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A Civil Engineering Magazine

Civil-o-sphere

By Department of Civil Engineering
Technique Polytechnic Institute

- Rain water harvesting
- Flood management
- Safety alarming system in construction sector
- Self-healing concrete
- India's first bullet train project: a journey into the future
- ISRO’s NAVIC: Navigation support to civil and military segments
- Drone Survey

Vision of Our Institute

To be a premier institute in pursuit of excellence in technical education and skill development committed to serve the society.

Institute Mission Statements

1. **To promote excellence in learning, teaching and technology transfer.**
2. **To improve the quality of skilled workforce through a structured programme and professional skills training.**
3. **To inspire students to learn and facilitate their overall development with social orientation and values.**

Vision of the department:

To become excellent in the field of Civil Engineering in developing highly competent technically skilled manpower to meet the current and future challenges.

Mission of the department:

1. To impart quality education and consultancy services to the community in all areas of Civil engineering.

2. To impart knowledge with emphasis on the development of leadership qualities among students in a congenial learning environment.

3. To impart knowledge and to equip students with skills to prepare them for successful diverse professional career.

4. To promote among the students attitude to serve society and the nation by providing solutions to the challenges in the field of Civil Engineering.

5. To provide opportunities to students and faculty members to innovate and disseminate knowledge.

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RAIN WATER HARVESTING

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The harvesting of rain water simply involves the collection of water from surfaces on which rain falls, and subsequently storing this water for later use. Normally water is collected from the roofs of buildings and stored in rainwater tanks. It is the accumulation and deposition of rainwater for reuse on site. The harvested water can also be used as drinking water, long term storage and for other purposes such as ground water recharge.

ADVANTAGES

- The technology is simple and easy to install.
- Local people can be easily trained to implement such technology and construction material is easily available.
- It has low maintenance cost and running cost.
- Water collected from roof catchments usually is of acceptable quality for domestic purpose.
- Rain water can be a continuous source of water supply for both the rural and the poor.
- Depending upon the conditions both water collection capacity and storage capacity can be increased as needed within the available catchment area.
- Increases groundwater table.
- Reduces runoff that clogs drain and prevents roads from flooding.
- Enables self-sufficiency in water supply and helps replenish home water needs during the summer and times of drought.
- It lowers the rate at which power is consumed when pumping groundwater. One meter of water level rise results in a 0.4 KWH reduction in energy use.
- Rainwater collection has helped communities in desert regions where rainfall is scarce.

DISADVANTAGES

- Disadvantages are mainly due to the limited supply and uncertainty of rainfall.
- If supplies aren't cleaned/flushed before use, bird/animal droppings on catchment surfaces and guttering structures could pollute them.
- Algal development and invasion by insects, lizards, and rats are two problems that can occur in improperly built water jars and containers. If they are neglected, they may serve as a breeding ground for disease vectors.

SUITABILITY

The augmentation of municipal water supplies with harvested rainwater is suited to both urban and rural areas. The construction of cement jars or provision of gutters does not require very high skilled manpower.

IMPORTANCE OF RAIN WATER HARVESTING

- The gathered rain water can be used for agricultural purposes. The environment may be helped to get rid of the tendency to drought.
- The requirement of water for feeding the livestock can be met.
- The ever-increasing demand for water can be satisfied.
- The quantity of the subterranean water can be increased.
- Wastage of water flowing through drain, gutter, or any water course of any type may be stopped.
- Water-logging on roads and thoroughfares can be checked and localities can be saved from being inundated.
- The quantity of water can be raised and soil erosion can be checked.

RAIN WATER HARVESTING PROJECT OBJECTIVES

- Finding the rainwater potential and its relationship with groundwater.
- Calculating the runoff from different areas of the colony according to land use.
- Calculating the number of recharging structures required for the colony.
- Locating the various types of recharging structures.
- Proposing a design prototype for each zone and each land use are all goals of this study.

RAINWATER HARVESTING PROJECT NECESSITY

The majority of rain that falls on the surface has a tendency to evaporate quickly, leaving very little for groundwater replenishment. As a result, even for home usage, water is scarce in the majority of India's regions. As a result, steps to ensure that rain falling over a region is absorbed as fully as possible through rainwater harvesting are required.

These techniques include either storing the water for later use or recharging it into groundwater aquifers.

RAIN WATER HARVESTING PROJECT AIM

To determine whether rainwater harvesting systems in Technique Polytechnic Institute is feasible and designed appropriately.

SYSTEM OF RAIN WATER HARVESTING

Commonly used systems are constructed of three principal components. They are: -

- Catchment areas
- Collection Devices
- Conveyance system

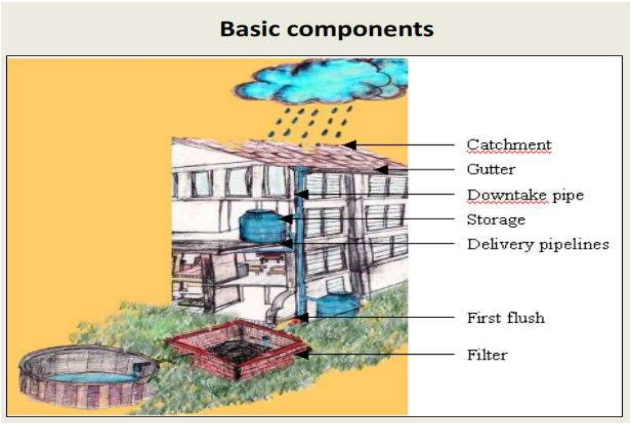
METHODS OF RAINWATER HARVESTING

- Surface Runoff Harvesting
- Rooftop Rainwater Harvesting

PROJECT ON RAINWATER HARVESTING COMPONENTS

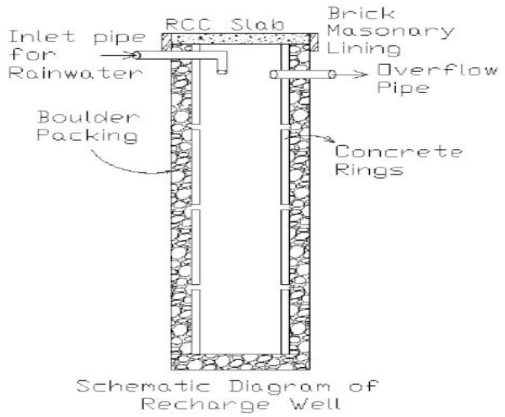
The project on rainwater harvesting mainly constitutes of the following sub-components:

- Catchment
- Transportation
- First Flush
- Filter
- Sand Gravel Filter
- Charcoal Filter
- Sponge Filter

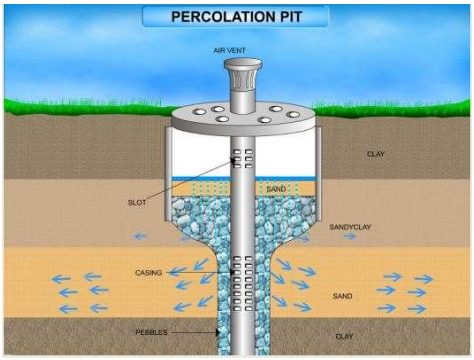


TECHNIQUES OF RAIN WATER HARVESTINGS

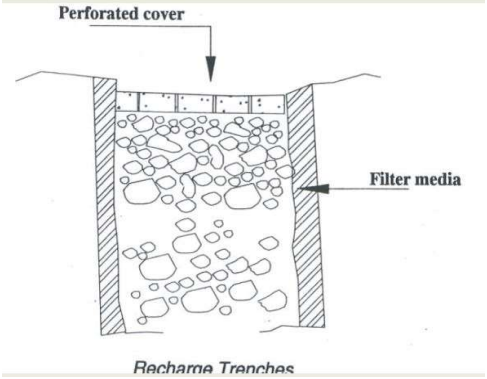
- Storage of rainwater on surface for future use: The storage of rain water on surface is a traditional techniques and structures used were underground tanks, ponds, check dams, weirs etc.



- Recharge to ground water: the collected rainwater is transferred to the ground through suitable means for recharging the depleting aquifers.
- Pits: - Recharge pits are constructed for recharging the shallow aquifer. These are constructed 1 to 2 m, wide and to 3 m. deep which are back filled with boulders, gravels, coarse sand.

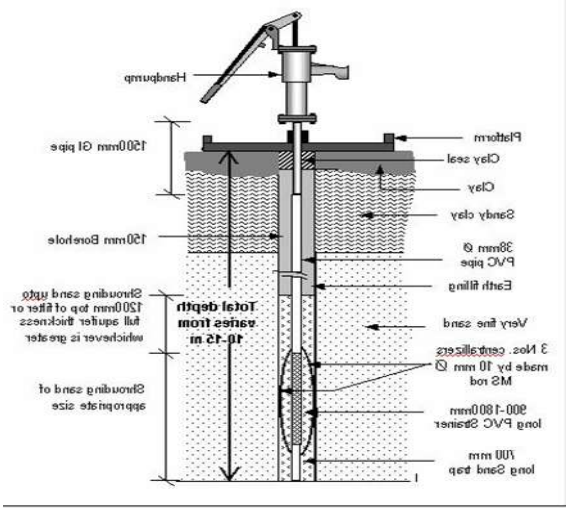


- Trenches: - These are constructed when the permeable strata are available at shallow depth. Trench may be 0.5 to 1 m. wide, 1 to 1.5m deep and 10 to 20 m. long depending up availability of water. These are back filled with filter materials.

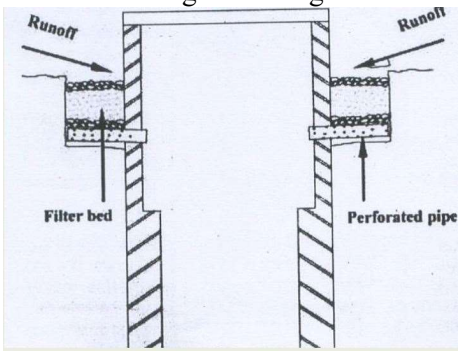


- Hand pumps: - The existing hand pumps may be used for recharging the shallow/deep aquifers, if the

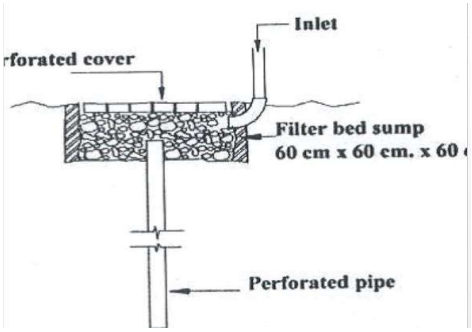
availability of water is limited. Water should pass through filter media before diverting it into hand pumps.



- Recharge wells: - Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells.



- Recharge Shafts: - For recharging the shallow aquifer which are located below clayey surface, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed and back filled with boulders, gravels & coarse sand.



- Catchment area/roof this implies the surface upon which rain falls. The roof has to be appropriately sloped preferably towards the direction of storage and recharge.
- Gutters and downspouts the transport channels from catchment surface to storage. These have to be designed depending on site, rainfall characteristics and roof characteristics.
- Leaf screens and roof washers the systems that remove contaminants and debris. At first, a rain separator has to be put in place to divert and manage the first 2.5 mm of rain.
- Cisterns or storage tanks Sumps, tanks etc. where collected rain-water is safely stored or recharging the ground water through open wells, bore wells or percolation pits etc.
- Conveying the delivery system for the treated rainwater, either by gravity or pump.

DESIGN CONSIDERATIONS

Three most important components, which need to be evaluated for designing the rainwater harvesting structure, are:

- Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water.
- Area contributing for runoff i.e. how much area and land use pattern, whether industrial, residential or green belts and general built-up pattern of the area.
- Hydro-meteorological characters like rainfall duration, general pattern and intensity of rainfall.

RAINWATER HARVESTING PROJECT CONCLUSION

The natural resources are under a significant deal of stress due to the expanding population and the increased demand for water. There will soon be a shortage of water worldwide due to the rapid depletion of underground reserves. This issue can be resolved if artificial methods are used. The necessity for and solution for rainwater harvesting in the Technique Polytechnic Institute are described in length in this study. In addition to helping with flood control, rainwater collection also helps with pollution control and continuous water supply.

Ways of harvesting water

- Capturing run-off from rooftops, roads.
- Capturing run-off from local catchments
- Capturing seasonal flood water from local streams
- Conserving water through watershed management. It involves utilization of rain water for domestic or agricultural purpose.

Three most important components, which need to be evaluated for designing the rainwater harvesting

structure, are:

- Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water
- Area contributing for runoff i.e. how much area and land use pattern, whether industrial, residential or green belts and general built-up pattern of the area
- Hydro-meteorological characters like rainfall duration, general pattern and intensity of rainfall.

SUGGESTIONS

For a small town such as Chinsurah we should try to harvest rain water from roof tops as it is less costly. We should try it first in: -

- Government buildings
- Offices
- Courts
- Government bungalows
- Public buildings
- Public toilets
- Hospital
- Any other commercial buildings.

We than check the effectiveness and efficiency of this system and proceed further for every household in town and try harvesting the surface runoff also. This will further reduce the water logging problem of our town and also would solve the problem of water supply in the town and nearby areas.

FLOOD MANAGEMENT

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Introduction

Floods have been recurrent phenomenon in many parts of India, causing loss of lives and public property and bringing untold misery to the people, especially those in the rural areas. There is also a larger economic impact, as they derail economic activities, thus affecting growth. Indian continent has peculiar climatic conditions since it has floods in some parts whereas drought in other parts. Over the years, several expert Committees have studied the problems caused by floods and suggested various measures for their management to the Government. However, despite the various steps undertaken over the last five decades, the trend of increasing damage and devastation brought by floods has posed a challenge to the Government as well as to the people. The approaches to flood management presently exercised in India also need to give a re-look to have an integrated strategy for policy and management related to floods.

River Systems and Associated Flood Problems

The rivers in India can be broadly divided into the following four regions for a study of flood problem.

- Brahmaputra Region;
- Ganga Region;
- North West Region; and
- Central India and Deccan region.

Brahmaputra River Region:

This region consists of the rivers Brahmaputra & Barak and their tributaries covering seven states Assam, Arunachal Pradesh, Meghalaya, Mizoram, Northern parts of West Bengal, Manipur, Tripura and Nagaland. The catchments of these rivers receive very heavy rainfall ranging from 110 cm. to 635 cm. a year which occurs mostly during the months of May / June to September. As a result, floods in this region are severe and quite frequent. Further, the rocks of the hills, where these rivers originate are fragile and susceptible to erosion thereby causing exceptionally high silt charge in the rivers. In addition, the region is subject to severe and frequent earthquakes which cause numerous landslides in the hills and upset the regime of the rivers. The predominant problems in this region are the flooding caused by spilling of rivers over their banks, drainage congestion and tendency of some of the rivers to change their courses. In recent years, the erosion along the banks of the Brahmaputra has assumed serious proportions.

Ganga River Region:

The river Ganga and its numerous tributaries, of which important ones are the Yamuna, the Sone, the Ghaghra, the Gandak, the Kosi and the Mahananda, constitute this river region. It covers ten states of Uttaranchal, Uttar Pradesh in its basin area, Jharkhand, Bihar, South and Central parts of West Bengal, parts of Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi. The normal annual rainfall in this region varies from 60 cm to 190 cm of which more than 80% occurs during the south west monsoon. The rainfall increases from West to East and from South to North.

The flood problem is mostly confined to the areas on the northern bank of the river Ganga. The damage is caused by the northern tributaries of the Ganga by spilling over their banks and changing their courses. Even though the Ganga is a mighty river carrying huge discharges of 57,000 to 85,000 cumec (2 to 3 million cusec), the inundation and erosion problems are confined to relatively few places. In general, the flood problem increases from the West to the East and from South to North. In the North Western parts of the region and some eastern parts, there is the problem of drainage congestion.

The flooding and erosion problem is serious in the States located in the downstream. In recent years some States which were not traditionally flood prone have also experienced some incidents of heavy floods.

North West River Region:

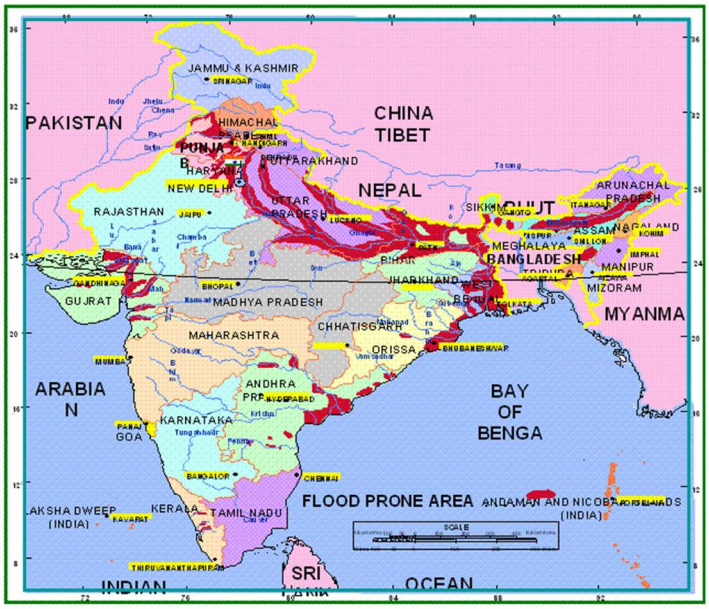
The main rivers in this region are the Sutlej, the Beas, the Ravi, the Chenab and the Jhelum, the tributaries of Indus, all flowing from the Himalayas. These carry quite substantial discharge during the monsoon and also large volumes of sediment. They change their courses frequently and leave behind tracts of sandy waste. The region covers the State of Jammu and Kashmir, Punjab and parts of Himachal Pradesh, Haryana and Rajasthan.

Compared to the Ganga and the Brahmaputra River

region, the flood problem is relatively less in this region. The major problem is that of inadequate surface drainage which causes inundation and water logging over vast areas.

Central India and Deccan Region:
The important rivers in this region are the Narmada, the Tapti, the Mahanadi, the Godavari, the Krishna and the Cauvery. These rivers have mostly well-defined stable courses. They have adequate capacity within the natural banks to carry the flood discharge except in the delta area. The lower reaches of the important rivers on the East Coast have been embanked, thus largely eliminating the flood problem.

Flood Prone Areas in India
National Flood Commission (RBA) -1980 assessed the total flood prone area in the country as 40 m. ha which included the unprotected flood area of 33.516 m ha and the balance as protected area. Subsequently, the Working Groups on Flood Management for X and XI Plans assessed the flood prone area in the country as 45.64 m ha.



Statutory Provisions about Flood Management

The subject of flood control, unlike irrigation, does not figure as such in any of the three legislative lists included in the Constitution State list, Union list and concurrence list of India. However, Drainage and Embankments, are two of the measures specifically mentioned in entry 17 of List II (State List), reproduced below:

"Water, that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power subject to the provision of entry 56 of List I (Union List)."
Entry 56 of List I (Union List) read as follows: -
"Regulation and development of inter-State rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest..."
It may thus be seen that the primary responsibility for flood control lies with the States. A number of States have already enacted laws with provisions to deal with matters connected with flood control works. Therefore, the subject "flood management" falls within the purview of the States. The schemes for flood control are planned, investigated and implemented by the States as per priorities within the State with their own resources and the role of central government is technical, advisory, catalytic and promotional in nature.

Existing Flood Management Mechanisms in India

In India, a two-tier system of flood management exists as briefly described below:
State Level Mechanism - The State Level Mechanism includes the Water Resources Departments, State Technical Advisory Committee and Flood Control Board. In some States, the Irrigation Departments and Public Works Departments look after flood matters.
Central Government Mechanism – The Union Government has set up following organizations and various expert committees to enable the State Governments in addressing flood problems in a comprehensive manner:
Central Water Commission (CWC)
The Government of India set up Central Water Commission as presently named in 1945 for achieving the goal of furthering and promoting measures of flood control, conservation and utilization of water resources throughout the country in the areas of beneficial uses, irrigation and hydropower generation, flood management and river conservation. As a national apex engineering organisation in the field of water resources development, the CWC with its vast experience gained in its strides towards progress in more than six decades, has developed considerable know-how in planning, investigation, management and design of water resources development schemes and made valuable contribution in the country's remarkable progress in this

field besides sharing the expertise with developing nations of the world.

Brahmaputra Board

The Government of India set up Brahmaputra Board under Brahmaputra Board Act, 1980 (46 of 1980) under the then Ministry of Irrigation (now Ministry of Water Resources) The jurisdiction of Brahmaputra Board includes all NE States in Brahmaputra and Barak Basin. The main functions of Brahmaputra Board are as under:

- Survey and investigations in Brahmaputra and Barak valley.
- Preparation of master plans to control floods, bank erosion, and improvement of drainage system.
- Preparation of DPRs for dams and other projects
- Standard specifications for construction operation and maintenance of dams.
- Construction of multipurpose dams and maintenance thereof.
- Any other function for implementation of Brahmaputra Board Act-1980.

  Brahmaputra Board prepared master plans for the flood management for river Brahmaputra and Barak. Besides this, the Board has undertaken survey and investigations for preparation of master plans for tackling the problems of flood, erosion and drainage congestion including DPRs for multipurpose projects.

Ganga Flood Control Commission

The Ganga Flood Control Commission (GFCC) was set up by Government of India in 1972 for preparation of comprehensive plan of flood control for Ganga Basin and to draw out a phased coordinated programme of implementation of works and monitoring & appraisal of flood management schemes of Ganga basin States. The GFCC has prepared comprehensive plans of flood management of the 23 sub-basins in the Ganga Basin besides drawing out a phased programme of implementation of these works to proper standards, examination and monitoring of various flood management schemes in the Ganga Basin States.

Farakka Barrage Project Authority

The Farakka Barrage Project Authority carry out anti-erosion and river bank protection works in its jurisdiction in near river vicinity of the Barrage.

National Disaster Management Authority (NDMA)

For prevention and mitigation effects of disasters including flood disasters and for undertaking a holistic, coordinated and prompt response to any disaster situation, the Government of India has set up a National Disaster Management Authority (NDMA) in 2005 under the Chairmanship of Hon'ble Prime Minister of India. The functions of the NDMA are:

Lay down policies on disaster management;

Approve national Plan;

Approve plans prepared by the Ministries or departments of the Government of India in accordance with the National Plan;

- Lay down guidelines to be followed by the State Authorities in drawing up the State Plan;
- Lay down guidelines to be followed by the different Ministries or departments of the government of India for the purpose of integrating the measures for prevention of disaster or the mitigation of its effects in their development plans and projects;
- Coordinate the enforcement and implementation of the policy and plan for disaster management;
- Recommend provision of funds for the purpose of mitigation;
- Provide such support to other countries affected by major disasters as may be determined by the central Government;
- Take such other measures for the prevention of disaster, or the mitigation, or preparedness and capacity building for dealing with the threatening disaster situation or disaster as it may consider necessary;
- Lay down broad policies and guidelines for the functioning of the National Institute of Disaster Management.

The NDMA has issued guidelines in January, 2008 for management of floods and the roles of various Central and State agencies have been specified for preparation of flood mitigation plans and taking relief measures during flood disasters.

Government's Initiatives and Policies on Floods

After the unprecedented floods of 1954, the Government of India took several initiatives and constituted a number of Committees to study the problem of floods in the country.

Recommendations of Expert Committees on Flood Management.

A brief account of the recommendations of some of the important expert committees are as follows.

Policy Statement - 1954

Following the unprecedented floods of 1954, the Union

Minister for Planning, Irrigation and Power, placed before the Parliament on 3rd September, 1954, two statements namely "Floods in India - Problems and remedies" and "The Floods in the country". The objective unequivocally set, in the policy statements, was to rid the country from the menace of floods by containing and managing floods and thus solving the problem.

In the supplementary statement placed before the Parliament on the 27th July, 1956, the above optimistic note changed a little, stating "We shall, however, be able to curb and confine the floods, more and more and do all that is possible to save ourselves from the harm and the devastation that they bring". Simultaneously, a statement on the flood situation and flood control programme was laid before the Parliament. In this Statement, it was, pointed out that absolute immunity from flood damage was not physically possible even in the distant future.

High Level Committee on Floods – 1957 & Policy Statement of 1958

- A High-Level Committee on floods submitted its report in December, 1957, and this was considered by the Central Flood Control Board in its seventh meeting held in May, 1958. Some of their important recommendations are
- Absolute or permanent immunity from flood damage is not physically attainable by known methods of flood control. Flood plain zoning, flood forecasting and warning, and like measures should, therefore, be given due importance, particularly as these do not require large capital investment.
- Flood control schemes should fit in with other water related plans to the extent feasible.
- Future multi-purpose project should consider flood control aspects simultaneously.
- Effects of embankments on river regime be considered, before approving such proposals.
- In general, embankments are satisfactory means of flood protection when properly designed, executed and maintained, but a suitable combination of this method with other methods such as storage dams, detention basins, etc. is usually more efficient and should be adopted as resources permit.
- Priorities for soil conservation work relating to flood control should be as under: -
  - Catchment areas of multi-purpose dams.
  - Himalayas with their foothills.
  - Indo-Gangetic plain and
  - Deccan plateau.
- Works relating to watershed management prioritized. Work commenced in a catchment should not be left incomplete to take up work in other catchments.
- The following order of priority in general is recommended: -
  - Emergent schemes,
  - Continuing schemes,
  - Schemes for the protection of important urban and industrial communities.
  - Schemes which would help in augmenting flood protection in the country.
  - Schemes which combine other beneficial utilization of waters.
  - Another policy statement placed in Parliament in 1958 also emphasizes that while substantial diminution of flood related distress is possible, immunity against flood is impracticable.
  - **National Flood Commission (Rastriya Barh Ayog) – 1980.**

The National Flood Commission (R.B.A.) submitted its comprehensive report in March, 1980. This contained a total of 207 recommendations covering the entire gamut of flood problem in the country. Some of the important recommendations are given below.

- Data collection for providing information on their long-term performance and their impact on various socio-economic factors.
- Legislation and enforcement by States to prevent unauthorized river bed cultivation and encroachments into drains etc.
- Separate reporting of flood damage for (i) Unprotected areas (ii) Protected areas and (iii) Areas situated between the embankments.
- Legislation for management of flood plains.
- A comprehensive dynamic and flexible approach to the problem of floods as a part of a comprehensive approach for the utilization of land and water resources.
- Priority for measures to modify the susceptibility of life and property to flood damage.
- Priority for completion of continuing schemes.
- Adequate funds for maintenance.
- States to enact legislation amending section 17 (II) of land acquisition act, to make the existing provisions for emergent situations, as applicable for flood control works.
- Intensifying studies on sedimentation of reservoirs.
- Forming a national council for mitigating disaster.

Expert Committee to Review the Implementation of the Recommendations of National Flood

Commission-2003 (R Rangachari Committee)

An Experts Committee under the Chairmanship of Shri R Rangachari was set up by Ministry of Water Resources, Government of India in October 2001 to review the implementation of recommendation of National Flood Commission.

The Committee suggested emphasis on 25 recommendations out of 207 and summed up its views as follows:

- Flood damage assessment, from year to year, is not done realistically or on scientific basis as per RBA recommendations, due to collateral reasons, which are surmised but not expressed. This needs corrective steps.
- Lack of representative, scientific and credible post-project performance evaluations of past flood management works is a serious handicap.
- Unabated and unplanned intrusion into the flood plains and river beds, sometimes with the approval or acquiescence of Government has now reached alarming dimensions. If this is not managed, flood losses will continue to mount.
- RBA has made a number of recommendations on the future approach and the planning and implementation thereof. Most of these have not been implemented or at the best partially implemented. They will have to be kept in view as part of future approach.
- The international dimensions of flood management as an integral part of Water resource development and management must be pro-actively addressed.
- A number of other issues of importance like adequate funds, legislation, research and people's involvement at all important stages, etc. are very important to effectively manage floods. However, the inter-state issues in multi-state river basins are a very important matter waiting to be effectively addressed.

National Water Policy (1987/ 2002/2012)

The Government of India while framing policy has laid significant emphasis on the management of floods which gets reflected in the National Water Policy as under:

The National Water Policy (1987) adopted by the National Water Resources council, inter alia, recommended that "adequate flood cushion should be provided in water storage projects wherever feasible to facilitate better flood management". While it recognized that "physical flood protection works like embankments and dykes will continue to be necessary", it laid emphasis on adoption of non - structural measures for the minimization of losses, such as flood forecasting and warning and flood plain zoning etc.

The National Water Policy of 2002 adopted by the National Water Resources Council inter alia recommended the following guiding principles:

There should be a master plan for flood control and management for each flood prone basin.

Adequate flood cushion should be provided in water storage projects, wherever feasible, to facilitate better flood management. In highly flood prone areas, flood control should be given overriding consideration in reservoir regulations policy even at the cost of sacrificing some irrigation or power benefits.

While physical flood protection works like embankments and dykes will continue to be necessary, increased emphasis should be laid on non-structural measures such as flood forecasting and warning, flood plain zoning and flood proofing for the minimization of losses and to reduce the recurring expenditure on flood relief.

There should be strict regulation of settlements and economic activity in the flood plain zones along with flood proofing, to minimize the loss of life and property on account of floods.

The flood forecasting activities should be modernized, value added and extended to other uncovered areas. Inflow forecasting to reservoirs should be instituted for their effective regulation.

The erosion of land, whether by the sea in coastal areas or by river waters inland, should be minimized by suitable cost-effective measures. The States and Union Territories should also undertake all requisite steps to ensure that indiscriminate occupation and exploitation of coastal strips of land are discouraged and that the location of economic activities in areas adjacent to the sea is regulated.

Each coastal State should prepare a comprehensive coastal land management plan, keeping in view the environmental and ecological impacts, and regulate the developmental activities accordingly.

General Flood Management Measures practiced in India

Different measures have been adopted to reduce the flood losses and protect the flood plains. Depending upon the nature work, Flood protection and flood management measures may be broadly classified as under:

Engineering / Structural Measures
Administrative / Non-Structural Measures

Engineering /Structural Measures

The engineering measures for flood control which bring relief to the flood prone areas by reducing flood flows and thereby the flood levels are –

An artificially created reservoir behind a dam across a river

A natural depression suitably improved and regulated, if necessary, or

By diversion of a part of the peak flow to another river or basin, where such diversion would not cause appreciable damage.

By constructing a parallel channel bye passing a particular town/reach of the river prone to flooding.

The engineering methods of flood protection, which do not reduce the flood flow but reduce spilling, are:

Embankments which artificially raise the effective river bank and thereby prevent spilling and

Channel and drainage improvement works, which artificially reduce the flood water level so as to keep the same, confined within the river banks and thus prevent spilling.

Different aspects of some of the important measures for flood management are enumerated below:

Reservoirs

Reservoirs can moderate the intensity and timing of the incoming flood. They store the water during periods of high discharges in the river and release it after the critical high flow condition is over, so as to be ready to receive the next wave. Their effectiveness in moderating floods would depend on the reservoir capacity available at that time for absorbing the flood runoff and their proximity to the likely damage center. They are operated with a carefully planned regulation schedule which takes into account both the safety of the dam and related structures and the safe carrying capacity of the lower reaches of the river in their present condition.

Reservoirs are more effective for flood management if, apart from the incidental moderation available for any type of storage on a river, specific flood space is earmarked, as in the case of DVC dams across the Damodar and its tributaries. The operation schedule or rule curve being followed should be reviewed and a suitable operation schedule/rule curve prescribed for the monsoon filling to ensure space for flood moderation but which can be filled for conservation at a later stage when high flows end.

In order to improve the efficiency of the reservoirs and improve the operation schedules for providing either incidental or specific flood moderation effects, arrangement for inflow forecasts should be made.

10.1.2 Detention Basins Detention basins are usually formed by utilizing natural depressions/ swamps and lakes by improving their capacity by constructing encircling embankments and providing suitable devices for regulating the release of stored waters. Since, the land under the marshes or low depression may hardly require much compensation and rehabilitation measures, this method is relatively in expensive. The Ghaggar detention basin in Rajasthan is a good example. Depressions available upstream of Srinagar City, on the left bank of river Jhelum, the Mokama Tal area in Bihar and Ottu, Bhindawas, Kotla lakes in Haryana and various beels/haors of Barak basin are some examples of a few natural basins.

Embankments

Embankments (including ring bunds and town protection works) confine the flood flows and prevent spilling, thereby reducing the damage. These are generally cheap, quick and most popular method of flood protection and have been constructed extensively in the past. These are reported to have given considerable protection at comparatively low costs, particularly in the lower reaches of large rivers. In many places, embankments may be the only feasible method of preventing inundation. Embankments are designed and constructed to afford a degree of protection against floods of a certain frequency and intensity or against the maximum recorded floods till the time of their planning only (in the absence of detailed hydrological data for longer periods) depending upon the location protected and their economic justification. The raising and strengthening of existing embankments have also been taken up in many of the flood prone States. In order that this work is done adequately it is necessary to adopt the flood frequency approach in their redesign, taking into account the data of historical floods, which is now available.

Apart from the raising and strengthening works, erosion along the embankments and natural banks of the river systems has been a serious problem on which considerable expenditure has been incurred in the past. Particular mention could be made of the erosion problem of the embankment systems in Assam, Bihar, U.P, Punjab and West Bengal. The embankments, under serious attack by the major rivers and their tributaries, have to be suitably protected by spurs, pitching and other suitable anti-erosion measures. On many embankment systems like the Kosi embankment and Piprasi-Pipraghat embankment on the Gandak in Bihar, the river attack is so severe that the protection measures

required to be taken are large and cannot be covered under the normal maintenance works.

A number of Committees constituted in various countries as well as in India have deliberated upon the utility of embankments as a means for flood protection. Divergent views have emerged out of these. Many NGOs have voiced serious criticism about existing embankments. One is that problems of flood can be solved by removal of all the existing embankments and the other diametrically opposite being that construction of more and more lengths of the embankments and their raising and strengthening is the only practicable medium/short term solution for the flood problems. The reason for such wide divergence in opinion is obviously due to the inadequacy of sufficient number of performance evaluation studies of existing embankments and the divergent views on their performance. As experienced, some embankments have provided positive benefits by ensuring sustained protection against floods and river spills while on the other hand, some embankments have, in certain reaches of the river, aggravated the flood problem by rising river bed levels, decreasing their carrying capacity, causing drainage congestion in the countryside and distorting the levels/gradient of the outfall points.

Construction of embankment with proper roads has been perceived as providing useful communication linkages and reliable surface network for areas that are liable to stand completely cut off during floods and thereafter. They could provide quick communication for facilitating better supervision and maintenance of the flood protection works and provide all weather communication facilities to the adjoining habitats. As such, they are often deemed as the life line during floods.

It is also recognized that embankments are not an unmixed blessing. They have adverse effects such as interference with drainage, inability to stand erosion, etc. which should be considered before planning this measure for flood management.

As such, this method of flood management may be undertaken only after carrying out detailed hydrological and other studies regarding their favorable and adverse effects.

Channelization of Rivers

Some of the states are proposing channelization of rivers, at least in certain reaches, in the context of tackling the extensive meandering problems of the rivers, activating navigational channels and training these rivers into their original courses. While venturing to channelize rivers, thought must be given in allowing the river certain freedom to flow and right of way to pass its flood waters and silt load within its natural waterway. The dynamic nature of the rivers should be appreciated and preventive measures planned accordingly instead of pinning down the river by channelizing.

Channel Improvement

The method of improving the channel by improving the hydraulic conditions of the river channels by desilting, dredging, lining etc., to enable the river to carry its discharges at lower levels or within its banks has been often advocated but adopted on a very limited extent because of its high cost and other problems.

Dredging operations of the Brahmaputra, which were undertaken in the early seventies on an experimental basis, were discontinued because of their prohibitive cost and limited benefits. Dredging in selected locations may perhaps be considered as a component of a package of measures for channel improvement to check the river bank erosion subject to techno-economic justification. It may be economically justifiable as a method for channel improvement where navigation is involved. Dredging is sometimes advocated for clearing river mouth or narrow constrictions.

Drainage Improvement

Surface water drainage congestion due to inadequacy of natural or artificial drainage channels to carry the storm water discharge within a reasonable period causes damages. It is often difficult to distinguish between flood and drainage congestion situations. This problem is rather acute in Andhra Pradesh, Bihar, Haryana, Punjab, Orissa, Uttar Pradesh, Assam and West Bengal, J&K, Gujarat and Tamil Nadu. Therefore, improvement of drainage by construction of new channels or improvement in the discharge capacity of the existing drainage system is recommended as an integral part of the flood management programme in the country.

Stress has to be laid on improving the existing natural drainage system in the flood plains so that what should essentially be flooding of a few days should not get prolonged for months. In this context, the importance of the system ‘dhars’ or ‘old channels’, which efficiently served the function of draining away the spillage and surface flows generated by local rains, must be recognized. The blocking of these natural drainage channels, which is normally done in the name of “reclamation for development” because of paucity of land or vested interest, must be firmly discouraged. This applies also to all natural

depressions, which are targeted for reclamation.

The adequacy of existing sluices and drainage channels should be reviewed in areas suffering from drainage congestion. If the capacities of existing sluices in embankments and drainage channels are inadequate, this should be improved by increasing the vents and improving outfall conditions.

Diversion of Flood Waters

Diversion of flood waters takes a part of the flood discharge to another basin or to the same basin downstream of the problem area or to a depression where it could be stored for subsequent release. This measure can be used to manage unusual floods around cities as in the case of flood spill channel near Srinagar and also in the lower reaches of a river near the sea as in the case of Krishna Godavari drainage scheme. Important schemes under execution or under planning are the supplementary drain in Delhi, the outfall channel in Jammu and Kashmir, the Damodar in the lower reaches in West Bengal, the Thottapally Spillway diversion in Kerala, the Kolleru lake diversion into the sea in Andhra Pradesh, the Kama-Pahari drain in Rajasthan and the Hulwaa drain in Uttar Pradesh.

Watershed Management

The watershed management measures include developing and conserving the vegetative and soil covers and also to undertake structural works like check-dams, detention basins, and diversion channels, etc. In the watershed management of upper catchment, land treatment through afforestation and grass land development practices should be supplemented by structural works for retarding the water velocity and arresting silt.

Administrative / Non-structural Measures

The administrative methods endeavor to mitigate the flood damages by;

Facilitating timely evacuation of the people and shifting of their movable property to safer grounds by having advance warning of incoming flood i.e. flood forecasting, flood warning in case of threatened inundation

Discouraging creation of valuable assets/settlement of the people in the areas subject to frequent flooding i.e. enforcing flood plain zoning regulation.

Providing absolute protection to all flood prone areas against all magnitude of floods is neither practically possible nor economically viable. Such an attempt would involve stupendously high cost for construction and for maintenance. Hence a pragmatic approach in flood management is to provide a reasonable degree of protection against flood damages at economic cost through a combination of structural and non-structural measures.

Flood Plain Zoning

Flood-plain zoning is a concept central to flood plain management. This concept recognizes the basic fact that the flood plain of a river is essentially its domain and any intrusion into or developmental activity therein must recognize the river's 'right of way'. Flood-plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones, so that whenever floods actually occur, the damage can be minimized, if not avoided. Unfortunately, while all generally endorse this approach in principle, scant attention is given to it in actual practice, leading to increased flood damages. The Central Water Commission (CWC) has been continuously impressing upon the states the need to take follow-up action to implement the flood plain zoning approach. A model draft bill for flood plain zoning legislation was also circulated by the union government in 1975 to all the states.

There has been passive resistance on the part of the states to follow up the various aspects of flood plain management including possible legislation.

Flood Proofing

Flood proofing measures adopted in India in the past, consisted in raising a few villages above pre-determined flood levels and connecting them to nearby roads or high lands. Under this programme, several thousand villages were raised in Uttar Pradesh in the fifties. In West Bengal and Assam also land-fills were attempted in villages to keep houses above flood levels even though nearby agricultural lands were liable to inundation. During X Plan, the Government of Bihar had also constructed, with Central assistance, the raised platforms for safety of the people in flood prone areas of North Bihar.

CWC National Flood Forecasting Network

The work of flood forecasting and warning in India is entrusted with the Central Water Commission (CWC). Flood Forecasting and flood warning in India was commenced in a small way in the year 1958 with the establishment of a unit in the Central Water Commission (CWC), New Delhi, for flood forecasting for the river Yamuna at Delhi. Presently, there are 878 Hydrological and Hydro-meteorological sites being operated by CWC across the country covering 20 river basins for gauge, discharge, sediment & water quality observations. The formulation of a forecast requires effective means of real

time data communication network from the forecasting stations and the base stations (380 no's approx. at present). Wireless Communication system installed in almost 550 stations is the backbone of the communication system required for flood forecasting activities. The activity of flood forecasting comprises of Level Forecasting and Inflow Forecasting. The level forecasts help the user agencies to decide mitigating measures like evacuation of people and shifting people and their movable property to safer locations. The Inflow Forecasting is used by various dam authorities in optimum operation of reservoirs for safe passage of flood downstream as well as to ensure adequate storage in the reservoirs for meeting demand during non-monsoon period.

Presently, Flood forecasts are issued by CWC at 175 stations (28 Inflow Forecast Stations and 147 Level Forecast Stations). Annually, about 6000 flood forecasts are issued by CWC during floods.

In order to meet the requirement of real-time data collection, automatic data transmission and flood forecast formulation, expeditious data / information dissemination, the Central Water Commission has undertaken modernization of its data collection and flood forecast network. During IX Plan, 55 telemetry stations were installed in Mahanadi and Chambal Basins besides setting up of two Earth receiving Stations (ERS) at Jaipur (Rajasthan) and Burla (Orissa). During X Plan, modernization of 168 stations was undertaken; out of which 166 stations besides 11 Modelling Centers have been set up till date. During XI Plan, additional 222 stations and 10 Modelling Centers are proposed to be installed; which would help the concerned States in taking appropriate measures in advance for evacuation of people and shifting them and their properties to safer locations.

SAFETY ALARMING SYSTEM IN CONSTRUCTION SECTOR

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The high frequency of work-related injuries and fatalities experienced on construction sites makes the construction process a very hazardous endeavor. The collection and analysis of safety data is an important element in measurement and improvement strategy development. Wearable sensing devices (WSDs) and the internet of things (IoT) have been identified as emerging technologies with strong potential for a transformative change in many aspects of construction workers safety monitoring including tracking and transmitting workers safety information in real-time. This paper provides an evaluation of the potential applications of WSDs and IoT for the continuous collection, analysis, and monitoring of construction workers' safety metrics to mitigate safety hazards and health risks on construction sites. Wearable sensors and systems that can be used for physiological monitoring, environmental sensing, proximity detection, and location tracking of a wide range of construction hazards and vital signals which can provide early warning signs of safety issues to construction workers are reviewed. A schematic model for integrating wearable sensors for interoperability and multi-parameter monitoring to capture and track several safety metrics is also presented. The challenges facing the widespread adoption of WSDs and IoT in construction are also identified and evaluated. Based on the outcomes of the review completed, recommendations are made on how WSDs and IoT can be effectively implemented to enhance safety performance on construction sites.

INTRODUCTION

The high rate of fatalities in the construction industry remains a major concern of practitioners and researchers. Given the high proportion of fatal and non-fatal accidents occurring in the construction industry, construction companies constantly seek novel strategies that promote safety (Demirkesen and Arditi 2015). Because of the transient and dynamic nature of construction, organizations must be able to quickly adapt to change by effectively capturing, storing, and disseminating new strategies that prevent injuries (Hallowell 2012). Thus, new technologies may be candidates for safety advancement. Although technology has undoubtedly played a major role in the improvement of construction processes, its application for personalized construction safety monitoring has not been fully explored (Cheng et al. 2012).

Most of the existing data collection approaches are manual and are faced with major challenges related to accurate recording, interpretation, and efficiency (Teizer and Vela 2009).

WSDs offer a non-intrusive solution that provides objective and real-time data that can be used to make efficient and proactive decisions. WSDs are considered a subset of IoT which traverses different market segments including smart appliances, connected cars, and many others. Wearable IoT (WIoT) is a technological infrastructure that interconnects wearable sensors to enable monitoring human factors including health, wellness, behaviors, and other data useful in enhancing individuals' everyday quality of life (Hiremath et al. 2014). WSDs can be used by workers to monitor and control their health profile via real-time feedback, so that the earliest signs of safety issues arising from health problems can be detected and corrected (Sung et al. 2005). Wearable sensors can also provide safety supervisors with quantitative measures of subjects' status on construction sites, thus facilitating decisions made concerning the adequacy of ongoing interventions and possibly allowing for prompt modification of the strategy if needed (Bonato 2009). In spite of the conceivable benefits of the application of WSDs and IoT, there remains some resistance to applying this class of technology in the construction industry. This paper provides an evaluation of the potential applications of WSDs and IoT for construction safety monitoring.

CONSTRUCTION SAFETY MONITORING USING WSDS AND IOT

Over the years, the world has transitioned from basic internet services to social networks to wearable web leading to a continuous upsurge in the need for interconnecting smart wearable devices. This emergence of wearable devices is giving a new dimension to IoT by creating an intelligent fabric of body-worn or near-body sensors communicating with each other or with the internet (Hiremath et al. 2014). The IoT is the network of physical objects supported by embedded technology for data communication and sensors to interact with both internal and external objects states and the environment (Haghi et al. 2017). According to Hiremath et al. (2014), the concept of IoT provides a solid framework for interconnecting edge computing devices—wearable sensors and smartphones—and cloud computing platforms for seamless interactions. It merges the virtual world and the physical world by bringing different concepts and technical components together: pervasive networks, miniaturization of devices, mobile communication, and new ecosystem (Chen

et al. 2014). Existing studies indicate that the adoption of WSDs based on IoT infrastructure has the potential to enhance worker safety through an efficient data collection, analysis, and provision of real-time information about safety and health risks to personnel (Bonato 2009; Anantha Narayan and Siek 2010; Nath et al., 2017; Awolusi et al. 2018).

However, the application of WSDs and IoT in construction is at the incipient stage when compared to other industries (Cheng et al. 2012). The constrained and slow implementation is due, in part, to a lack of reliable data supporting their potential benefits and absence of critical information needed for integrating such technologies into work processes (Yang et al. 2016; Nnaji et al. 2018). Recently, the construction industry has been experiencing a gradual increase in the adoption of mobility and automation tools as well as other technologies that can increase efficiency. It is anticipated that in-line with this industry trend, a rise in the use of IoT based WSDs could uncover Possibilities for improvement in construction, particularly in their implementation for personalized safety monitoring. It is expected that the increased utilization of these technologies will improve construction safety performance by reducing injuries, illnesses, and fatalities on construction sites. The various applications of WSDs for construction safety monitoring are discussed as follows.

Physiological Monitoring:

Construction site workers often encounter various health risks as a result of the austere and dynamic work environments that can impact the safety performance and overall working effectiveness of construction personnel. Physiological data such as heart rate, breathing rate, body posture, body speed, and body acceleration can be automatically recorded and analyzed using different sensors and systems such the Physiological Status Monitoring (PSM) system and GPS tracking device to assess ground workers and construction equipment operator's health (Gatti et al. 2011; Awolusi et al. 2016; Shen et al. 2017). A broad set of physiological sensors commonly used may include electrocardiogram (ECG/EKG) sensor, electromyography (EMG) sensor, electroencephalography (EEG) sensor, skin temperature sensor, blood pressure sensor, tilt sensor, breathing sensor, and movement sensors. The various metrics captured by these sensors give an indication of a construction worker's stress level and health status that are measures of the safety performance of the workers. WSDs containing gyroscope, accelerometer, and magnetometer have gradually found practical applications in human motion analysis to improve balance control and reduce falls. Data analysis procedures could be exclusively developed to detect falls via processing of motion and vital sign data.

Environmental Sensing:

Construction work environment poses health and safety risks to workers not only due to the continuous exposure to weather elements but also because of the inherent need for certain materials that might be hazardous to construction workers. Automated sensing of these injurious materials and inclement weather elements is necessary to provide early warning signals to construction personnel. More generally, it is now possible to use environmental sensors to measure a range of concerns, including temperature, air quality, humidity, barometric pressure, gas leaks, visibility, light intensity, spectrum, radiation, hydrogen sulfide, and carbon monoxide (Swan 2012). Workers can be monitored when performing their normal work and simultaneously having the ability to see highly localized, real-time data on things like temperature, hazardous gases, air particles, and possible toxic chemical leaks.

Proximity Detection:

The high rate and severity of contact injuries experienced on construction sites can be prevented in a timely manner using a real-time proximity detection and warning system. WSDs for proximity detection are capable of alerting construction personnel and equipment operators during hazardous proximity situations (Marks and Teizer 2012). Many proximity avoidance systems have been developed by utilizing various technologies, such as an ultrasonic-based sensor (Choe et al. 2014), radio-frequency identification (RFID) sensing technology (Chae and Yoshida 2010; Teizer et al. 2010; Park et al. 2016), radar (Choe et al. 2014; Ruff 2006), GPS (Oloufa et al. 2003; Wang and Razavi 2016), and magnetic field generators (Li et al. 2012), to prevent contact accidents, particularly for accidents due to being struck by equipment. Most of these technologies provide some form of warning signals to workers when they are close to heavy equipment. These signals could be visual, vibratory, or audible warning signals. The choice of the type of signal chosen is also dependent on the type of task being carried out on the construction site. The proximity zones could either be within warning zones with limited risks or within danger zones, which constitute regions of high risks.

Location Tracking:

Locating and tracking resources is critical in many industrial applications for monitoring productivity and safety. In construction, various technologies such as GPS (Papapostolou and Chaouchi 2011), RFID and RF localization (Zhu et al. 2012), UWB (Cho et al. 2010; Saidi et al. 2011; Shahi et al. 2012), sonar, magnetic field, and radar have been proposed for monitoring safety performance. Localization and tracking technologies have been applied to identify undetected obstructions in blind spots (Fullerton et al. 2009) and have also been utilized in the tracking of workers to manage factors related to human error, such as lack of hazard recognition (Hallowell et al. 2010). All these applications highlight the importance of real-time location and progress tracking technologies. The prominent development of low-cost and small in-size wearable sensors that work with the IoT system can collect location information and then provide services based on the collected location information.

Daily, approximately 6.5 million people work at about 252,000 construction sites across the U.S. (OSHA 2017). Due to the inherent nature of the diverse tasks performed on construction sites, these workers are continuously exposed to a wide range of safety and health hazards that increase the potential for becoming sick, ill, and even disabled for life. Some of the potential safety and health hazards for construction workers include falls from heights due to improper erection of scaffolding or use of ladders; repetitive motion injuries; heat exhaustion or heat stroke due to body temperatures rising to dangerous levels; and being struck by moving equipment working in close proximity to workers (OSHA 2017). Table 1 illustrates the sensors and systems that are currently used in IoT enabled WSDs for monitoring and tracking the common safety and health hazards associated with the construction process (Awolusi et al. 2018).

Sensors and Systems for Construction Safety Monitoring

	Construction Site Hazards	Metrics	Sensing Technologies
Physiological Monitoring	Falls from height Slips and Trips Stress Heat or cold	Body posture Body posture, Body speed, Body rotation and orientation Heart rate, Blood Pressure, Respiratory rate Body temperature	Gyroscope, Accelerometer, Magnetometer ECG/EKG, Infrared, Radar Thermistor
Environmental Sensing	Fire and explosions Noise	Smoke and fire detection Noise level	Infrared Noise Noise level Noise sensor
Proximity Detection and Location Tracking	Caught-in or -between Cave in Struck-by object Electrocution	Proximity detection Location tracking Proximity detection, Location tracking Proximity detection, Location tracking	RFID, UWB, Infrared, Radar, Bluetooth GPS, RFID, UWB RFID, UWB, Infrared, Radar, Bluetooth, GPS RFID, Infrared, Radar, Bluetooth, GPS, RFID, UWB

sectors based on parameters such as size/weight, power source/battery life, sensors and sensor network, wireless connectivity, data logging and storage, software library, etc.

From the existing works on the implementation of WSDs in construction, no efficient solution has been developed to integrate different sensors for a comprehensive construction safety monitoring that covers physiological monitoring, environmental sensing, proximity detection, and location tracking. Creating systems such as multiple sensors on one node, multiple nodes on one individual, and multiple individuals on one cloud system might offer a possible breakthrough. Figure 1 illustrates how different sensors and systems can be integrated into WSDs for multi-sensor platforms and multi-parameter monitoring.

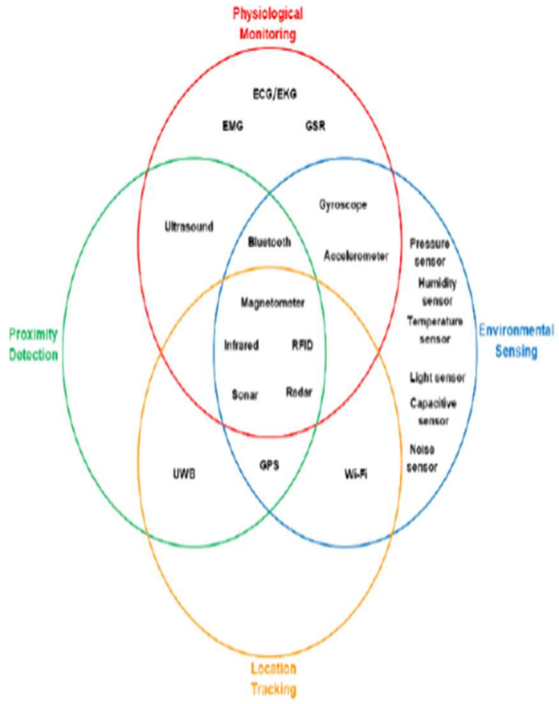

Figure 1. Sensors and Systems for WSDs

CHALLENGES FOR IOT AND WSDS ADOPTION IN CONSTRUCTION

WSDs based on IoT platforms must provide simple, powerful application access to IoT devices, intelligent learning, fast deployment, best information understanding and interpreting, and privacy protection against fraud and malicious attack (Chen et al. 2014). Some of the key capabilities that leading IoT platforms must enable are simple and secure connectivity, privacy and security (i.e. reduced risk of data loss), power consumption (energy sustainability), wear ability, and interoperability (Chen et al. 2014; Haghi et al. 2017). For instance, some WSDs required for monitoring construction workers safety collect sensitive information such as the user's physiological data, absolute location, and movement activities that compromise the user's privacy. This information must be protected during the processes of storage or communication. For instance, a protocol could be developed that limits the type of information that is transmitted through the IoT platform, thereby ensuring that workers have primary control of certain important, yet private health-related information. Furthermore, a non-punitive, opt-in-based system that provides some wellness benefits to workers should be considered. To mitigate the Computing in Civil Engineering 2019 Downloaded from ascelibrary.org by Ibukun Awolusi on 06/15/19. Copyright ASCE. For personal use only; all rights reserved. Risk of cyber-attacks on WSDs based on IoT, there is a need for strong network security infrastructure for short- and long-range communication (Hiremath et al. 2014; Arias et al. 2015). Careful precautions are desired in each passing layer of the system from the wearable sensors to the gateway devices to the cloud, and to ensure users' privacy and security. Heterogeneity of connected wearable devices, multi-dimensionality of safety data that can be collected and generated make the demand for interoperability very high. Interoperability is the essential issue for crossing layers of the physical device, communication (protocol and spectrum utility), function, and application (Chen et al. 2014). A holistic approach is required in addressing and solving the interoperability of IoT devices and services at several layers.

Large scale service deployment of new technologies needs to be framed within a set of standards. Because IoT spans multiple industries with many manufacturers and differs broadly in application scenarios and user requirements, large-scale commercial deployment of related IoT services seems very challenging. IoT itself currently lacks theory, technology architecture, and standards that integrate the virtual world and the real physical world in a unified framework (Chen et al. 2014). Developments and coordination of standards and proposals will stimulate the effective expansion of IoT infrastructures and applications, services, and devices including WSDs. In general, standards developed by a concerted effort of multiple parties, information models and protocols in the standards, shall be open. It should be noted that global standards are typically more relevant than any local agreements.

CONCLUSION

This paper provides a review of the potential applications of WSDs and IoT for the continuous monitoring of construction workers' safety metrics to mitigate safety hazards and health risks on construction sites. The study evaluated wearable sensors and systems that can be used for physiological monitoring, environmental sensing, proximity detection, and location tracking of a wide range of construction hazards and vital signals which can provide early warning signs of safety issues to construction workers. The schematic model presented in this study can be used by manufacturers of WSDs as a tool for integrating wearable sensors and systems into a single device for interoperability and multi-parameter monitoring of construction safety metrics.

For technologies such as WSDs and IoT to be accepted

by end-users, their effectiveness, applicability to operations, and value-adding impact as identified and discussed in this study must be continuously evaluated and established. The application of WSDs and IoT is expected to foster proactive and active construction safety management strategies for reducing injuries, illnesses, and fatalities on construction sites. Further research effort should be directed toward identifying factors and developing tools that can drive the effective application of these technologies whenever they are deployed on construction sites.

To enhance the diffusion of WSDs and IoT in construction, there is a need to further evaluate some of the challenges facing their wide-spread adoption as identified and discussed in this study, particularly, users' inherent concerns with respect to privacy and security, interoperability, and standardization of the technologies. Additionally, more research is required in understanding the resistance of construction employees to WSDs. This review has unlocked areas of further in-depth research studies on how to enhance the application of WSDs and the IoT for proactive and active construction safety management. The evaluation of the adoption, adaptation, and infusion of WSDs in construction; evaluation of commercially available WSDs in construction; and development of prototypes of construction specific WSDs are subjects of further research currently being undertaken by the researchers involved in this study.

SELF-HEALING CONCRETE: A REVOLUTION IN MODERN CONSTRUCTION

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Introduction

Concrete is the backbone of modern civilization. It forms the foundation of our cities, the bridges we cross, the tunnels we drive through, and the buildings we live and work in. However, despite its strength, concrete is prone to cracking, which can compromise its integrity and lead to expensive repairs or even catastrophic failures. To address this issue, scientists and engineers have developed a remarkable innovation known as self-healing concrete. This breakthrough technology promises to revolutionize the construction industry by enabling concrete to repair its own cracks, extending its lifespan and reducing maintenance costs.

What is Self-Healing Concrete?

Self-healing concrete is a type of concrete that can automatically repair minor cracks when they occur. The concept is inspired by nature, where certain organisms, like plants and animals, have the ability to heal themselves. By incorporating specific healing agents, such as bacteria, capsules, or other chemical compounds, self-healing concrete can close up small cracks before they develop into larger, more serious problems.

There are several methods used to create self-healing concrete, and each has its own unique mechanism for sealing cracks. The most popular methods involve the use of bacteria, microcapsules containing healing agents, and shape-memory materials.

Types of Self-Healing Mechanisms

1. Bacterial Self-Healing

One of the most promising methods of self-healing concrete involves the use of bacteria. In this approach, dormant bacteria and a calcium nutrient (calcium lactate) are embedded in the concrete mixture. When cracks form, water seeps into the concrete, reactivating the bacteria. The bacteria then consume the calcium lactate and produce limestone, which fills the crack and seals it.

Advantages:

1. Effective in healing cracks up to a few millimeters wide.
2. The process mimics natural limestone formation.
3. Environmentally friendly approach.

Disadvantages:

1. The cost of embedding bacteria and nutrients is still relatively high.
2. Requires specific conditions for optimal effectiveness.

2. Microcapsule-Based Self-Healing Microcapsule-based self-healing

It involves embedding small capsules filled with healing agents (such as epoxy or other adhesives) within the concrete. When a crack forms, it ruptures the microcapsules, releasing the healing agent that fills and seals the crack.

Advantages:

1. Immediate response to cracks as they appear.
2. Can be tailored to specific applications based on the size of the capsules and the type of healing agent used.

Disadvantages:

1. Limited effectiveness in very large cracks.
2. Potential degradation of capsules over time.

3. Shape-Memory Self-Healing

Another innovative approach involves the use of shape-memory materials that can contract when exposed to heat or water. These materials are embedded in concrete, and when cracks appear, the shape-memory material expands to close the gap.

Advantages:

1. Can be used in applications requiring specific conditions.
2. Mechanically driven repair process.

Disadvantages:

1. Expensive materials make it less economically feasible.
2. Still in the experimental stages.

Benefits of Self-Healing Concrete

1. Extended Lifespan of Structures Traditional concrete can deteriorate over time due to factors such as weather, temperature changes, and mechanical stress. Self-healing concrete addresses these issues by repairing minor cracks as soon as they appear, thus preventing them from growing into larger problems that could weaken the structure.

Example: Bridges and roads can remain functional for longer periods without frequent maintenance.

2. Cost-Effective Solution while the initial cost of self-healing concrete may be higher, it drastically reduces the need for repairs and maintenance over the lifespan of the structure. This can lead to significant cost savings for large infrastructure projects.

Example: A study showed that using self-healing concrete on a 1 km stretch of road saved up to 30% in maintenance costs over a decade.

3. Environmental Impact Cement production is one of the largest contributors to carbon dioxide emissions worldwide. Self-healing concrete can help reduce the environmental footprint of the construction industry by minimizing the need for frequent repairs and reducing the overall consumption of concrete.

Example: Reduced repair frequency means fewer resources are needed, leading to less waste and lower carbon emissions.

Challenges and Future Prospects

Despite its promising benefits, self-healing concrete still faces several challenges. The technology is relatively new, and more research is needed to refine the mechanisms and reduce production costs. Another challenge is ensuring that the self-healing process can occur uniformly across large structures.

However, as the technology advances, there is potential for self-healing concrete to become a mainstream construction material, especially for critical infrastructure projects that require long-term durability. Researchers are also exploring new types of healing agents and mechanisms that could improve the effectiveness of the technology.

Applications of Self-Healing Concrete

1. Bridges and Flyovers Bridges experience constant stress and exposure to harsh weather conditions, making them prone to cracking. Self-healing concrete can significantly extend their lifespan by automatically sealing minor cracks.

2. Tunnels are built to withstand immense pressure, but even the smallest cracks can lead to water infiltration and long-term damage. Self-healing concrete can prevent such leaks and ensure safer, longer-lasting tunnels.

3. Dams Cracks in dams can lead to catastrophic failures. Implementing self-healing concrete ensures that minor cracks are sealed before they become dangerous, maintaining the integrity of the structure.

4. Residential and Commercial Buildings The use of self-healing concrete in everyday construction can help improve the durability of buildings, making them more resilient against natural wear and tear.

Conclusion

Self-healing concrete represents a significant leap forward in the field of construction. By mimicking natural healing processes, it offers a practical solution to the persistent problem of concrete cracking. Although there are still hurdles to overcome, the benefits of increased durability, cost savings, and environmental impact make self-healing concrete a promising technology for the future of sustainable infrastructure.

As research continues to advance, we may soon see self-healing concrete becoming a standard material in everything from roads to skyscrapers, allowing our cities to stand stronger, longer, and more resilient than ever before.

India's First Bullet Train Project: A Journey into the Future

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Introduction

As one of the country's most ambitious projects – a High-Speed Rail (HSR) corridor connecting India's most populous city of Mumbai with Ahmedabad – gathers steam, the country is all set to make a giant leap in terms of development and enter the league of developed nations on the Global HSR map. Soon, clogged highways, airport delays and uncomfortable journeys will be a thing of the past. Our very own 'bullet' train, a nickname the train gets from its bullet-like shape and speed, will be seen tearing along west India's landscape, covering the 508 km distance between the two financial hubs in just about two hours. This will be a huge time saving compared to current travel times between the two terminal stations of about nine hours (by bus) or six hours (by conventional railways).

Indian Railways is the fourth largest railways in the world, ferrying a mammoth 8,400 million passengers and over 1,500 million tonnes of freight every year on its massive track network spanning across a distance of about 70,000 km. The HSR project will be a complete game-changer in this landscape and is set to redefine the way we Indians travel. The state-of-the-art high-speed trains, running on the Japanese Shinkansen technology, will zip at speeds of 320 km/h, which is more than double that of Indian Railways' fastest trains – the Gatiman Express and Vande Bharat Express – those chugs along at 160 km/h. And we as passengers will get to experience one of the best HSR technologies available globally, offering the highest levels of safety, comfort and reliability as we hop aboard this world-class system. As India takes giant strides on the path to development and positions itself to join the coveted list of global superpower nations, a transformation of our 167-year-old railway system is an integral part of this journey. Towards this end, Indian Railways has envisioned a phased up gradation of its network, both passenger and freight. The National Rail Plan (NRP) for India envisions enhancing the outreach of the HSR system and increasing connectivity to all the cites of importance.

The Mumbai-Ahmedabad High-Speed Rail Project, popularly known as the Bullet Train Project, will introduce the first-ever Indian Bullet Train operational in the country. The train will run between Ahmedabad and Mumbai, covering about 500 km (310 miles) distance. As per the current statistics, it takes 8 hours to cover the 500-km distance, which will be cut down to 3 hours with the Bullet Train. This is an ambitious target to achieve, and it will surely benefit the country's railway network.

The Indian Bullet Train Routes

The following table provides information regarding the high-speed train projects in India.

Project Name	Network
Mumbai – Ahmedabad High-Speed Rail	508.2 km
Delhi – Varanasi High-Speed Rail	865.0 km
Delhi – Ahmedabad High-Speed Rail	886.0 km
Mumbai – Nagpur High-Speed Rail	741.0 km
Mumbai – Hyderabad High-Speed Rail	711.0 km
Chennai – Mysore High-Speed Rail	435.0 km
Delhi – Amritsar High-Speed Rail	459.0 km
Varanasi – Howrah High-Speed Rail	760.0 km
Delhi – Mumbai High-Speed Rail	1384.0 km
Mumbai – Chennai High-Speed Rail	1334.0 km
Chennai – Kolkata High-Speed Rail	1670.0 km
Delhi – Kolkata High-Speed Rail	1447.0 km
Mumbai – Kolkata High-Speed Rail	1961.0 km
Delhi – Chennai High-Speed Rail	2184.0 km

Project Overview: India's First Bullet Train Project

India's First Bullet Train Project - the Mumbai - Ahmedabad High Speed Rail corridor, spanning across 508 kilometers, will offer fast connectivity between Maharashtra and Gujarat states in western India. After starting from Bandra Kurla Complex (BKC) area in Maharashtra, the high-speed train running at a speed of 320 km/h will revolutionize intercity

travel in the region and will integrate the economies of Mumbai, Vapi, Surat, Anand, Vadodara & Ahmedabad. It will have stops at 10 cities in between namely Thane, Virar, Boisar, Vapi, Bilimora, Surat, Bharuch, Vadodara, Anand, Ahmedabad and will terminate at Sabarmati. The entire journey will be completed in about 2 hours 7 minutes with limited stops (at Surat, Vadodara and Ahmedabad), which is substantially less than the time taken by conventional trains or road journeys.

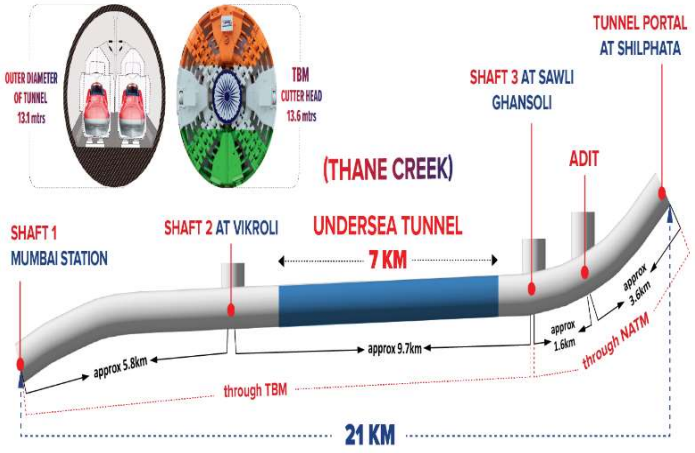
National High-Speed Rail Corporation Limited (NHSRCL) implementing this project was incorporated on 12th February 2016 under the Companies Act, 2013 with an object to finance, construct, maintain and manage the High-Speed Rail Corridor in India. The Company has been modelled as 'Special Purpose Vehicle' in the joint sector with equity participation by Central Government through Ministry of Railways and two State Governments viz. Government of Gujarat and Government of Maharashtra.

As per the feasibility report, the estimated cost of the project is INR 1,08,000 crore (USD 17 billion) excluding taxes and being executed with Official Development Assistance (ODA) Loan assistance from Japan International Cooperation Agency (JICA).In overall capital structure, 81% of the total cost of the project will be funded by the Government of Japan through JICA. The remaining project cost will be funded by Government of India. According to the equity structure of the Special Purpose Vehicle, 50% is held by the Government of India (GoI), through the Ministry of Railways, and 25% each by the Government of Maharashtra and the Government of Gujarat.

The conditions of the loan being given for MAHSR are at concessional terms and conditions. The tenure of the loan is 50 years at 0.1% interest rate and with a moratorium period of 15 years. Thus, the loan repayment will be done in 35 years.100% land has been acquired for the project. Out of 1390 hectares earmarked for the line, 430 hectares is in Maharashtra and another 960 hectares is in Gujarat and Union Territory of Dadra and Nagar Haveli.

About 90% of the alignment is elevated and is being constructed mainly using the Full Span Launching Method (FSLM). This unique construction method, is being used for the first time in the country. India is one of the few countries in the world to use and master this technique. FSLM is 10 times faster than the conventional segmental construction technique used for viaduct construction. 28 steel bridges of spans varying between 60 meters and 130 meters have been planned along the length of the corridor spanning over National and State Highways, Irrigation Canals, River and Railway tracks. In addition, 24 bridges are being constructed on rivers as part of the alignment, of which 20 bridges are located in the state of Gujarat and 4 bridges in the state of Maharashtra. The MAHSR corridor will include 8 mountain tunnels, which will be constructed using the New Austrian Tunneling Method (NATM). Seven of these tunnels are located in the Palghar district of Maharashtra, while one is situated in the Valsad district of Gujarat. Noise barriers are being installed on the either side of the viaduct, to help reduce the noise which will be generated during the operations.

India's First Undersea Rail Tunnel



The alignment features a 21 km long tunnel, including India's first 7 km long undersea tunnel under Thane Creek. The entire 21 km stretch will be constructed using a combination of two tunneling methods – New Austrian Tunneling Method (NATM) to carve out 5 km of the tunnel and the remaining 16 km through Tunnel Boring Machines (TBM).

A single tube of 13.1 m diameter will carry both the tracks in the tunnel. A cutter head of 13.6 m diameter which is the largest for any railways project in India, is being used for the TBMs.

Stations - Gateways to the Future

The design of each of the 12 stations on the MAHSR line will reflect the spirit of the city it is located in. This will bring about an instant connection with the local populace, and promote a sense of ownership of the high-speed rail system. The stations are being designed with contemporary architectural facade and state-of-the-art modern finishes. For a seamless travel experience, the stations on the alignment will be developed as transport hubs through integration with other modes such as metro, buses, taxis and autos for better, faster and hassle-free connectivity to and from the station. Such interface will reduce travel time, enhance accessibility and promote the use of public transportation, thereby

decreasing congestion and emissions in our cities. In order to enhance accessibility & convenience of commuters and to promote economic activities around the station, the surrounding areas are planned to be developed in accordance with the policies of TOD (Transit Oriented Development). The areas around stations at Sabarmati & Surat in Gujarat and Virar & Thane in Maharashtra have also been shortlisted by the respective state authorities for preparation of Station Area Development schemes.
To achieve seamless integration of various transport modes, a multi-modal transit terminal has been constructed connecting Sabarmati Bullet Train station in Gujarat.

Track Work

The J-Slab track system of ballast less track based on the Japanese Shinkansen track technology is being used for the project. This is for the first time, the J-slab ballast less track system is being used in India.
The entire process of track installation is mechanized with cutting edge machinery specially designed and manufactured as per Japanese specifications. The fleet of machines such as Rail Feeder Car, Track Slab Laying Car, CAM Laying Car and Flash Butt Welding Machine, will be used for track construction work. To understand the methodology of Shinkansen track construction works, extensive training and certification courses are being organized for the Indian engineers, work leaders and technicians on various subjects in the relevant fields by Japanese experts.

Comfortable & Safe Ride

The trains for this corridor are state-of-the-art trainsets with consideration of comfort and reliability. The trains are being designed to suit Indian environmental conditions. Three Rolling Stock depots at Sabarmati and Surat in Gujarat and Thane in Maharashtra are under construction. To meet the energy requirements, 12 traction substations, 2 depot traction substations and 16 distribution substations are being built along the corridor.
Automatic Train Control technology will be used for safe operations of the trains.

Bullet Train Project for a Brighter Future

Bullet Train project is stimulating economic growth by creating jobs during construction and operation, while also attracting investment and revitalizing areas around stations. By improving mobility and connectivity, Bullet Train will shorten travel time between cities, enhancing worker productivity and fostering business collaboration. It also connects underserved regions to major urban centers like Ahmedabad, Mumbai, Surat & Vadodara, promoting balanced regional development. The project resonates with the PM Gati Shakti initiative of transforming India's infrastructure and connectivity to build a Viksit Bharat, Saksham Bharat & Sashakt Bharat.

Benefits Of Introducing the Indian Bullet Trains

- Employment opportunities: The Mumbai-Ahmedabad High-Speed Rail Project alone, as estimated, will generate approximately 4,000 direct jobs. Apart from this, 20,000 indirect jobs will also be generated along with 20,000 construction workers availing the opportunity of employment till the commencement of the bullet train.
- Good connectivity: Well-connected, high-speed railway network boosts the economy. It assists in connecting smaller towns and cities to bigger economic hubs.
- Safety Concern: Bullet trains have proved to be invincible in terms of safety. The Shinkansen trains of Japan have an impeccable record of no casualties to date.
- Reduced migration: High-speed connectivity between the cities and towns will reduce the hassle of commuting, resulting in reduced migration.
- Attracting new investors: The Indian Bullet Train projects, when completed, will attract new investors in the field of high-speed train projects.
- Environment Friendly: The high-speed train projects could prove to be a cleaner way of travelling between cities.

Parameters That Will Make the Indian Bullet Trains Attractive

The citizens of India have a variety of options to commute, which includes private transport, buses, and airlines.

- To make railways a prime mode of transportation, speed, and comfort, frequency of operation and punctuality must be enhanced.
- To make the railway network more appealing to the citizens, there should be at least one high-speed train available every hour running between the major Indian cities.
- Nothing could beat a modern and comfortable experience on these trains.
- The most important aspect to consider is the pricing of the tickets. It should be nominal as per the affordability of the Indian citizens.

The Geopolitical Strategic Significance of The Indian Bullet Train

The Indian bullet train deal sends out a powerful message by the two Asian nations sharing a strategic partnership with each other, countering China's control over the Asia Pacific region.
India is important to Japan as the nation lost the bullet train deal in Indonesia against China at the very last moment. Japan faces tough competition from China, which provides the Maglev Bullet Train at a cheaper rate.
In spite of the huge difference in the rates, India chose Japan over China, thus, making its intentions crystal clear. Japan could invest more in the upcoming Indian railways projects.
The deal is not only beneficial for the economic growth of India but also for Japan's growing economy, providing numerous employment opportunities to Japanese citizens.
The Mumbai to Ahmedabad Bullet Train Project strengthens India's Look East Policy. It also counters China's Belt and Road Initiative, which China sees as a measure to become a global superpower.

Conclusion

India's aim to achieve the target of USD 8.4 trillion in terms of the economy by 2030 will make them the third-largest economy in the coming 25 years. India has proven its immense ability in other fields, including space, as a major contributor. The nations which are a part of the high-speed rail network are considered well-developed; now, it's time for India to speed up the rate of the Bullet Train Project. This will enhance India's international stature and further boost the relationship between India and Japan, leading to more such investments. Development of any form has a plethora of pros and cons. But to measure them wisely is the need of the hour to compete with the world and stand out.


Operational Speed
320 km/hr
12 Stations
8 Gujarat
4 Maharashtra
Time
(Limited stops) 2.07 hr
(All stops) 2.58 hr
MUMBAI-AHMEDABAD
HIGH SPEED
RAIL CORRIDOR
Viaduct
465 km
Bridges
10 km
Bank, Cut & Cover
7 km
Tunnel
(including 7 km Undersea)
21 km
Mountain Tunnels
5 km
STRUCTURES
12 Aesthetically Designed Stations
3 Rolling Stock Depots
8 Maintenance Depots
High Speed Rail Multi Modal Hub, Sabarmati
HSR Training Institute in Vadodara
SABARMATI
AHMEDABAD
ANAND
VADODARA
BHARUCH
SURAT
BILIMORA
VAPI
BOISAR
VIRAR
THANE
MUMBAI
Total Length 508 km
GUJARAT
348 km
DNH
4 km
MAHARASHTRA
156 km

ISRO's NAVIC: Navigation Support to Civil and Military Segments

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INTRODUCTION

DURING 1999 Kargil war, India's request for use of U.S. owned GPS for information about positioning, timing & navigation of hostile forces was denied. Likewise, in 2009 and 2012, India's Brahmos missile failed to hit targets in trial operations as U.S. shut off GPS satellites without any warning, causing crippling of missile's guiding system, which failed to achieve its objectives. Such unsavory incidents necessitated the need for an Indian Navigation Satellite System. Geopolitical vicissitudes point out that some countries can deny us the service in times of conflict. Likewise, it's a way of arm twisting & we should protect against that.

In 2006, the government gave assent to the project called "Indian Regional Navigation Satellite System" (IRNSS) that requires seven satellites. ISRO launched nine satellites between 2013-2018: IRNSS-1A, IRNSS-1B, IRNSS-1C, IRNSS-1D, IRNSS-1E, IRNSS-1F, IRNSS-1G, IRNSS-1H & IRNSS-1I, two extra satellites were launched due to failure of Rubidium atomic clocks on-board the first satellite, IRNSS-1A & also the failed launch of its replacement.

IRNSS, is an operational name of NAVIC, which is the acronym for Navigation with Indian Constellation. It also, denotes NAVIC, "sailor" or navigator in Hindi. IRNSS II was launched to finally complete NAVIC's constellation. Additionally, two backup satellites are also available. NAVIC provides accuracies of 10 m throughout the Indian landmass and 20 meters over Indian Ocean, termed Standard Position Service (SPS). NAVIC's primary operational range covers Bangladesh, Pakistan, Sri Lanka & parts of China besides India landmass and 1500 km distance from shore. On the other hand, GPS is a global tracking constellation, covering the whole earth. For common public, Interface Control Document (IC D Ver. 1.1) released by ISRO gives essential information besides facilitating R&D for commercial use.

Practical benefits of NAVIC chipset receivers

- Makes possible navigation at sea, land and in air
- Help during disasters to track & manage a fleet
- Receivers provide users with a satellite-based navigation system
- Receivers support frequency bands for both GPS & NAVIC systems
- Give location services on phone, maps etc.
- Help trekkers/hikers/travelers in terrestrial navigation
- Creation of maps via capture of geodetic data
- Provide audio-visual navigation guide for drivers
- Accurate data creation with understanding of the local terrain.

CIVIL AVIATION REQUIREMENTS

To meet Civil Aviation requirements, ISRO worked with Airport Authority of India (AAI) to establish the GPS Aided Geo Augmented Navigation (GAGAN) system GAGAN uses satellite-based navigation services with utmost accuracy & integrity needed for civil aviation applications in order to provide better Air Traffic management over Indian Airspace. Moreover, it is compatible with global systems, leading to seamless navigation across regional boundaries. GAGAN navigation payloads were launched on May 21, 2011 and Sep 29, 2012 aboard GSAT-8 and GSAT-10.

Benefits of induction of GAGAN include:
Flight safety, high position accuracy, fuel saving, saving in equipment cost, efficiency, increased air space capacity, enhancement of reliability, reduction in work load for operators, coverage of oceanic area for air traffic control, etc.
Additionally, GAGAN benefits other sectors like:

- Navigation and Safety Enhancement in Railways, Roadways, Ships, Spacecraft
- Geographic Data Collection
- Scientific Research for Atmospheric Studies
- Geodynamics
- Natural Resource and Land Management
- Location based services, Mobile, Tourism, etc.

GLOBAL ENDORSEMENT

The global wireless communications standards body 3GPP has accepted the interface specifications of NAVIC, which implies it can be integrated into devices like smart phones

and tablets. It also received recognition by the International Maritime Organization (IMO) as part of the World-Wide Radio Navigation System for operation in the Indian Ocean Region. IMO is the United Nations' agency responsible for safety and security of shipping and prevention of marine and atmospheric pollution by ships. International Maritime Organization urges individual countries for developing own navigation systems for reducing their reliance on other navigation systems. These recognitions impart big boost to India's mobile telecom industry while encouraging use of NAVIC throughout the Asia-Pacific region. At present, all merchant vessels including small fishing vessels are authorized to use the IRNSS. The vessels having transponders installed in them are tracked by satellite navigation showing their accurate position in the Indian Ocean region. At least 2,500 merchant vessels are there in the Indian waters which are authorized to use this system. Outcome will be that Smart phones and IoT devices using location information will start using the NAVIC system, which will enable mass market usage in 4G, 5G and IoT. Accordingly, domestic entities have opportunities to design chips and ICs based on NAVIC. This will create market for these chipsets and products for exports.

With this, India became the fourth country in the world to have its independent regional navigation satellite system developed to provide accurate position information service to assist in the navigation of ships in the Indian Ocean region. Glonass from Russia using 26 satellites, Galileo from the European Union using 30 satellites besides US-owned GPS, employing32 satellites.

FREQUENCY BANDS

NAVIC uses dual frequency bands, L5 (1.17GHz) & S band (2.5 GHz). On the contrary, GPS uses a single frequency band, namely L band. Now, when microwave signals travel through the atmosphere, it gets affected due to atmospheric disturbances. Therefore, GPS relies on atmospheric model to assess any frequency error. The model requires updating from time to time, to assess & correct any error. While in NAVIC, error is assessed by measuring the differences in the delay of the dual frequencies (L5 & S bands), making NAVIC more reliable & accurate in comparison to GPS.

ACCURACY

All the satellites of GPS revolve in a Semi-Geosynchronous orbit. Additionally, GPS's satellites take 11 hours (almost 1/2 of earth's rotation time) to complete one revolution. This makes acquiring position of an object more tedious. The fast velocity provides for relatively inaccurate positioning. The user will keep on jumping around from one satellite to another (for signal) increasing the acquisition time frame. Therefore, for densely built areas GPS lacks reliability.

Contrary to this, NAVIC provides a pin-point accuracy. This is due to the direct line of sight maintained between the satellites (in Geosynchronous orbit) and the user (all the time). Also, NAVIC's satellites take 23hr, 56min & 4 sec out (exact earth's rotation time) to complete one revolution. This makes the accuracy more precise and reliable.

The number of operational satellites will be increased to 11
in the future to further expand coverage & enhance accuracy.

DEFENCE FORCE-MULTIPLIER

Services provided by NAVIC multiplies Indian armed force's strength. The Army, Navy and Airforce can rely on assured positional data during hostilities on land, sea or air. Most modern weapon systems like guided missiles, bombs, defense systems use navigation systems for proper targeting and maximum lethality. An indigenous system like the NAVIC will ensure reliable development and execution of such capabilities. Although, the civilian side service of both NAVIC& GPS is equal (accuracy wise), NAVIC will improve everything that GPS lacks in terms of navigating in Indian environment. It is the best option for geographically diverse terrains of India.

MANUFACTURING ECOSYSTEM

ISRO's NAVIC is supported by mobile chipset manufacturers like Qualcomm, MediaTek and Broadcom across various chipset platforms. For instance, Smartphones with the latest Qualcomm chipsets can now latch on to NAVIC. It will provide a Standard Positioning Service to all users and an encrypted Restricted Service to authorized users. NAVIC will provide drivers and other users in India with visual and voice navigation. Its primary beneficiaries will be Indian mariners and fishermen, who are being provided with NAVIC handsets.

Qualcomm has launched several NAVIC compatible chipsets
— Snapdragon 865, Snapdragon 765, Snapdragon 720G, Snapdragon 662, and Snapdragon 460. The first phone in

India with NAVIC support is Realme X50 Pro 5G. Qualcomm claims that ISRO's navigation will have a more accurate location tracking in dense urban environments, where normally geolocation accuracy has a tendency to degrade.

ARCHITECTURE

Space Segment: Satellites are positioned in both geostationary as well as geosynchronous orbits. Of the seven satellites, three are geostationary orbits located at 32.5° East, 83° East and 131.5° East longitude while the other four are located 550 East and the other two at 111.75° East (two satellites in each plane). Life span is 9.5 years of GEOs while GSOs have a life span of 11 years.

An Extended Service Area lies between primary service area and area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East.

- *Ground Segment:* The IRNSS Ground Segment consists of the following:
  1- IRNSS Spacecraft Control Centre 2-IRNSS Navigation Centre
  IRNSS TTC & Up linking Stations
  IRNSS Range and Integrity Monitoring Stations
  IRNSS Timing Centre
  IRNSS CDMA Ranging Stations 7- Laser Ranging Station
  8- Data Communication Network.

- *User Segment:* The IRNSS User Segment consists of dual- frequency IRNSS receivers (L5 and S-band frequencies) or the single frequency IRNSS receivers (L5 or S-band frequency). Total cost of the project is Rs.14.2 billion, of which ground segment costs Rs.3 billion, each satellite costs Rs. 1.5 billion and the PSLV-XL version rocket costing around Rs.13 billion.

Drone Survey

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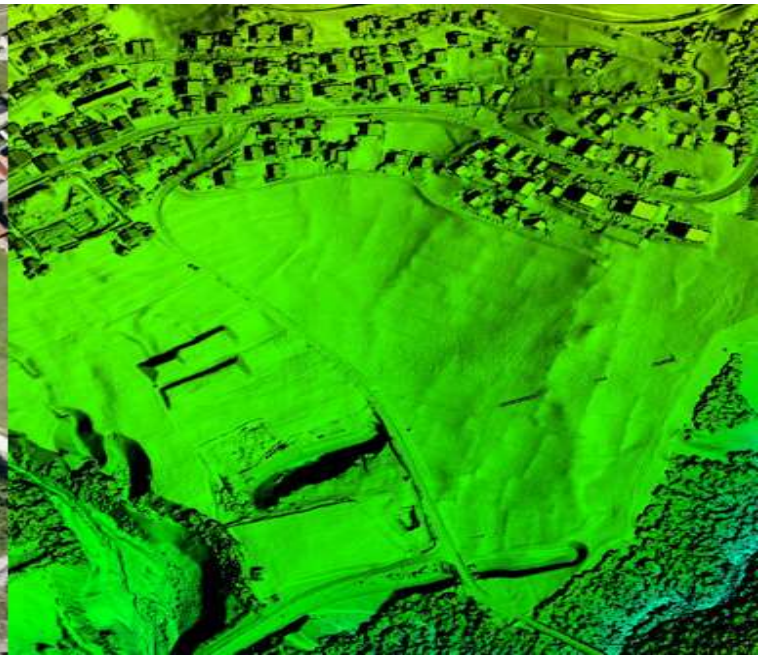
Drone surveying is an aerial survey conducted using drones and special cameras to capture aerial data with downward-facing sensors. It is frequently used by surveyors and engineers in construction for terrain assessments and mapping.



Drone Mapping in Surveying

Drone surveying can be 90% faster than manual surveying methods. It helps in creating highly accurate maps and survey points. In addition to surveying, firms also use drone mapping to identify job-site errors, track work progress, predict schedule delays, etc.

This article details the features and applications of drone mapping and surveying in the construction industry.

Features of Drone Mapping and Surveying

During drone survey, the ground is photographed several times from different angles, and each captured image is tagged with certain coordinates.

The collected data are processed using drone mapping software to create construction assets like 3D models, 2D maps, digital elevation models, from which highly accurate measurements and volumetric calculations are taken.

Drone captures highly precise data quickly, without the need for surveying staff to walk over dangerous terrain or height to collect the information.

The two common types of drone mapping methods are photogrammetry and LiDAR.

Photogrammetry involves capturing high-resolution images that are later processed and stitched using sophisticated software to recreate a survey area in the form of measurable 2D maps or 3D models.

LiDAR sends pulses of light to the earth's surface to detect small objects during drone mapping.

The drones in drone mapping consist of Red Green Blue Visual Imaging (RGB) for photogrammetry, thermal, LiDAR, or multispectral sensors to capture aerial data.

The different maps or deliverables obtained from drone surveying are orthomosaic maps, Digital Surface Model (DSM), Digital Terrain Model (DTM), and contour line maps.

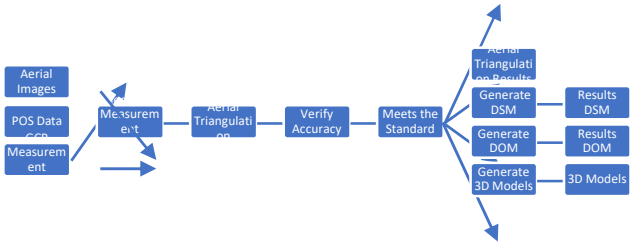
GCPs, PPK, and RTK in Drone Surveying

For very precise drone surveying, it is necessary to accurately locate the position of a drone in flight. This can be done either using Ground Control Points (GSPs), Real-Time Kinematic Survey (RTK), or Post Processing Kinematic (PPK) survey.

GCPs are reference points present in the ground whose coordinates are already known. GCPs enable the drone to return accurate data about its location and the distance it travelled between the two places. As laying GCPs on the ground is time-consuming and requires labor, vehicles, equipment, and lots of paperwork, techniques like PPK and RTK have been developed.

RTK is a GPS correction technology in which the location data of the drone is provided real-time corrections during the drone surveying and image capturing process.
PPK surveying is a GPS correction technology that corrects the location data of the drone only after the complete survey data is collected and uploaded. It is performed post the site work.

Drone Surveying Workflow for Onsite Data Collection



Drone Surveying Workflow - Data Processing

Applications of Drone Surveying

The main applications of drone surveying are in:

- Land surveying
- Precise measurements
- Land management and development
- Volumetric measurements
- Slope monitoring
- Urban planning

1. Land Surveying/Cartography

Drone surveying generates high-resolution orthomosaic maps and 3D models of areas to create accurate cadastral maps. It provides information on a site with low-quality/outdated/no data available.

2. Land Management and Development

The aerial images obtained from drones simplify topographic surveys for land management and planning. It facilitates site scouting, allotment planning, design, and the final construction of roads, buildings, and utilities. In addition, the data is used for pre-construction engineering studies transferred to CAD or BIM software to work with 3D models.

3. Precise Measurements

The surveyors can perform highly-accurate distance and surface measurements using the high-resolution orthomosaic photos from drone surveying.

4. Volumetric Measurements

The images obtained from drone surveying can be used in 3D mapping software, from which volumetric measurements are obtained. The method is used primarily for calculating stocks in mines and quarries for inventory or monitoring purposes.

Volume Measurement of Landfill

5. Slope Monitoring

The DTMs and DSMs generated by drone imagery and GIS analysis enable the extraction of slope measurements. Moreover, in some site conditions, the orthomosaic maps are generated at different times to detect changes in the earth's movement and measurement of velocity. This method, hence, helps in slope monitoring for landslide mitigation and prevention, for example, predicting landslides, preventing potential damage to roads, railways, bridges, etc.

6. Urban Planning

Drone surveys help urban planners collect up-to-date data of a complex urban area quickly using less staff to study the existing social and environmental conditions of the sites. This makes the planning stage of the development of an urban area easier.