Landslide Hazard Management on Mountainous Highways – A Critical Need

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Abstract:

Indian highways in mountainous terrain are uninterruptedly suffered due to frequent Landslides of various kinds. It is generally noticed that, the landslides trigger due to unprecedented rainfall of short duration, prolong rainfall of normal intensity and cloud bursting and also during earthquakes. Once such landslides hazards experienced, they become the treasury for repeated recurrence, making the highways unsafe to the commuters. A huge amount of revenue spent only on restoration of highways from repeatedly recurring landslides misbalances the annual maintenance budget, as a result of which most of the highways are found under maintained. This further aggravates the problems of the concerned agencies, mainly the Border Roads Organization who looks after most of the roads in difficult hilly terrains of the country. An assessment of the landslide situation in various parts of the country was made so that to highlight the gravity of the problem concerning to such hazards, particularly along various highways of the hilly terrain. The hills and mountains of complex geological conditions and fragile rock formations make the slopes sensitive to failure in case of sudden external triggering forces like unprecedented rainfall and earthquake tremors. But, not all the slopes behave identical and only a few slopes experience failure. It was observed that none of the highways are left without such hazards and most of them are linked to the difficult terrain characteristics, adverse climatic conditions etc. but not often to the ill planned developmental activities which are conspicuously more responsible to such happenings. Through this paper authors would like to highlight the need for the effective disaster management scheme which could become the part of the developmental activities and result in minimising the frequency of the hazards and risk associated with them.

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Introduction

Landslides are widespread phenomena, all over the world and every part of the mountainous regions is subject to landslides. Landslide occurs in all geographic regions of the country in response to a wide variety of natural conditions. Its distribution is not confined to the only hilly or mountainous areas rather it can be found in coastal areas and offshore too. In fact 27 states of the country are affected by landslides, although they differ from the scale of severity of disaster (Table 1). They affect at least 15% of land area of our country exceeding 0.49 million km^2. Because of their unpredictability in nature, these have become a major threat to the human life as well as to the economy of the region. Landslide hazards stand the second geological hazards following earthquake (Li et al., 1999; The U.S.Geological survey, 2000). According to the Global Assessment Report, preventionweb.com, India ranks 2nd out of 162 countries on population exposed (180,254) and 9th out of 162 on GDP exposed 1.07 (billion US$). Landslides are among the major hydro-geological hazards that affect large parts of India, especially the Himalayas, the Northeastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhyas, in that order. In the Himalayas alone, one could find landslides of every fame, name and description- big and small, long and short, quick and creeping, ancient and new. The northeastern region is badly affected by landslide problems of a bewildering variety. Landslides in the Darjeeling district of West Bengal as also those in Sikkim, Tripura, Meghalaya, Assam, Nagaland and Arunachal Pradesh pose chronic problems causing all kinds of losses. There are landslides in the Western Ghats in the south, along the steep slopes overlooking the Konkan coast. Landslides are also very common in the Nilgiris, characterized by a lateratic cap, which is highly landslide prone (Bhandari 2006). Himalaya's dynamic nature including its geological setup, narrow and deep gorges, meandering rivers, snow clad bodies, climatic diversities sudden and heavy downpour including cloudbursts, flash floods, earthquakes etc., have always been considered as part of its natural developmental processes. Landslide and other mass movements have also been part of its natural developmental process. The scenario however has changed completely and the rare incidences or events of natural landslides, floods etc have increased manifolds compare to the last few decades. The loss of life and the property have also increased and more areas have come under the vulnerable category which was considered safer earlier. Landslides and other mass movements like weathering and erosion have always been occurring since the origin of the earth, including mountains and hills, and considered as part of landscape forming. Generally the areas uninhabited and away from human intervention have been considered less prone to such phenomena. While, the areas where human interaction with nature increased, vulnerability of the land to such processes has also increased. As the population has increased quite rapidly over the last century, people had to venture in new areas, not inhabited earlier, for their survival. Most of these areas are vulnerable to such processes and pose a threat to the life and property of the people. The new areas ventured for multiple developmental activities have generally not been considered based on their vulnerability to landslides and other like processes. As a result the life and the property of the inhabitants also become vulnerable. The areas which have already witnessed such processes are generally vulnerable to future recurrences and the areas which have been acquired without vulnerability assessment and did not witness such processes shall remain in the list of vulnerable areas.

Indian highways in hilly areas have been experiencing horrific landslide incidences. The Darjeeling floods of 1968 destroyed vast areas of Sikkim and West Bengal. The 60km mountain highway to Darjeeling got cut off at 92 places resulting into loss of lives and total disruption of the communication system. Yet another landslide tragedy of an unprecedented dimension was the great Alaknanda Tragedy of July 1970 in Uttarakhand State that resulted from the massive floods in the river Alaknanda, killed several and washed considerable length of road forcing to construct new road of 13km. The Malpa rock avalanche tragedy of 18 August 1998 instantly killed 220 people and wiped out the entire village of Malpa on the right bank of river Kali with the tracking route, in the Kumaun Himalaya of the state of Uttarakhand. A few notable examples of the recent disasters are: in the year 2009, heavy rains triggered landslides in Darjeeling and took 81lives. 41,000 affected people were sheltered in 109 relief camps. Over 61,000 dwellings were razed to the ground and 1.32 lakh hutments partly damaged. A cloudburst followed by heavy landslide had completely wiped out three hamlets in Munsiyari sub-division of Pithoragarh district, Uttarakhand, killing 43 people and more than 100 cattle on 8th August 2009. At least 28 people were killed in landslides triggered by heavy rains in the north-eastern in Sikkim. Lambagarh, a chronic landslide site very close to Badrinath shrine, recur almost every year. This year, 2011, as well the slides have recurred and millions of tourist got stranded for many days creating economic and social unrest in various regions of the country. A large number of landslides occurred during 2010 monsoon in Uttarakhand, on and away from the highways, has created a situation of widespread unrest. The situation reached to that extent that the Chief Minister of Uttarakhand state has appealed to the nation to contribute funds so that to meet out the minimum economic need of the affected people of the State. Among the 250 people killed in various disastrous incidences of landslides belongs to Himachal, Arunachal, Leh Ladhak, and Uttarakhand states. Every time the tragedy strikes, huge amount of budgetary funds are pumped into the

rehabilitation and restoration works without giving a least thought to pre-disaster planning. By the time the tragedy stricken areas are rehabilitated, monsoon reappears again and this vicious process repeats again and again. The restoration and rehabilitation process never gets completed and an unimaginable sum of tax payers' money washes off without much fruitful results. The cost on direct losses such as the costs of repair and maintenance, restoration, rehabilitation or the replacement of the damaged properties is met out of maintenance budget allocated for the whole year excluding such exigencies; as a result, overall maintenance of the roads is also affected. The frequent and long duration blockade of national highways in critical landslide locations create social unrest amongst the communities living at both the sides of the blockade location because of their inability to attend the social obligations, hardship in reaching the destinations through the tougher and longer alternate routes, inability to provide medical aids to the critical patients, steep hike in prices of the commodities, inability to run their business etc. These scenes with series of sufferings are repeated during every monsoon. In view of the above stated facts, it is therefore required to have an effective landslide hazard management system which shall be made as a part of the overall development in the hilly areas of our country.

Table 1
Macro-Zonation of Landslides

Hill Range	Landslide Incidences Potential	Proximate Causes
Himalayas	Very high to high	Predominantly naturally increasing due to human intervention
North Eastern Hill Ranges	High	Predominantly natural
Western Ghats & Nilgiris	High to Moderate	Human intervention dominant Natural causes Secondary
Eastern Ghats	Low	Predominately due to human intervention
Vindhyans	Low	Predominantly due to Human Intervention

Landslide Hazard Management

Despite the decades of research and development on the diverse aspects of mitigation and management of natural disasters in India, the following questions continue to defy neat and practical answers. (Gangopadhyay & Kumar 2009)

- What are the predicted most likely natural disaster scenarios that must be taken into account in planning, design, construction, utilization and management of the roads and highways in India? The answer to this question, inter alia, demands large-scale multi-hazard maps of disaster prone areas, not yet available.
- What methodology needs to be followed in the risk assessment of roads and road networks, given the single and large scale hazard maps? To date, absence of professional consensus at the national level points to an identified gap in knowledge on a critical matter.
- How the uncertainties due to incomplete knowledge base as also those due to the deficiencies of maps interms of quality and scale impact on the reliability of the risk estimates and how the powerful tools of modelling, instrumentation and monitoring could be deployed in engineering practice to close the unacceptable gap between engineering prediction and the actual performance?
- How the science and art of landslide instrumentation and monitoring could be improved to a level that delivers effective and reliable and cost effective early warning systems against landslides, keeping pace with the revolutionary developments in the areas of instrumentation and Information and Communication Technology?
- How should technology packages for landslide remediation and control be designed to meet situation specific requirements with fullest consideration of the landslide history of the area, ongoing development programmes, environmental imperatives and climate change?

- How the local communities could be made aware of landslide hazards in their respective areas, and trained in the management of landslides to avert disasters?
- How the Landslide Knowledge Networks are further developed and linked with allied global networks to serve all the various stakeholders and landslide management agencies?

In view of the above mentioned facts, concerns and the gravity of the situation of landslides impact on the society we urgently need a Landslide Hazard Management System which would help the concerned people, such as the planners, policy makers, manager of communication, road construction units, or the public to know, understand and take appropriate action to address the landslide issues, particularly on the highways. The system proposed would have the following objectives:

(i) To ensure that the safety of the hazardous slopes along the highways is adequately managed and their stability maintained.
(ii) To ensure that the common people of landslide hazard and risk prone areas as well as the concerned agencies are kept informed about the risk during the recurrence period of such disasters so that they can take appropriate steps to avoid loss of life.
(iii) To provide background data and guidelines on acceptable limits of risks such as – to accept the risk, to avoid the risk, to reduce the likelihood of the risk, reduction of consequences of risk, Monitoring of risk and transfer of risk
(iv) Ensure, risk free, year round operability of highway network which has strong bearing on socio-economic development of the region and also on strategic needs in the border areas through online forecasting system of the critical disastrous areas.

The proposed Hazard management System

1. Landslide hazard Inventory

Landslide database and inventory map of existing landslides is an important and, in fact, a first step towards landslide hazard management and mitigation studies. For any hill development, the planning would prove erroneous if advance information about the gravity of the problem concerning to landslides is not considered. Landslide inventory provides the following information, which is prerequisite for better management of landslides (Fig. 1).

I. Landslide hazard database and inventory enables to retrieve information about the old and new, active and inactive landslides and to a certain degree indicates areas susceptible to future problems. The area(s) under consideration can be said susceptible for landslides, when the terrain conditions are comparable to those where a slide has occurred.
II. Classifications of condition/circumstances under which the landslides have developed in the past and relationship with future probability get known.
III. Validation and correction of the landslide susceptibility potential maps, if already prepared based on the database and inventory of landslides can be done.
IV. Identification of recurrent and old but quiescent landslides which generally cause devastation without prior noticed warning signatures particularly during rains can be satisfactorily accomplished.
V. To compare landslides distribution in different areas such as: along the roads, inhabited areas, agriculture land, forest land, and other areas to estimate the gravity of landslide problems and its influence on socio-economic condition of the region.

2. Landslide Monitoring and Forecasting System

The increasing trend of the landslides incidences and recurrences along the highways is quite alarming and raise concerns regarding the stability of landslide areas along these highways and their potential impact to the safety of the travelling public, infrastructure and their property. There are a number of such landslides all over the hilly areas of the country; a few of the examples of typical landslides are shown in Table 2, (Kishor et.al.2009). This system will provide the following inputs to the management system for making it more effective.

I. Identify critical, strategic and recurring landslides along highways which are chronic in nature and have considerable socio-economic impact on the society.
II. Scientific study as a pacesetter examples and state of the art work involving every step right from reconnaissance survey, large scale mapping and investigations, including geotechnical, geomorphological and geological.
III. To study the various factors controlling factor of safety with a view to have an integrated approach concerning the mechanism of landslides under various conditions, the system will consist of a network of instruments installed at critical locations on the slope of selected landslides.
IV. To undertake real time instrumented monitoring for risk analysis, forecasting for early warning and remedial actions.
V. The real time monitoring data would be transmitted to the base station for further processing, analysis, interpretation and decision making.
VI. The information about forecasting of the landslide would come on public domain through web based information system.

3. Multiple hazard information

I. Landslide often occurs as elements of interrelated multiple hazard processes in which an initial event triggers secondary events or in which two or more natural hazard processes occur at the same time. They commonly occur in conjunction with other major natural disasters, such as earthquakes, volcanic activity and floods caused by heavy rainfall.
II. There are several examples of multiple hazards such as floods and earthquake. Floods occur every year resulting not only considerable erosion of river banks but also huge landslides which once generated continue year after year and act as site of perpetual failure.
III. Similarly there are examples of formation of landslide dams in almost all parts of hilly areas of our country. The massive landslide dams on various rivers burst to create flood waves down the river to destroy whatever came to oppose the flow, as a result, loss of life and property takes place and numerous landslides develop.
IV. There are instances, when large number of landslides has occurred after the Earthquakes as “carry forward effect”. Each type of earthquake-induced landslide occurs in various geological environments, ranging from steep rock slopes to gentle slopes, with unconsolidated sediments. The area affected by landslide in an earthquake correlates with the magnitude, geological conditions, earthquake focal depth, and specific ground motion characteristics therefore requiring focused studies. Damage from landslides and other ground failures have sometimes exceeded the damage directly related to earthquakes. Multiple landslide hazard situations therefore should be part of a holistic framework of landslide studies.

Conclusion:

1. The proposed landslide hazard management system may be utilized to drastically reduce the direct losses in term of reduction in: Loss of life, Loss of property and assets, Loss of infrastructure and lifeline facilities, Loss of Resources, Loss of farmland, Loss of places of cultural importance etc.
2. Indirect losses which could be avoided are: Loss in productivity of agricultural or forest lands, Reduced property values, Loss of revenue, Increased cost, Adverse effect on water quality, Secondary physical effects, Loss of human productivity, Reduction in quality of life, Impact on emotional wellbeing etc.
3. If the proposed system properly utilized, the economic losses expected to be reduced to the tune of at least 30 to 40% during the initial years of implementation which can further be increased. Loss of life from the landslides can be reduced significantly because most of the deaths generally happen due to simple ignorance, lack of awareness, lack of timely information, lack of early warning, lack of networking, lack of pre-disaster planning etc,. These issues are foreseen in the proposed system and 70 to 80% causalities can be avoided.
4. The proposed system will provide the information to educate the public living in disaster prone areas about the landslides and related hazard and risk from these events.
5. It will forewarn the public about the impending hazard/disaster due to such events in specific risk prone areas so that they can get into alert mode and ready for appropriate action for their safety
6. It will forewarn and update concerned agencies such as manager of communication, road construction and maintenance units (BRO, PWD’s) so that timely action can be taken to save the people and property from the disasters.

7. It will provide an insight to the planners and policy makers to help the country in framing a holistic national policy on landslide hazard and risk management in hilly areas of our country.
8. CRRI can become a repository of the GIS enabled Regional Database Management System on landslides which will be shareable to any agency in the country involved in planning, construction and maintenance of the road for risk free road development.

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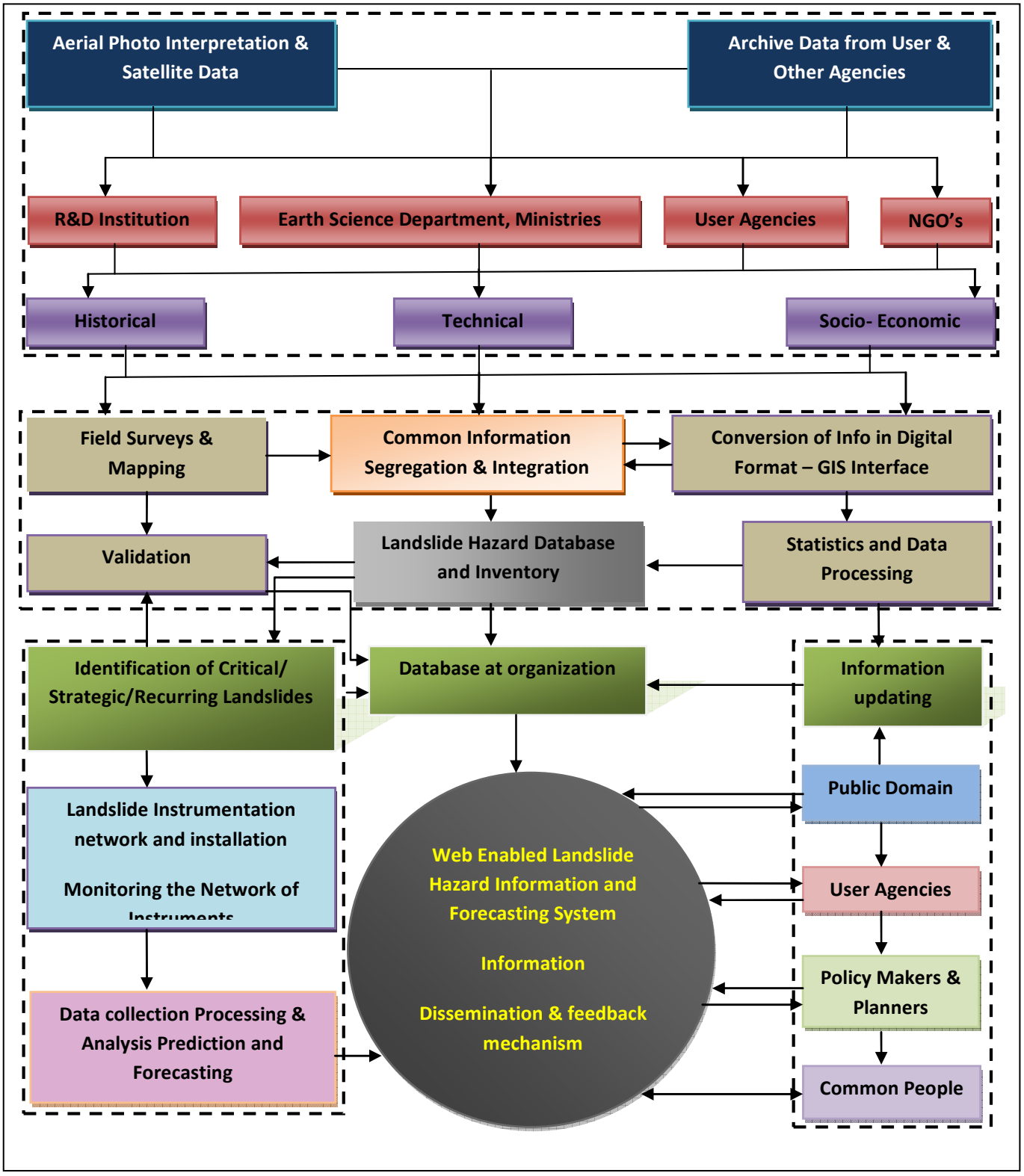

Fig: 1 – An Outline of Landslide Hazard Management System

Table 2
Landslides Distribution in Uttaranchal

Location	No of L.S	Type of Landslides	No. of Landslides
Okhimath tehsil, Rudraprayag-Kedarnath road, district Chamoli	10	Rock fall- Debris Slide-	02 07
Okhimath tehsil, Haridwar-Badrinath road, and Rudraprayag-Kedarnath road, district Chamoli	35	Rock fall- Debris slide- Subsidence- Slump-	01 32 01 01
Haridwar-Badrinath road, Dist. Chamoli	14	Planar Failure- Rock fall- Debris slide- Slump-	01 04 07 02
Karanprayag-Gwaldam road, Dist. Chamoli	04	Debris slide-	04
Haridwar-Badrinath road, Dist. Chamoli	04	Debris slide-	04
Rudraprayag-Kedarnath road, Dist.Chamoli	01	Unclassified	01
Haridwar-Badrinath road and Rudraprayag-Kedarnath road, Dist.Chamoli	02	Wedge Failure- Slump-	01 01
Haridwar-Badrinath-Mana road, Dist. Chamoli	02	Debris slide-	02
Reni, Ganai village, Joshimath-Marlari road, Dist. Chamoli	04	Debris slide-	04
Karmi village, Dist.Almora	02	Debris slide-	02
Pithoragarh-Almora road, Dist.Almora	01	Planar Failure-	
Jalikhan-Jiakhan road Dist.Almora	01	Subsidence	01
Bareilly -Almora road. Dist. Almora	02	Debris slide-	02
Nainital: Sher ka Danda Hill, Naina Peak, Balia nala and Jangali village	03	Planar Failure- Rock fall- Slump-	01 01 01
Barielly-Kathgodam road, Dist.Nainital	05	Rock fall- Debris slide- Minor Slip-	01 03 01
Bhagirathi valley, Dist.Uttarkashi	181	Planar Failure- Wedge Failure- Rock fall- Debris slide-	16 19 28 101
Bhagirathi valley, Dist.Uttarkashi	54	Planar Failure- Wedge Failure- Rock fall- Debris slide- Subsidence-	05 03 03 32 01
Kannauldiya gad, Dist. Uttarkashi	03	Subsidence- Minor slip-	02 01
Durlokh village, Dist.Pithoragarh	01	Debris slide-	01
Kinwani Slide, Dist.Pauri Garhwal.	01	Debris slide-	01
Dharchula-Tawaghat road, Tawaghat village, Dist.Pithoragarh	08	Planar Failure- Wedge Failure- Subsidence- Slump-	02 01 03 02


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