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Spatial Analysis of Indian Railways

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Abstract: Railway is the largest undertaking in the country. A retrospective study of prevailing conditions is necessary to assimilate the progress of the sector and how far have the changes introduced in previous few years been successful. The paper examines how the proposed changes in the Indian railways have changed the face of it through rigorous spatial analysis in diversified fields. A balanced analysis of shortcomings as well as achievements has been tried to be achieved through this paper for few selected regions of India.Each year there has to be more emphasis on enhancing the services provided. The rail budgets play a vital role and are responsible for taking care of it. The numerous promises made in terms of introduction of trains, electrification of routes, gauge conversion, doubling and increasing frequency of trains are made every year, in order to keep track of fulfillment of those decisions the spatial analysis is conducted rigorously. Railway has also witnessed a number of disasters in past few years; the spatial analysis conducted brings out few major reasons of those. A section of study also covers the topographic conditions in the state of Jammu and Kashmir that have not allowed the progress of railways in these regions.

Keywords: Spatial Analysis, Union Railway Budget, Gauge Conversion, Doubling, Electrification, Topographic conditions, Disaster.

Introduction:

Country growth is seen as a direct consequence of transport development. There won't be prosperous growth ifthereistheabsenceofa well-developedtransportationsystem [1]. There is need for these systems to be equipped with geospatial technologies for policy making and showing rapid advancements. Railway being the biggest public sector of India and serving a

large section of population is thus chosen for our analysis through emerging geospatial technologies with the use of proprietary as well as open source geospatial tools. The size of sector itself describes the amount of databases one has to handle for effective functioning of it. A seamless repository of database is necessary for its interpretation and assistance in decision making to facilitate policy making and thus resulting the growth of sector. This is exactly where the major role of geospatial tools comes in to picture. Hence, we first create 2 kinds of open access repositories for conducting the spatial analysis. Geographic Information Systems (GIS) are used in populating this repository. A geographic information system (GIS) is a system for capturing, storing, managing, processing and displaying the data spatially referenced to the surface of the Earth [2]. The information in GIS is stored in form of geometry elements with attributes associated to them. The paper further comes out as a mix of modeling proposals and contribution of geospatial technology affirming them suitably through thorough budget studies of an entire decade.The budget study doesn't cover the entire country rather a portion of western, North Western and South Western and central part of country.

Data: Railway budgets [3] for financial years 2000 to 2009 have been collected to carry out the spatial analysis. Along with it, the official maps and textual documents [4] freely available serve the purpose for determining the current state of rail routes in terms of completed tasks and work in progress in the field of doubling and electrification of routes. In order to study limitations in state of Jammu and Kashmir, topographic conditions which include the height variations across various districts of the state have also been collected. The disaster occurrence patterns have been understood through collection of list of the major rail accidents over last decade and their probable reasons.

Methodology and Results:

The major phases of the methodology used in the study are:

1) Data acquisition through official textual documents.
2) Replication of data into geometric elements through Geographic Information Systems.
3) Data interpretation and analysis.
4) Model development and derivation of assumptions from analyses.

Development of repository:

Two types of repositories are mentioned in the introduction.

One is structured with the use of open source GIS – OpenJump 1.4.2 and use of open source library GDAL and its OGR toolkit. The programming language used is C++. The repository is built over a district-wise geo-referenced map of India in form of Shape (.shp) files. Each district in the file is represented in form of a polygon element and the layer of point elements representing the Railway Station for districts is created by calculating the centroid of the district polygon elements using the function – **int OGRGeometry::Centroid (OGRPoint * poPoint) const [virtual]**. Each connection between two railway stations is displayed with the use of line element created using the function – **OGRLineString ()** with vertex station point elements serving as vertices using the function – **Void setPoint (int, OGRPoint *)**. This is how the entire rail network across country is populated. . A value in the point elements shape file representing the stations in the attribute table represents the no. of trains originating from the station. The snapshots of generated network are shown in figure 1 and 2. However, there is a limitation associated with this repository, this only looks at the district level information and overlooks the sub district stations that come in the network.

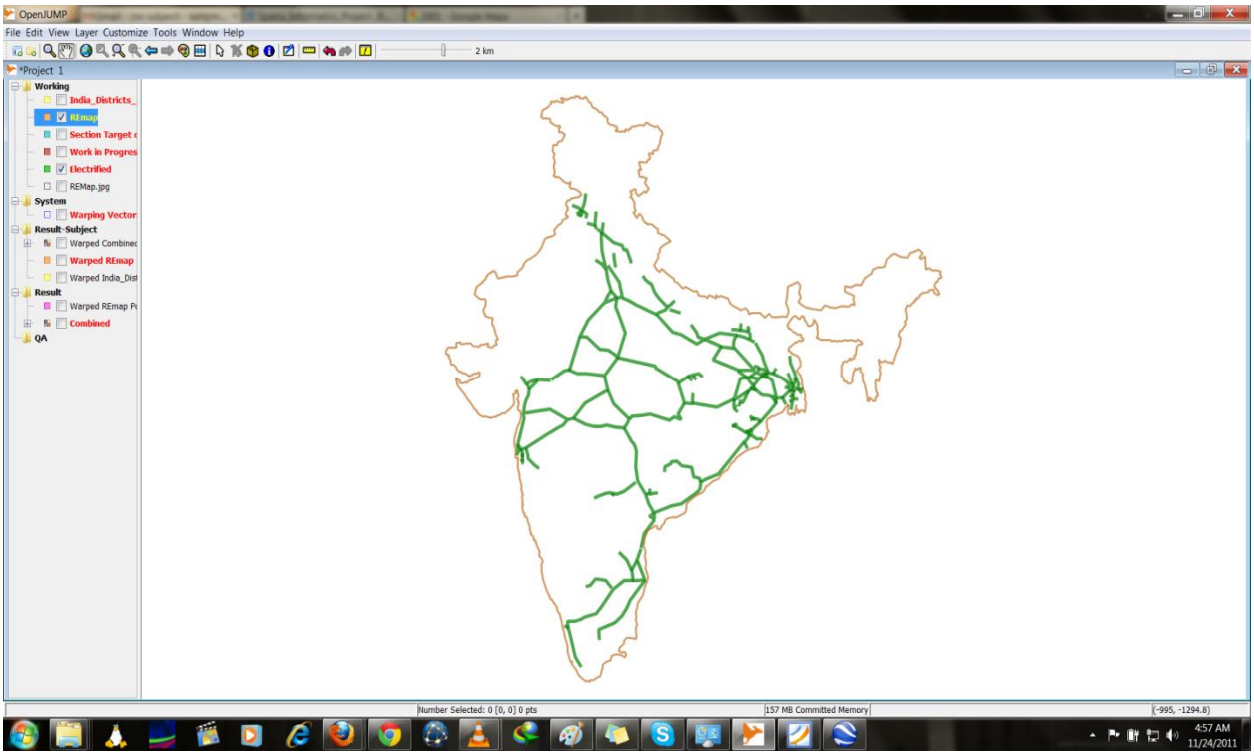


Figure 1: Electrified Routes

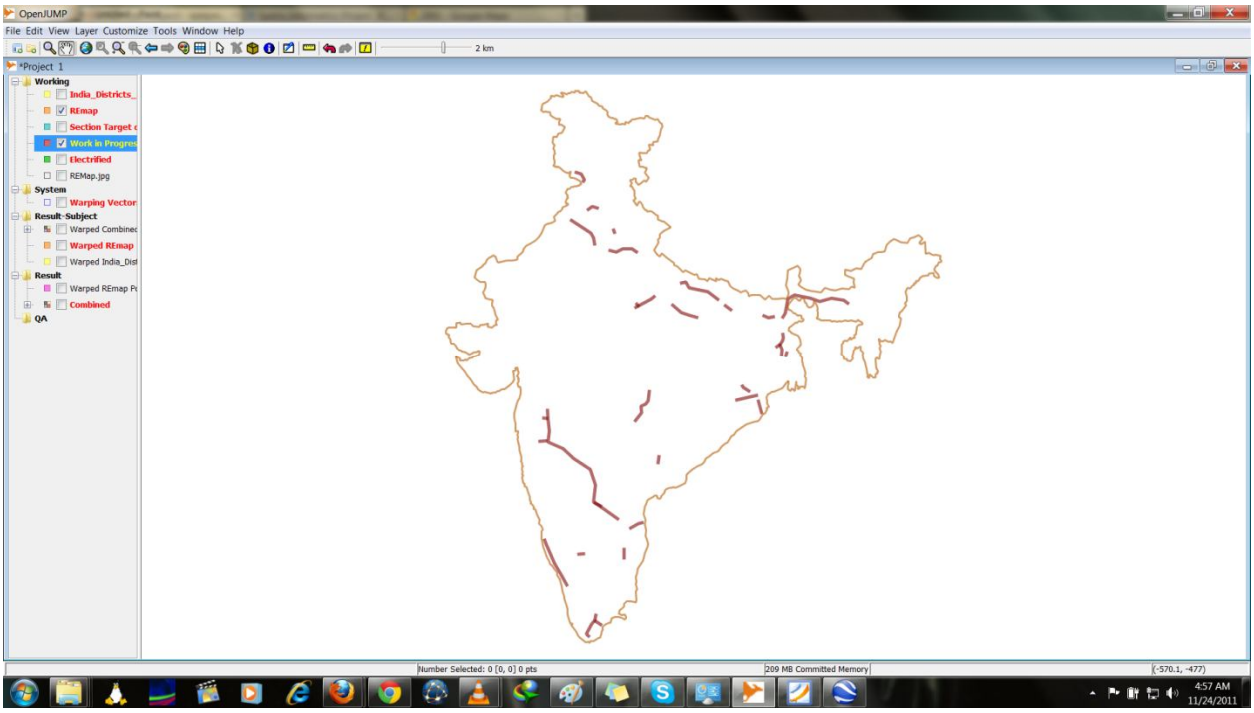


Figure 2: Work in progress

The other repository is an open access Google Earth repository, the files can be imported to the local system that can be accessed offline. This repository serves the purpose of inquisitive travelers who would like to see the actual routes followed by major trains of their interest. The collection of routes of announced trains for the decade mentioned above in the selected regions along with their important stoppages and approximate track lengths has been done through Google maps. The process is described below and represented in figure 3 and 4:

- Verification of existence of proposed train
- Finding route of train if it exists.
- Tagging important stoppages of the train along its route.

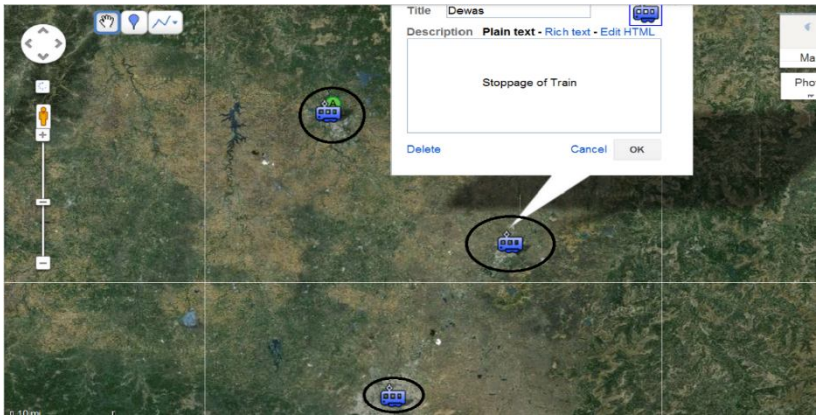


Figure 3: Stoppages of train

- Plotting the route with the help of marked stoppages.

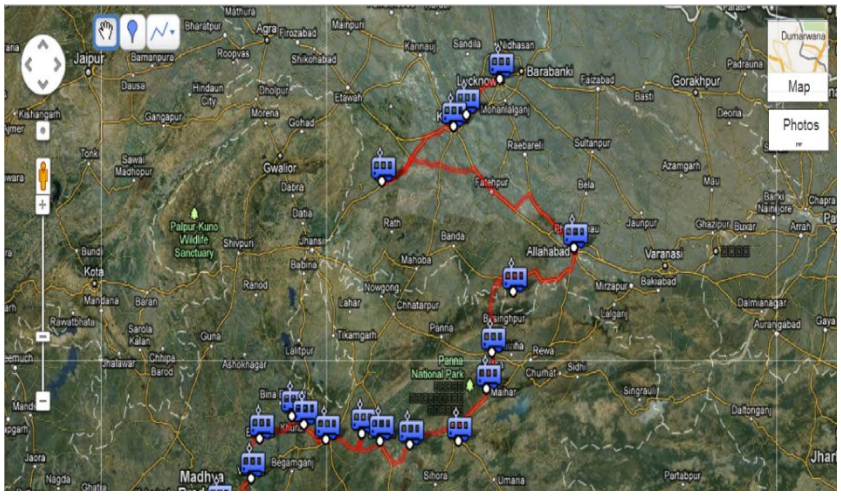


Figure 4: Rail route representation

The limitation of this repository is that it does not follow the actual rail tracks rather the road transit system which is assumed to be parallel to the rail network and thus solving the purpose.

Inclusion of new train services and their impacts for decade 2000 to 2009:

Indian Railways hasn't been a failure in terms of delivering the promises made in the field of introduction of trains. The connectivity of places within a state as well as across the states has been improved over the years. Few statistics affirming this remark is displayed in the figures 5 and 6.

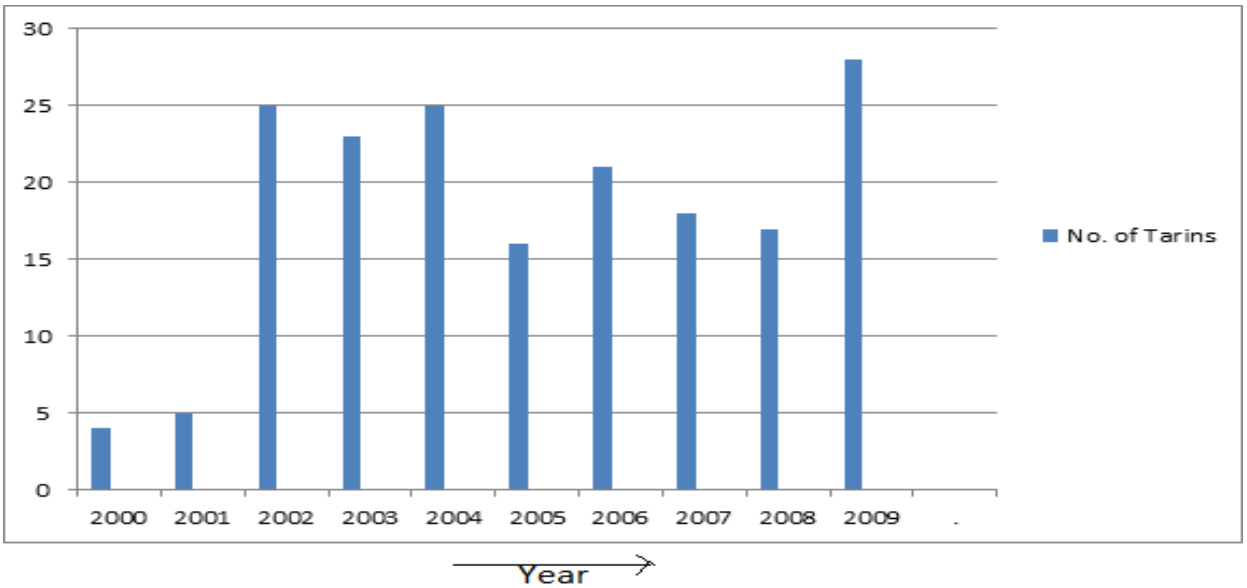


Figure 5: Graph representing newly added trains in respective years

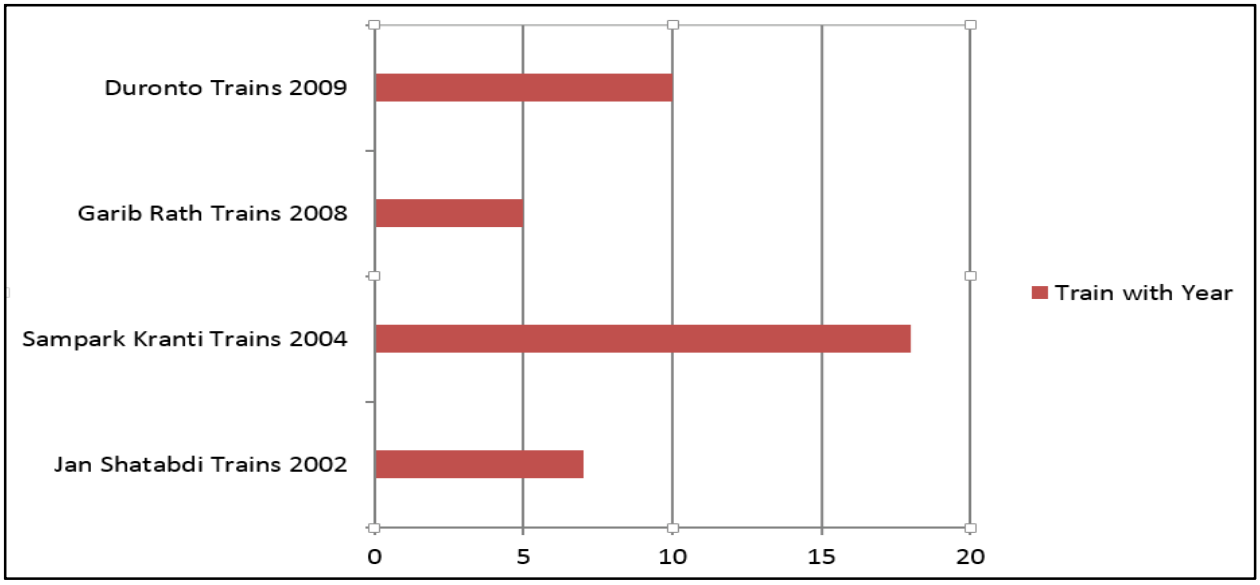


Figure 6: Graph representing introduction of bulk of trains in a single category

The arrival of several new services mentioned in above graph can be cited as one of the reason for the sudden increase in the number of introduction of trains from year 2002.

Relation of increase in no. of trains with new lines, gauge conversion and doubling: It has been observed that the gradual increase or consistency in the increase in no. of trains is possible due to linear increase in length of new tracks, gauge conversion and doubling of lines. The linear increase can be understood as:

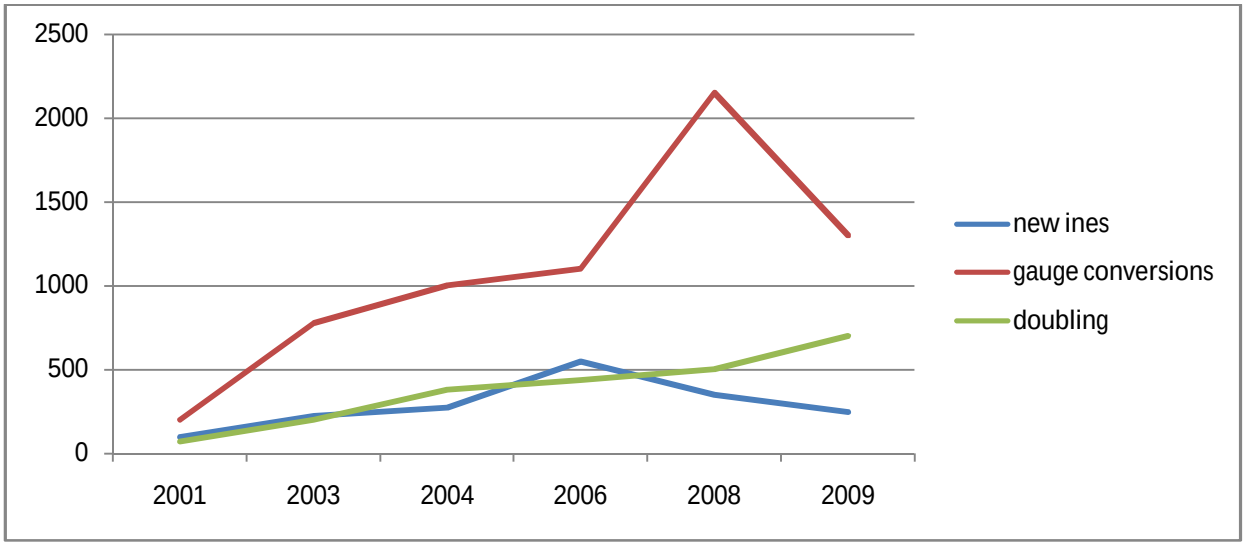


Figure 7: Graph representing completed new lines, gauge conversion and doubling works promised

As, it can easily be observed from the graph that curves shooting up in a linear fashion with consistent slope with each budget has been the driving factor to accommodate several introduced trains and avoid heavy congestion in the existing network, though there have been cases of minor congestion and accident to a certain extent (as the slope isn't desirably high for doubling) that will be addressed in the later part of the paper.

State wise distribution of electrified network: This portion entails parameters involved in electrification progress in states and study of pattern of electrification for various states.

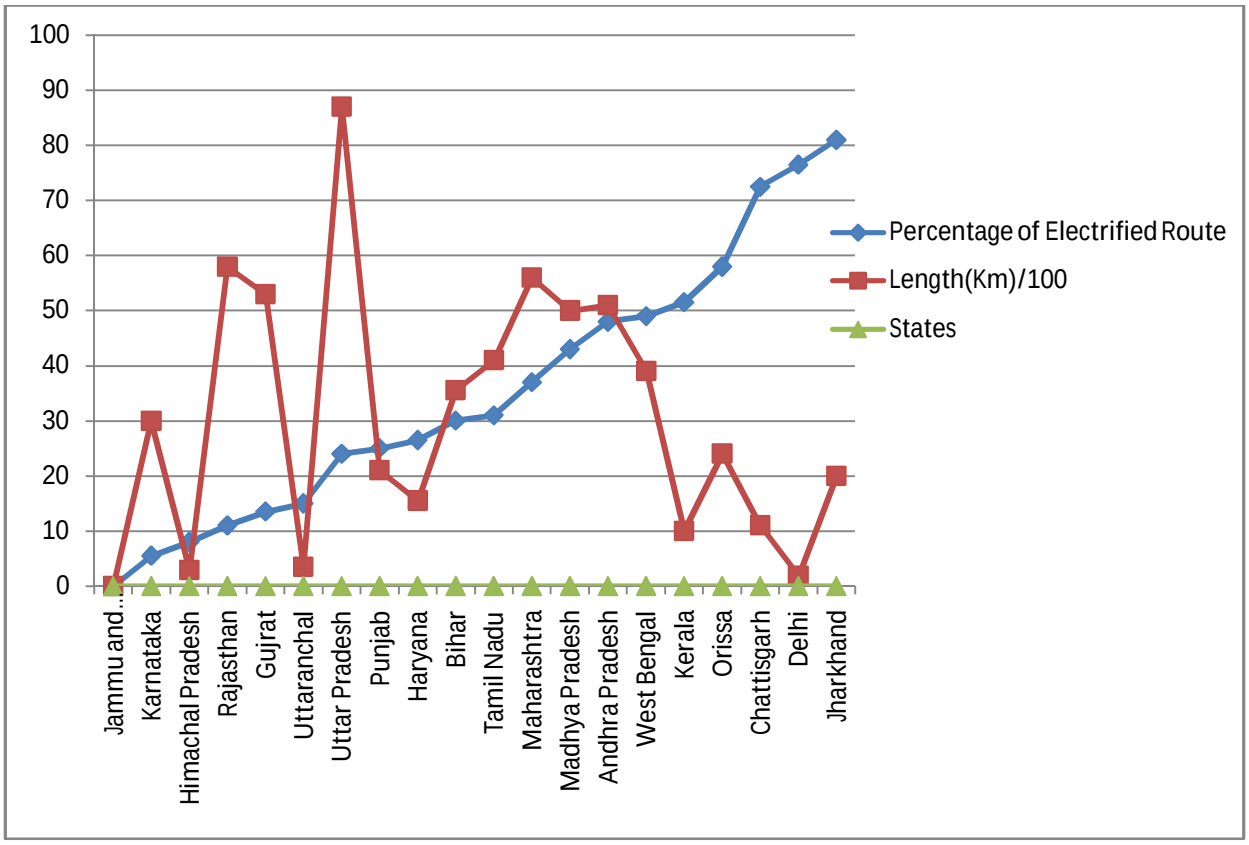


Figure 8: Graph showing percentage of electrified network and length of total rail network for each state

The relation between the percentage of electrified route and the length of total rail network in state are observed to be inversely proportional to each other for most of the states. The pattern can be easily realized in almost all the states marked after Tamil Nadu in the above graph. For the exceptions, the reasons are topography and availability of resources.

Predictive model based on gradual increase in length of electrified network across country for the past 85 years: This study entails the analysis of patterns of route electrified over the years.

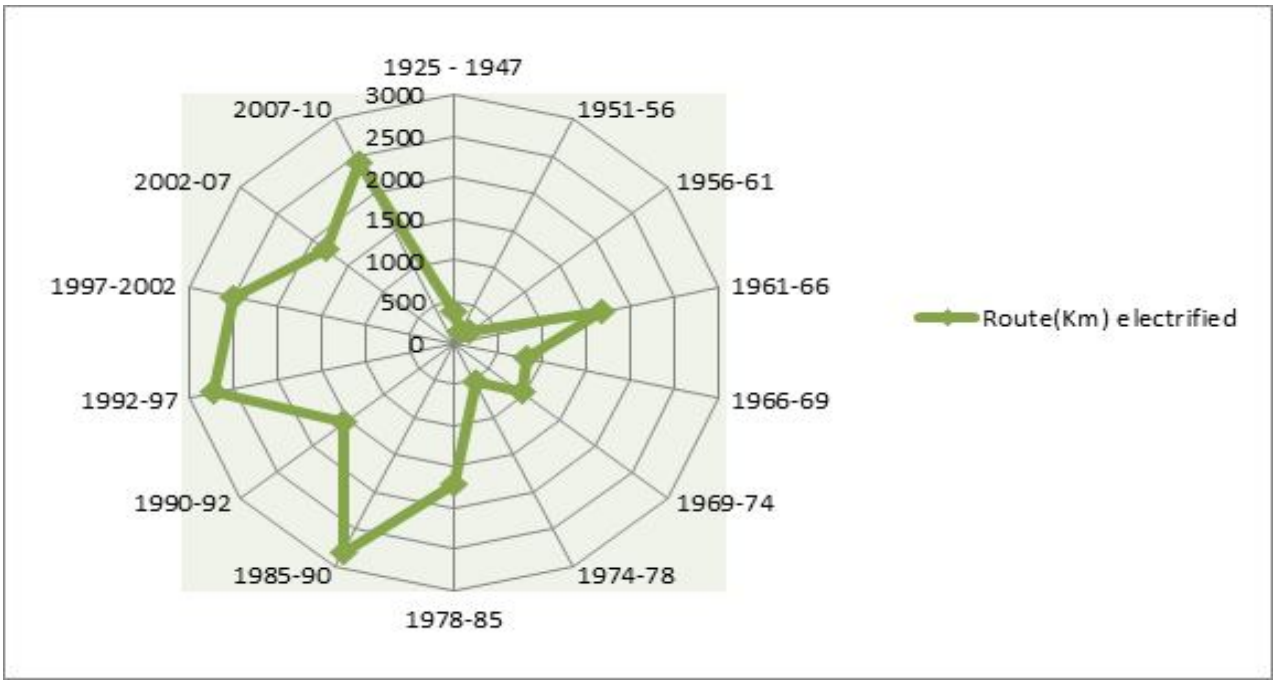


Figure 9: Graph showing length of network electrified during five year plans:

However, a fixed pattern doesn't appear, but a conclusion can be drawn that the 5 year plan from 1980-85 brought revolution and more emphasis was being given to electric engines since then. A sudden rise in length of electrified route has been carried through and the points on the spiral almost form a circular pattern for the period 1990 to 2010 that means a constant rate has been kept to electrify the routes. The spiral web maintains a constant radius for some time and jumps suddenly; this may help in making futuristic growth assumptions and sufficient enough to derive the following predictive model for growth in the sector.

The definition of the developed model can be summarized as: the duration for which there is consistency in the length of rail route electrified is directly proportional to the length of route electrified in a year.

Topographic limitations in specific regions of India:

Figure10: Present scenario of rail network in Jammu and Kashmir

The rail route in Jammu and Kashmir could not be extended beyond that displayed in the image above. The major reason cited for this is actually large variation in heights at places situated very near to each other. In order to avert possibility of major disaster that railway has not expanded its reach there.

Following are the major possibilities of occurrence of disaster if railway network is actually established in this area decided to topographic characteristics of the location:

- Collapse of bridges: The length of several bridges to establish rail channels in Jammu Kashmir would be more in comparison to any bridge established earlier due to high volume of waters flowing in basins and low availability of plane lands. The risk factor for any bridge increases with its length.

- Caving in of tunnels: If compromises are to be made with construction of bridges, the other suitable arrangement for making traffic possible in Jammu and Kashmir is blasting off of mountains and hills to make tunnels. Impacts of powerful blasts and their large frequency loosen the structure and there is high probability of caving in of tunnels.

- Derailment of trains due to high speed on slopes: As there are large variations in the heights of very closely situated regions. The slope of tracks laid there would be considerably high. This adds to risk in terms of handling high speed of trains.

Limitations of railways in Jammu and Kashmir due to variation of heights:

Data specifying large variations in height even at places which are near to each other:

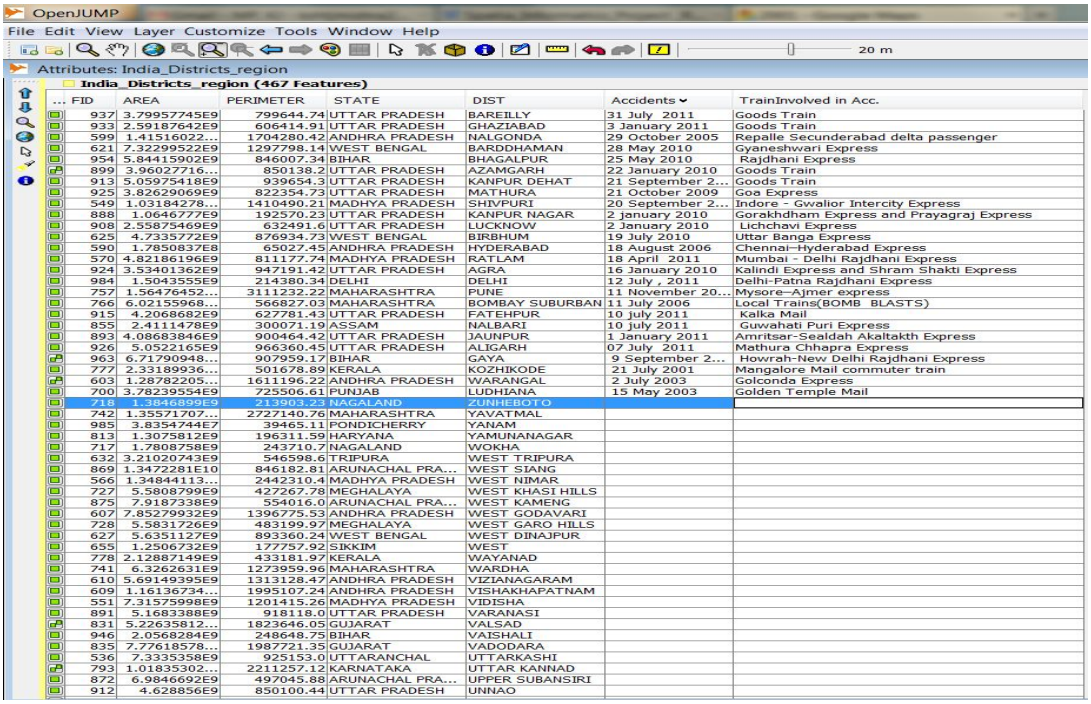
- Rajouri 1000 m to 2000m
- Poonch 1000 m to 2000 m
- Udhampur 600m to 3000m (Only One Line)
- Kulgam 1000 m to 1700m
- Budgam 2400 m to 4000m (Only One Line)
- Ganderbal 1600 m to 3000m
- Baramulla 3500m to 5000 m
- Kupwara 4000m to 5300 m
- Kargil 4500m to 5500m

- Variation in height = 2000m
- Distance=100km
- Slope=Height/Distance
    - Slope=1/50

However, this is a general case. In the extreme cases the value of tangent of angle reaches 1/20 and it is not only difficult but impossible to grant a permit to establish rail network in such regions.

This could better be understood through the use of digital elevation model and simulation of the studied area which are not made part of this study.

Repository of Rail accidents using OpenJump 1.4.2:



... FID	AREA	PERIMETER	STATE	DIST	Accidents	TrainInvolved in Acc.
937	3.799577455E9	799644.74	UTTAR PRADESH	BAREILLY	31 July 2011	Goods Train
933	2.59187642E9	606414.91	UTTAR PRADESH	GHAZIABAD	3 January 2011	Goods Train
599	1.41516022...	1704280.42	ANDHRA PRADESH	NALGONDA	29 October 2005	Repalle Secunderabad delta passenger
621	7.32299522E9	1297798.14	WEST BENGAL	BARDDHAMAN	28 May 2010	Gyaneshwari Express
954	5.84415902E9	846007.34	BIHAR	BHAGALPUR	25 May 2010	Rajdhani Express
899	3.96027716...	850138.2	UTTAR PRADESH	AZAMGARH	22 January 2010	Goods Train
913	5.05975418E9	939654.3	UTTAR PRADESH	KANPUR DEHAT	21 September 2...	Goods Train
925	3.82629069E9	822354.73	UTTAR PRADESH	MATHURA	21 October 2009	Goa Express
549	1.03184278...	1410490.21	MADHYA PRADESH	SHIVPURI	20 September 2...	Indore - Gwalior Intercity Express
888	1.0646777E9	1925570.23	UTTAR PRADESH	KANPUR NAGAR	2 january 2010	Gorakhdham Express and Prayagraj Express
908	2.55875469E9	632491.6	UTTAR PRADESH	LUCKNOW	2 January 2010	Lichchavi Express
625	4.7335772E9	876934.73	WEST BENGAL	BIRBHUM	19 July 2010	Uttar Banga Express
590	1.7850837E8	65027.45	ANDHRA PRADESH	HYDERABAD	18 August 2006	Chennai-Hyderabad Express
570	4.82186196E9	811177.74	MADHYA PRADESH	RATLAM	18 April 2011	Mumbai - Delhi Rajdhani Express
924	3.53401362E9	947191.42	UTTAR PRADESH	AGRA	16 January 2010	Kalindi Express and Shram Shakti Express
984	1.504355SE9	214380.34	DELHI	DELHI	12 July , 2011	Delhi-Patna Rajdhani Express
757	1.56476452...	3111232.22	MAHARASHTRA	PUNE	11 November 20...	Mysore-Ajmer express
766	6.02155968...	566827.03	MAHARASHTRA	BOMBAY SUBURBAN	11 July 2006	Local Trains(BOMB BLASTS)
915	4.2068682E9	627781.43	UTTAR PRADESH	FATEHPUR	10 july 2011	Kalka Mail
855	2.411147E9	300071.19	ASSAM	NALBARI	10 July 2011	Guwahati Puri Express
893	4.086838466E9	900464.42	UTTAR PRADESH	JAUNPUR	1 January 2011	Amritsar-Sealdah Akaltakth Express
926	5.0522165E9	966360.45	UTTAR PRADESH	ALIGARH	07 July 2011	Mathura Chhapra Express
963	6.71790948...	907959.17	BIHAR	GAYA	9 September 2...	Howrah-New Delhi Rajdhani Express
777	2.33189936...	501678.89	KERALA	KOZHIKODE	21 July 2001	Mangalore Mail commuter train
603	1.28782205...	1611196.22	ANDHRA PRADESH	WARANGAL	2 July 2003	Golconda Express
700	3.78239554E9	725506.61	PUNJAB	LUDHIANA	15 May 2003	Golden Temple Mail
718	1.3846899E9	213903.23	NAGALAND	ZUNHEBOTO		
742	1.35571707...	2727140.76	MAHARASHTRA	YAVATMAL		
985	3.8354744E7	39465.11	PONDICHERRY	YANAM		
813	1.3075812E9	196311.59	HARYANA	YAMUNANAGAR		
717	1.7808758E9	243710.7	NAGALAND	WOKHA		
632	3.21020743E9	546598.6	TRIPURA	WEST TRIPURA		
869	1.3472281E10	846182.81	ARUNACHAL PRA...	WEST SIANG		
566	1.3484413...	2442310.4	MADHYA PRADESH	WEST NIMAR		
727	5.5808799E9	427267.78	MEGHALAYA	WEST KHASI HILLS		
875	7.9187338E9	554016.0	ARUNACHAL PRA...	WEST KAMENG		
607	7.85279932E9	1396775.53	ANDHRA PRADESH	WEST GODAVARI		
728	5.5831726E9	483199.97	MEGHALAYA	WEST GARO HILLS		
627	5.6351127E9	893360.24	WEST BENGAL	WEST DINAJPUR		
655	1.2506732E9	177757.92	SIKKIM	WEST		
778	2.12887149E9	433181.97	KERALA	WAYANAD		
741	6.3262631E9	1273959.96	MAHARASHTRA	WARDHA		
610	5.691493955E9	1313128.47	ANDHRA PRADESH	VIZIANAGARAM		
609	1.16136734...	1995107.24	ANDHRA PRADESH	VISHAKHAPATNAM		
551	7.3157598E9	1201415.26	MADHYA PRADESH	VIDISHA		
891	5.1683388E9	918118.0	UTTAR PRADESH	VARANASI		
831	5.22635812...	1823646.05	GUJARAT	VALSAD		
946	2.05682844E9	248648.75	BIHAR	VAISHALI		
835	7.77618578...	1987721.35	GUJARAT	VADODARA		
536	7.3335358E9	925153.0	UTTARANCHAL	UTTARKASHI		
793	1.01835302...	2211257.12	KARNATAKA	UTTAR KANNAD		
872	6.9846692E9	497045.88	ARUNACHAL PRA...	UPPER SUBANSIRI		
912	4.628856E9	850100.44	UTTAR PRADESH	UNNAO		

Figure 11: Major accidents displayed (with date) in district table:

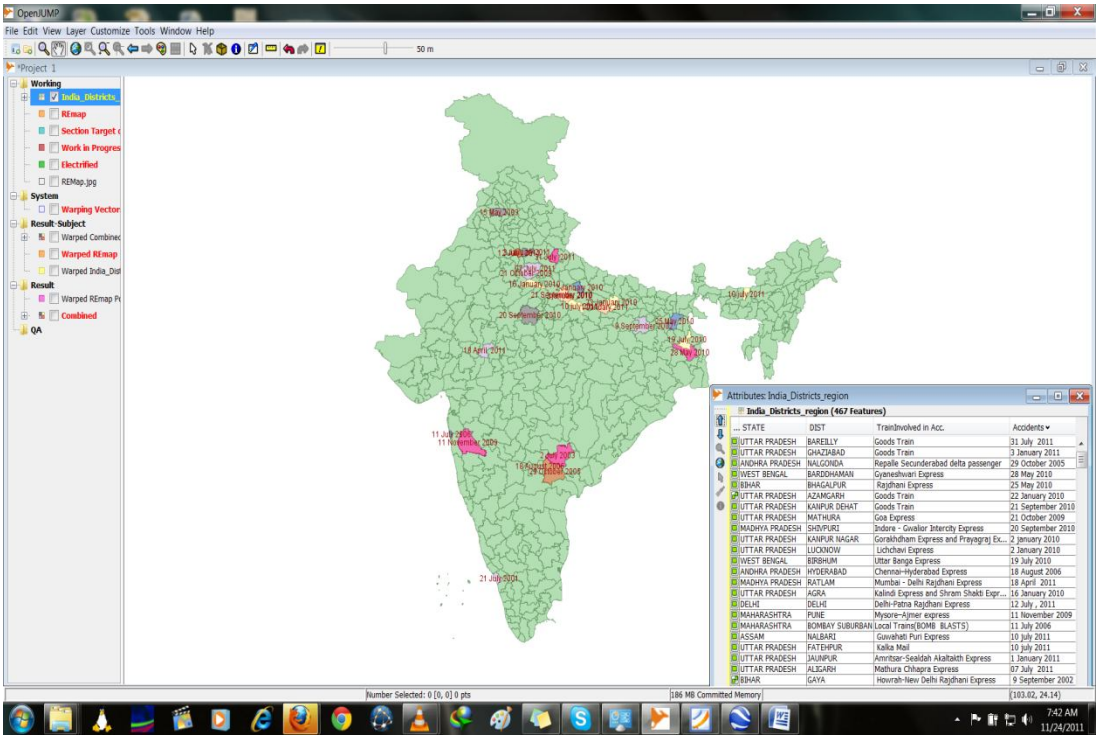


Figure 12: Map displaying the areas hit by rail disasters:

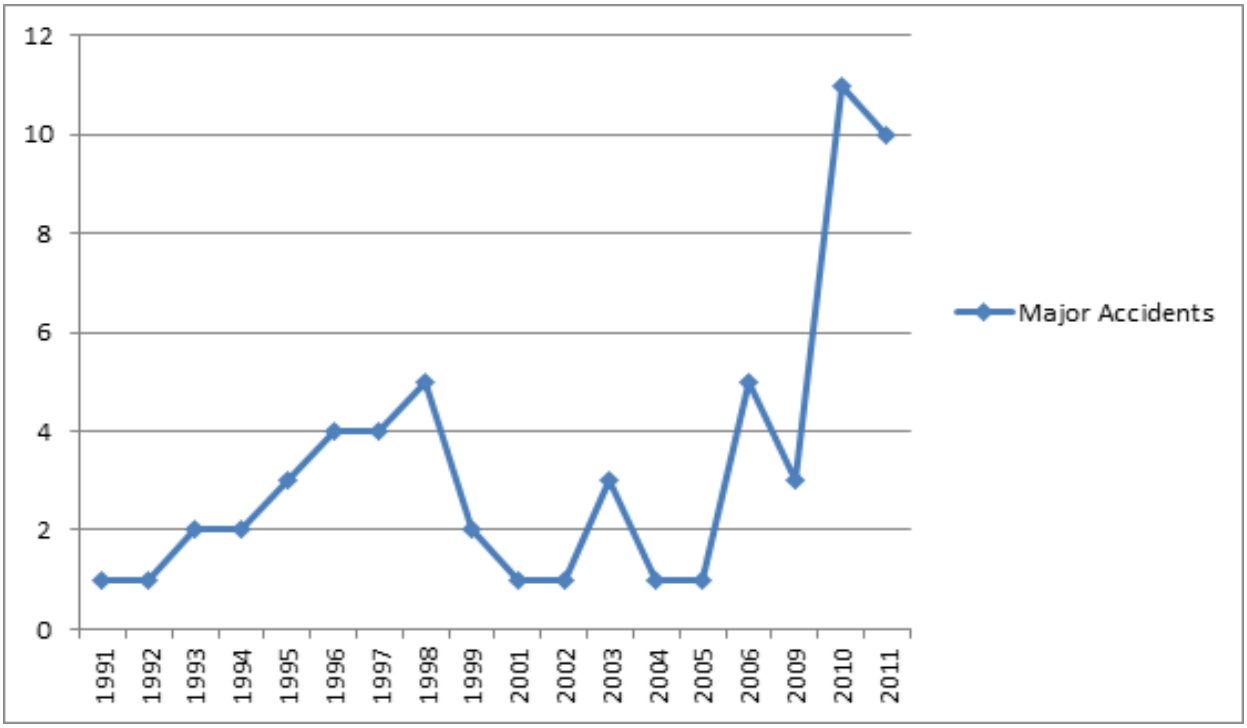


Figure 13: Graph showing year wise major rail accident:

Graph patterns are observed where values are nearly the same at all points but suddenly shoot up at certain points.

Areas of impact: Uttar Pradesh is observed to be an area highly prone to rail disasters. There are few cases where same place has been hit by rail disaster more than once in the span of less than 5 years, Bhagalpur being one of them.

Assumptions: The reason detected for sudden rise in number accidents occurring in year 2003 can be cited to be introduction of large number of trains in year 2002 which might have been implemented till 2003 causing heavy traffic on nearly the same length of route length. There are few other reasons discussed later in this paper on the basis of climatic effects on Railways. This has been discussed with the help of geospatial tools.

ClimaticAnalysis on major accidents:

From the data, it is clear that the frequency of rail disasters is more in the months of winter or monsoon. From the map digitized below it, the reason can be better understood. The main reasons cited for these accidents are usually:

- Dense fogs in the northern parts of the country.
- Heavy rainfall causing damage to machinery and flooding of tracks.

Both of these cause mismanagement and difficulty in operations of signals and instructions to the rail drivers.

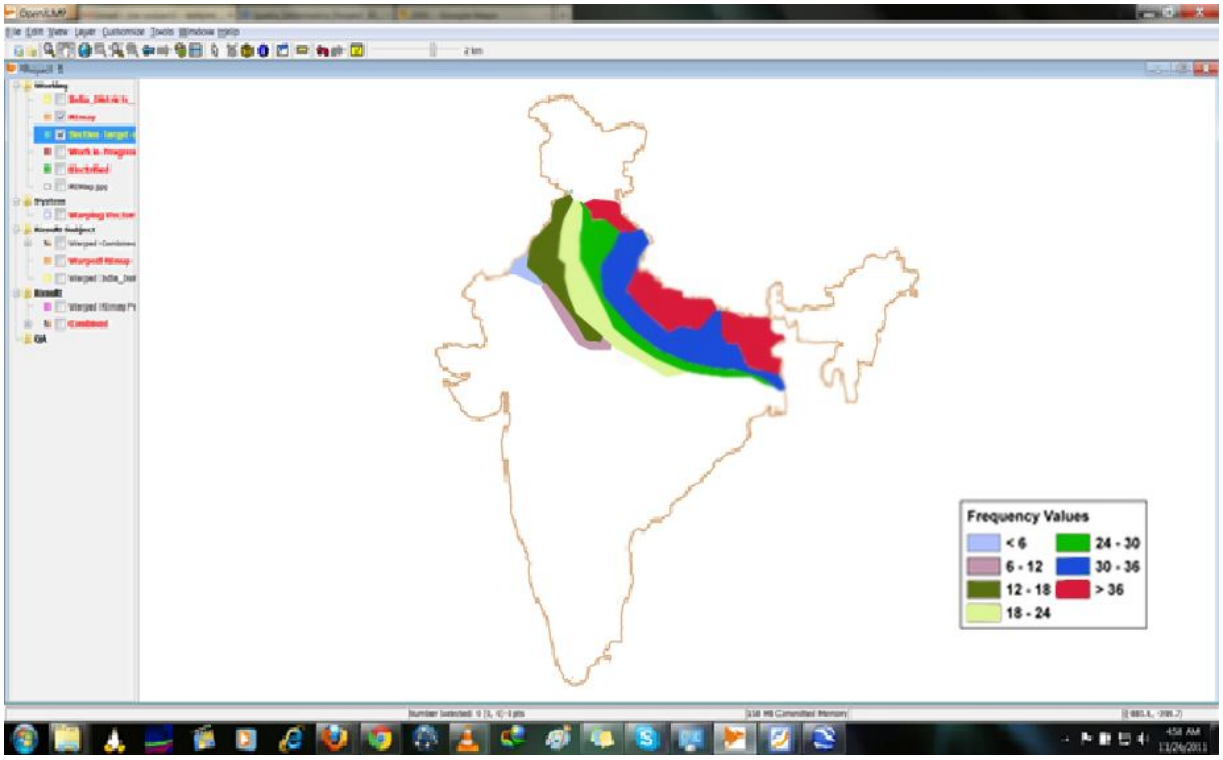


Figure 14: Map displaying the frequency classification of the fog affected belt of northern India during 2002-2008 winters (Dec-Feb)

Conclusions:

The visualization of Indian Railways has been made very effective through the integration of geospatial technology in data storage and representation by developing repositories. These repositories definitely have advantage over the existing schematic view of Indian railways that displays just the network without any coordinates attached to the nodes and edges.

The whole study led to a conclusion that the Railways have been keen on fulfilling the announcements made in the Budget sessions but has been continuously marred by mismanagement of services that led to several mishaps in last few years. An increase in load of trains without large scale increasein track lengths (through doublings, gauge conversions etc.) never averts the possibility of a disaster. Effective use of available modernized techniques may however make it possible to enhance the connectivity in Jammu and Kashmir and accidents may be reduced in high fog zones.

Discussions and future work:

Until the base map database for Indian Railways with geographic coordinates is introduced by the Centre for Railway Information Systems, India [5], the repository developed as part of this work can serve as an aid to visualize railway elements, though it has got limitations. Geographic relations developed have simplified the management of geographically distributed data. An innovative idea of inculcating budgets with GIS has brought a transparency in the management and functioning of works in the sector. A simple predictive growth model can easily be derived out of such studies that can assist quick decision making. The future work includes sharing of the repository information through the development of a web portal assisted with a feedback system, and further developing small query based applications for users to fetch information of their use from the large pool of data. The essence of feedback systems is from usability perspective of the stakeholder, this feedback information may be anything – the type of data that user frequently visits, the design of elements, the query result format and what not.

We hope for success in our commitments.

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