faeces or brown water is collected in a chamber with wood chips, charcoal, and kitchen waste and composted with lactic acid bacteria solution. After a week, worms are added, and the resulting black soil can be used as a fertilizer.

- Urine is stored anaerobically in a plastic or concrete container and used as a fertilizer for agroforestry, together with the nutrient-rich Terra Preta humus.

- Proper maintenance is crucial to avoid nuisances such as strong odours, pipe scaling, and insect/pest growth

5.3.3 Smart Sanitation Tank

- Using bricks or cement blocks, the solid waste pit is built as a layered depression in the ground.
- A bamboo mat is placed at an angle to facilitate the rolling of solid waste towards the far end.
- The bamboo mat functions as a sieve to filter washing water from solid waste.
- The mat allows the washing water to flow through and accumulate in the lower area of the pit.
- The wastewater is further filtered through a sand, lime, and gravel bed before eventually draining into the ground.
- Bacteria naturally decompose the solid waste, converting it into nutrient-rich manure.
- Pipes attached to the waste disposal system carry the segregated **brown water, urine, and grey water** from a housing unit. The bamboo filter is now being used to filter the black water that has no trace of pee. The faeces in the black water are filtered, then held for nine to twelve months to create compost after sliding past the filter.

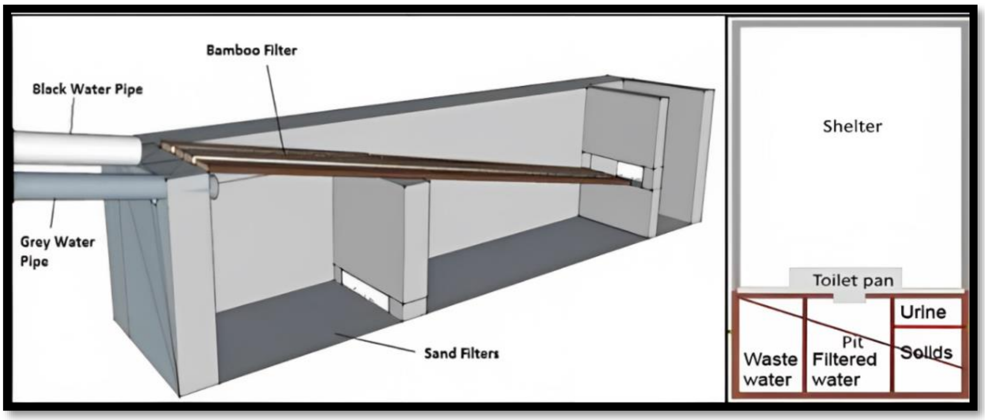


Fig 8: Septic tank

5.4 Agriculture

- To improve soil fertility, it is essential to make crop diversification and practice agroforestry techniques. We need to design an efficient layout of farming lands for agroforestry techniques. This layout should include the planting of different trees like fruit trees such as mango, guava, and timber trees like eucalyptus with appropriate spacing to allow adequate sunlight for crops.

Fig 9: A typical agroforestry layout
(source: ecomatcher.com)

- Practice efficient farming techniques like efficient irrigation techniques like drip and sprinkler irrigation to prevent groundwater depletion. these techniques are not only efficient but also prevent soil erosion. And use to use biofertilizers instead of chemical fertilizers to restore soil fertility.

- For the stubble burning problem, we can reuse stubble in many ways it can be decomposed to produce organic manure through the application of a fermented liquid solution created by IARI., and it also can be moulded into usable boards. A new start-up Kriya Labs of IIT Delhi uses this to make fibres. By providing the necessary infrastructure we can tackle this problem.

- We will also implement digital technologies like Geographic Information System (GIS) and remote sensing Agricultural mapping and GIS play a vital role in monitoring and managing soil and irrigation, helping with the management and control of agricultural resources. Remote sensing and GIS technology can be used to monitor crop growth, identify stress, disease, pest and weed infestations, and identify potential irrigation sites. Precision farming allows for precise tracking and turning of production, making farm planning easier with the use of map data for determining long-term cropping plans and erosion and salinity controls.

- Remote sensing (RS) and GIS can be used to determine the crop's maturation stage, agricultural challenges like nutrition and water stress, disease, pest infestation, and weed infestation. To establish field management for chemical application, cultivation, and harvest, data collected by various sensors and referred to using GPS can be integrated.

- GIS and RS are systems that allow for layering of different real-world information to create precise agricultural models. Once soil mapping is done, it can be used to simulate crop yields with different inputs and varieties. This flexibility helps farmers optimize their agricultural practices.

- It can help in mapping hotspots for disease infestations in crops, providing an early warning system for farmers to take preventive measures and targeted treatments, reducing the overall impact of the disease. This approach not only provides maps but also analytical tools for disease management in agriculture. It is like a post-disaster management strategy that helps farmers identify areas with high disease incidence and simulate the spread of disease.

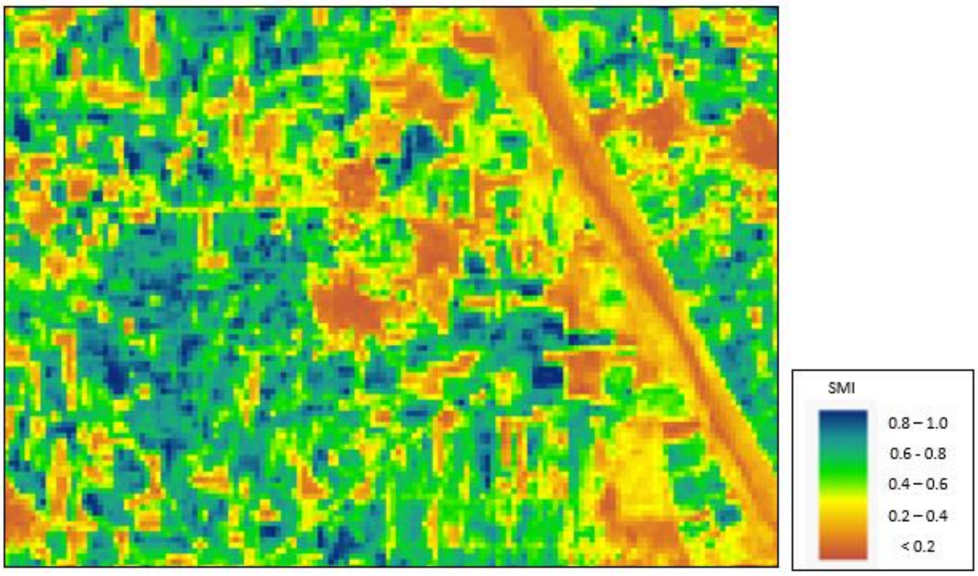


Fig 10 – Soil moisture index using GIS

5.5 Solid waste management

- To tackle these problems First, we will provide different bins to prevent the mixing of different waste. This makes it easy to collect waste into different categories such as organic, inorganic, hazardous, dry combustibles and recyclable so that further processes can be done in more efficient ways

- To ensure proper waste collection and transportation to appropriate facilities for processing, proper infrastructure will be provided this includes building waste transfer stations and purchasing garbage trucks.

- Establish recycling facilities to process the segregated waste. This will not only reduce the amount of waste that needs to be disposed of but will also create employment opportunities. The recycled products can also be sold, generating revenue for the city.

- Organic waste can be managed by different techniques such as composting by providing multiple small composting sites composting process results in compost which is a nutrient-rich fertilizer which can be used to increase soil fertility. Organic waste can also be used as a substrate for mushroom cultivation. These mushrooms are a high-value crop and can be sold to restaurants and supermarkets.

- Dry combustibles like paper, wood and plastics can generate Refuse Derived Fuel (RDF) which can be used in industrial processes or to generate electricity. This dry waste can be transported to some operational plants like the solid waste processing plant in Dadumajra.

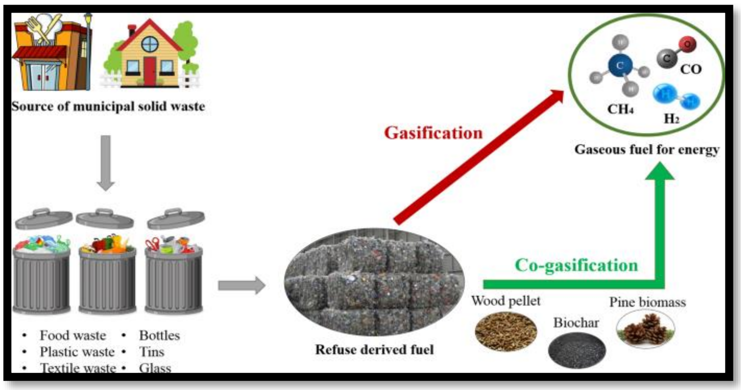


Fig 11– Transformation of solid waste to gaseous fuel
(Source: link.springer.com)

- The leftover waste which cannot be composted or recycled further can be disposed of by using proper waste disposal methods such as landfilling or incineration. These methods should be implemented in a way that is safe for the environment and public health.

5.6 Electricity

1. **Energy efficient building solution:** A building that has been designed and built in a way to minimize energy use while maximizing performance and occupant comfort is said to be energy efficient. In comparison to conventional buildings, these structures are built to use less energy for heating, cooling, lighting, and other energy-intensive tasks, which lowers energy costs and lowers carbon emissions. Building designs may use elements like high-performance insulation, effective HVAC systems, energy-efficient lighting, and cutting-edge building automation technologies to achieve energy efficiency. Energy efficiency is also greatly influenced by the building's orientation, usage of natural light, and material selection. An energy-efficient building's overall objective is to maximize energy usage while maintaining comfort and functionality, lowering energy expenditures and having a less negative impact on the environment.
2. **Solar power solution:** Solar energy is a sustainable, environment friendly and cost-effective source of energy that can help to reduce greenhouse gas emissions and increased energy security. It accounts for 3.7% of total world's electricity.

   Solar panels can be installed on the rooftops of every house in Bhalian village and also in the fields. Installing the solar energy plants in fields will also be beneficial for a farmer as they can also grow crops in the gaps and beneath the panels. The crops which require less sunlight e.g., tomato, brinjal, chillies can be grown under the panels while wheat, maize can be grown in the gaps between panels. Fish farming can also be done between the gaps.

PM KUSUM Yojana

Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM) Yojana is a scheme launched by the Government of India in 2019[2]. The program's goal is to give farmers money and other incentives so they will install solar power projects on their uncultivated or arable land or utilize solar pumps for irrigation.

The government offers farmers a 60% subsidy under the PM KUSUM Yojana for the installation of solar pumps for irrigation and for the construction of solar power facilities with capacities ranging from 500 kW to 2 MW. We can install solar plants in fields of **Bhalian** village by taking benefits of this scheme.

Calculations are shown for 1.5-hectare land: -

i) Solar panels required=3000 (330W capacity each)
ii) 4 inverters- 250KW each
iii) AC, DC wiring
iv) Galvanized Iron solar panel stands

Cost estimation:

Components	Cost (Cr)
Solar Panel	2.1
Inverter	0.4
GI Structure	0.5
DC/AC wiring	0.1
Transmission line	0.4
Total	**3.5**

Table 8: Cost estimation of solar powerplant

This cost of 3.5 crores can be fulfilled by **Bhalian** village panchayat and by taking loan from the bank which can be paid by revenue generated by power selling.

If we assume 6 hours of sun on average in a day weighing for every season, in this way, they can produce 5900 units of electricity per day i.e. (3000*30*6) and about 178MW of energy per month. After usage by the village, they will have surplus energy. The surplus energy can be sold at a rate of 5 Lac/month (excluding all the maintenance and other costs.

5.6.1 Motivation

Odanthurai village: Odanthurai is a panchayat situated in Mettupalayam taluk of Coimbatore district of Tamil Nadu. This village has been a model for other villages for more than a decade. In addition to producing electricity for its own consumption, the panchayat also sells electricity to the Tamil Nadu Electricity Board (TNEB) *[3]*.

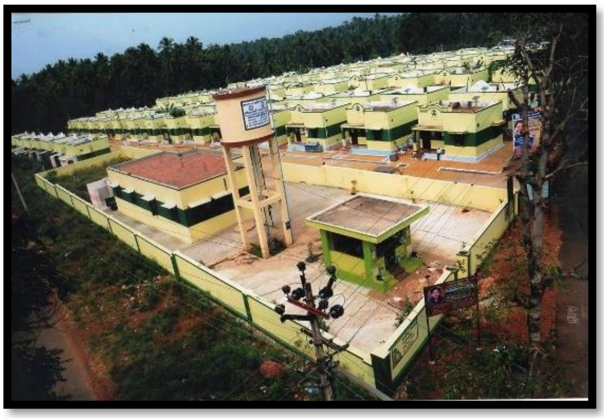


Fig 12 – Odanthurai village
(Source: thebetterindia.com)

After R. Shanmugam, the panchayat president, fought to improve access to basic amenities including housing, energy, and water, Odanthurai panchayat, which had seen almost no development before 1996, underwent significant changes. Over a ten-year period, a variety of development initiatives brought the villages out of extreme poverty.

In 2005, Odanthurai installed a 350kW wind turbine in Maivai, close to Udumalai, for a total of Rs 1.55 crore. It is interesting to note that it generates 6.75 lakh units of energy and sells roughly 2 lakh units to the TNEB, generating more than Rs 20 lakh in revenue annually. For the panchayat, they are consuming roughly 4.75 lakh units. The panchayat has contributed Rs 40 lakh of their savings towards the cost of the wind farm. The panchayat obtained a loan from a nationalised bank in 2005 for Rs. 1.15 crore to cover the remaining sum. The panchayat has been paying back the debt with the money it has earned from selling power to TNEB, and it will soon pay off the remaining balance of the loan.

Under the state government's "Green House" program, which is reportedly the most extensive in the state, some 850 homes were constructed and distributed to beneficiaries.

Every house has installed solar panels on their roofs which also fulfil their energy requirements.

6. Conclusion

The total difficulties in Bhalian village have decreased because of using all these services and techniques. This has a positive impact on the cultural, social, economic, environmental, educational, living standard, and overall status of the village. It improves the well-being of each member of society, fosters self-sufficiency, and reduces poverty. Village gains independence as a result and contributes to the growth of the country.

The engineering challenges involved in developing a smart village can be divided into various categories which are:

1. Road and connection: Building roads within villages and connecting towns poses challenges for those who work in the field of road and highway engineering. In-depth knowledge of the subject will be helpful in coming up with workable connection solutions.
2. Irrigation: Since agriculture is the principal industry in most villages, irrigation and its methods should be studied as part of the study of irrigation engineering. This will enable us to offer solutions to areas without good water access.
3. Sewer and drainage systems: The issue with the drainage system is one that involves both fluid mechanics and pipe hydraulics. Consequently, the multidimensional approach has a drawback.

Other issues include the creation of alternative energy sources (electrical engineering) and providing network connectivity (information technology), which are issues that are not directly related to our field but nonetheless represent significant engineering challenges.

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