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The Geospatial Way!

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Geospatial technologies and their uses for highway sector
Geospatial Technologies – defining the boundaries

**Classic Definition**
Geospatial technologies – ability to process data associated with a location

**Evolution**
First maps, Cartography, Aircraft imaging, satellites, GIS

**Current Approach**
Analyze information from various sources via automatic interpretation tools (for example imaging platform, satellite imagery, GPS) ArcGIS
Why modern technology based interventions are needed in Highway Sector

Transport Supply outstrips Demand — especially in the growing economies like India

Low technology adoption
- Barely 6% companies globally use digital planning tools
- Less than 1% of industry’s revenue is used for R&D activities

Inaccurate estimation and implementation
- Cost and time overrun in majority of projects
- World Bank analysis reveals that 62% of highways projects are overestimated
Key expectations from technology interventions

**Reliable** - To optimise the Infrastructure availability

**Safe** - Ensure that the solutions reduce the incidents via monitoring and design

**Sustainable** - Minimising the impact on Environment

**Future Ready** - Designing solutions that are in line with future disruptions
Transportation is a requirement for every nation regardless of its industrial capacity, political stability, population, size or technological development. Moving goods and people from one place to another is crucial to maintaining strong economic and political ties between the various components of any given nation and among nations.

The geographic information system (GIS) and the global positioning system (GPS) are the 2 geospatial technologies that are being used in monitoring of transportation generally.

The geospatial techniques are being used by NHAI to generate digitalized map of National Highways. Consequently, it is possible to determine the location of any object, incident, accident or event along these roads and determine distances between points thereby enhancing efficient monitoring of vehicles along these roads and safe driving.
Key Uses of GIS for highway sector

**Highway Planning & Designing**
- Overlay various maps in one combined map and perform integrated analysis
- Alignment finalization
- Land susceptibility mapping
- Identifying source of Man & Material & Estimation

**Project Monitoring**
- GIS based project monitoring - NHAI PMIS

**Pavement Management**
- Creating physical inventory of road assets
- Condition mapping of development work
- Investment analysis by comparing options, and their relative investments

**Traffic Engineering & Safety**
- Understanding and predicting traffic trends
- Comparing options and their impact on traffic trend
- Map the exact position of incident and alert rescue team
- Identify blackspots and do a causal analysis

**NHAI’s examples of road designing and cost savings**
Case study – Best route selection

Data Collection

Primary Data
- Satellite Imagery
- GPS Data
- Topographical surveys

Secondary Data
- Population, accidents, traffic, road condition

Data Extraction
- Maps correction
- Geoprocessing

GIS Analysis

Best route selection

Loganathan and Elangovan, 2017
Technology deployed globally across Highway Value Chain
NHAI has already begun to adopt certain technology interventions

**Technology Interventions**

1. **Process Stage**
   - Planning
   - Preparation
   - Construction
   - Operations

2. **Technology Interventions**
   - 1a Geospatial Network Planning
   - 1b Traffic Analysis and Simulation
   - 1c Digital Cadastral Mapping
   - 1d 3D Modelling

3. **Technology Interventions**
   - 2a Remote Sensing for Topographic Survey / Mapping
   - 2b Radar based Sub-surface Utility Mapping
   - 2c Auto Traffic Counter Classifier
   - 2d Digital Cadastral Mapping

4. **Technology Interventions**
   - 3a Advanced Constr. Technologies
   - 3b Advanced Constr. Materials
   - 3c GIS based Land Asset Management
   - 3d SCADA

5. **Technology Interventions**
   - 4a Mobility
   - 4b Maintenance
   - 4c Tolling
   - 4d Safety

6. **Technology Interventions**
   - 4e Digital Command and Control Centre

**Enterprise-wide Technology Solution**

- Project Monitoring
- Procurement Mgmt.
- Asset Management
- Information Mgmt.
- Workflow Mgmt.
- Finance Mgmt.
- Record Mgmt.
- Network, Security, Infrastructure
- Resource Mgmt. (HR, Admin)

**Khazana (Photo-luminescent markings, Solar roads, Wind powered lights)**

**Technology Deployed Globally Across Highway Value Chain**

** Already implemented**  **Under implementation**  **To be implemented**
<table>
<thead>
<tr>
<th>Methodology followed to identify lane augmentation requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. GIS mapping of NH and IP network, including projects currently underway</strong></td>
</tr>
<tr>
<td><strong>2. Superimposing traffic data with lane configuration</strong></td>
</tr>
<tr>
<td>• Traffic data collected from traffic surveys</td>
</tr>
<tr>
<td>• TS points plotted on each stretch</td>
</tr>
<tr>
<td><strong>3. Identifying stretches for augmentation</strong></td>
</tr>
<tr>
<td>• &lt;10,000 - No augmentation</td>
</tr>
<tr>
<td>• 10k - 40k - 4L</td>
</tr>
<tr>
<td>• 40k - 80k - 6L</td>
</tr>
<tr>
<td>• &gt;80k - 8L or parallel road</td>
</tr>
<tr>
<td><strong>4. Prioritizing the lane augmentation stretches</strong></td>
</tr>
<tr>
<td>• Budget</td>
</tr>
<tr>
<td>• Criticality for logistics efficiency of corridor</td>
</tr>
<tr>
<td>• Existing level of congestion / black spots</td>
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<td>• …</td>
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</table>

Screenshot of GIS based solution used for augmentation study

Under development for MoRTH, NHAI and other impl. Agencies through PMIS
GIS solution extensively being used for planning and decision making

GIS is primary data management system for planning
• Not used standalone but integrated to several additional tools

GIS is helping in performance driven approach to planning
• Monitoring mobility performance
• Identifying freight performance metrics

2 GIS based tools used by SC DOT
• ITMS (Integrated Transportation Management System) for asset management
• Project Management support in geospatial database

GIS offers the ability to layer different types of information

GIS based solution integrated with various types of systems for planning, monitoring & management
GIS based Land Asset Mgmt.: Parcel level planning and tracking of land acquisition

GIS based system for land asset management - Key features

- Visual representation of asset details
- Integration with cadastral maps and land records
- Dynamic land status updation
- Integration with Google/Bing Maps

Benefits of an online Land Asset Management System

a) Improved Planning
   - Ready access to Right of Way availability / vacant land details
   - Easy determination of land acquisition costs and consequent budgeting
   - Effective alignment planning to optimize costs

b) Improved Monitoring
   - Parcel level monitoring of 3A, 3D, 3G, 3H and disbursement status

c) Dispute Resolution
   - Ready availability of historical ownership records and sale/transfer transactions
   - Automate detection of illegal settlements

d) Better Asset management
   - Efficient identification and implementation of monetization / revenue opportunities
**TRANSIMS**: Micro simulation for conducting regional transportation system analyses

### Transportation Analysis and Simulation System

#### Network data
- Nodes
- Links
- Lane use and connectivity
- Intersections (signs and signals)
- Activity locations
- Parking
- Transit stops

#### Vehicles

#### Transit data
- Route paths in network
- Schedule of stops
- Driver plans
- Vehicle properties (e.g., Starting location)

#### Traveler plans

#### Traveler events
- Traveler id, trip id, leg id
- Time, location
- Inconvenience measures
- Anomalies
- Events

#### Snapshot data
- Vehicles on links
- Vehicles in intersections
- Traffic controls
- Vehicle sub-populations

#### Summary data
- Link travel times
- Link/lane densities
- Turn counts

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- Integrated tools to conduct transportation system analyses based on cellular automata\(^1\) microsimulator
- Models individual travelers and their multi-modal transportation
- Represents time consistently and continuously, as well as detailed persons and households

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Note: (1) A cellular automaton consists of a regular grid of cells, each in one of a finite number of states, such as on and off (in contrast to a coupled map lattice). The grid can be in any finite number of dimensions.
Sub-surface utility mapping: Ground Penetrating Radar (GPR) being used in DPR Preparation

Ground penetrating radar (GPR)

Description of system

- High frequency radio waves emitted into ground
- Reflected signals returned to receiver
- Graphic display to view waveforms digitally
- Used for mapping of underground cables and pipes

Benefits

- Rapid ground coverage – Towed by hand/vehicle
- Can accurately determine location/depth (x,y,z coordinate)
- Instant graphic display enables on-site interpretation
- High-resolution coverage of the survey area
- Useful for detecting even small objects
- Induction locator can be used to further differentiate electrical vs. non-electrical utility

Limitations

- Signal may be scattered by boulders etc.
- Data acquisition maybe slow over hilly / difficult terrain
- Depth of penetration dependent on soil conditions
**Digital Cadastral Maps: DPR consultants mandated to digitize land cadastral maps**

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- **Procure revenue map from local authorities**
  - Procure revenue map from local authorities
  - Map typically on paper/clothes
  - Some states already have digital maps (E.g., WB, KN)

- **Trace and scan map using scanner**
  - Scan revenue map using flat bed/roller type scanner
  - In case map on cloth/unclear, trace map first and then scan
  - Establish control points on map

- **Digitise map using software-AutoCAD etc**
  - Digitize map using any raster to vector conversion software such as AutoCAD, R2V
  - Cross check control points on map with ground conditions

- **Superimpose alignment on map**
  - Superimpose alignment on digital cadastral map to find out land/survey numbers to be acquired
3D Engineering models: Highway alignment and design can now be done in 3D

Four elements of 3D engineering

- **Surface models**: Comprehensive 3D model of existing site including:
  - topographic survey data
  - digital terrain models
  - surface and subsurface layers
  - utility information

- **Proposed utilities and structures**: Horizontal alignment and vertical profile of roadway

- **Road alignments**: Grading and pavement surface model of proposed project - e.g. top of pavement, subgrade, subbase, topsoil etc.

- **Existing conditions**: 3D models of proposed structures (bridges, culverts, RE walls) and utilities (drainage, power lines, traffic signals, street lights, amenities etc.)

3D engineered models can be further enhanced with time (4D) and cost (5D) information
SCADA (Supervisory Control and Data Acquisition) system can be used for quality control of road construction

Monitoring & control system

- SCADA system is an assemblage of computer and communications equipment
- Designed to work together for controlling a commercial process

In road construction, SCADA system with sensors remotely monitors large number of parameters
- Covers entire process starting from production of BC to levelling of pavement
- System can give a warning beforehand of equipment failure

SCADA is modern day’s information technology tool for quality construction of roads

SCADA architecture for road works

- Batching plant data
- Truck and Roller VTS data (GPS)
- Compaction data

Mobile devices
IPADS and tablets
Computers
Information collection system
**Smart highways: Development of new innovative solutions underway (I/II)**

**Concrete healing bacteria**
- Researches developed bacteria that when exposed to water produce limestone which seals cracks in concrete
  - Currently double the price than normal concrete
  - Bacteria able to survive for up to a staggering 200 years without oxygen or food.

**Photo-luminescent road markings**
- Photo-luminising powder for road markings: charge during the day & emit green glow at night
  - Temperature-sensitive paint to create giant snow flake-shaped warning signs on the roads to indicate icy conditions
  - Currently pilot project in the Netherlands under ways

**Energy transmitting roads**
- South Korea utilizing electric cables embedded in asphalt to power e-vehicles
  - No more large batteries, no more stops to recharge, and messy overhead trolley
  - Cables produce magnetic fields, which receiving devices in the vehicles’ undersides pick up & convert into electricity

Source: Global Energy Initiative, ARUP
**Smart highways:** Development of new innovative solutions underway (II/II)

### Solar cells embedded roads

- **Surface Features**
  - Flat place to drive
  - Provides traction
  - Doesn’t soften at high temp
  - Intelligent
  - LED lights for signage
  - Charge EVs
  - Independent Energy

- **Solar Roads**
  - Concrete: ✓
  - Asphalt: ✓

### Interactive wind powered lights

- **Road lights that only light up as cars pass by the area by using pinwheels to generate electricity**

  Pinwheel generators will be set up along the car’s path at the roadside, to continuously light up paths as cars drive through.

  Pilot in Netherlands

### Piezoelectric Energy roads

- **Piezoelectric devices can be embedded in roads to capture the energy created from passing traffic**

  Integrates with existing infrastructure requiring no additional real estate.
**Equipment based road inspection** plays key role in assessing road conditions and identifying maintenance needs

1. **Network Survey Vehicle**
   - Used for measuring **surface defects** such as cracking, rutting & **roughness**
   - Consists of multiple modules- laser profilometer, TPL, crack detection sys

2. **Falling Weight Deflectometer**
   - Used for measuring **pavement strength**
   - Measure vertical deflection response of a surface to an impulse load

3. **Mobile Bridge Inspection Unit**
   - Electro-mechanical device mounted on a truck
   - Provides access to hidden parts of **bridges for their proper inspection**

4. **Retro reflectometer**
   - Used for measuring **retroreflection of road signs** and markings
   - Portable hand held device

Under implementation by NHAI as part of IE's scope of work in the new RFP document
GeoAnalytics can be used to identify "black spots" and secondary crash zones

Potential applications/insights:

- Placement of On-Road Incident Mgmt. units & Security units
- Optimal routes and zones for alternative planning
- Optimization of CCTV camera placement
- Effective use cases for on-road units
Digital Command & Control Centre: Nerve centre for Highway management

- Single help-line (1033) - Citizen Communication
  - Variable Message Signs
  - Multi-media (E.g., Highway Radio, Website)

- Incident Management: Visualization, Analytics, Decision Making
- Traffic Management
- Construction Management

- State Governments
- Contractors / Concessionaires
- DPR Consultants / IE / AE
- Police / Fire Departments

- Connected Ambulances, Tow-away cranes and Highway Surveillance Units
- Geoanalytics for blackspots
- Lane control system
- Automated loop detectors
- SCADA for real time monitoring
- GIS based land asset management
- Auto Traffic Counting & Classification

- Express Tolling
- Electronic Tolling
- Weigh in motion system
GIS Interface developed for easy tracking of projects

1. GIS map with entire base network – National Highways (NH), Bharat Mala, In-principle NH
2. Projects and related details data mapped for visualization

Layers for customizing the visualizing on the map
Path ahead

Data
- Ensuring interoperability between data formats
- Creating data library across organizations

Technology
- Ensuring backward and forward compatibility
- Adapting technology as per local requirements

Institutions
- Creating pool of experts
- Educating decision makers regarding the possibilities

Market
- Reducing the cost of technology
- Exploring new avenues of monetizing the existing information
THANK YOU

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