Effective Road Network's Hazardous Locations Management Via Geospatial Information Systems

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Abstract:
Development of road safety activities and verifying its effects require implementing and utilizing of an effective them are arised because of the lack of compatibility between their natures and complexity evaluation and control system. Spatial elements such as road geometry, climate, terrain topography and man-made features can be used as factors of an effective hazardous locations management system. Applying the effects of these elements in multicriteria decision-makings, encounter the management processes with a variety of challenges, most of and ambiguity of their inter- and intra-relationships in real world. In this situation, utilization of a common part like their spatially referenced specification and implementing the required relationship, create the possibility of an integrated and seamless environment development copped with real world situation. Development and utilization of such an environment is possible through the exploitation of new technology of spatial datasets creation (eg. GPS, RS and...) And Geospatial Information management Systems (GIS) beside the realization of information society concepts in this domain like data sharing, interoperability and spatial data infrastructures (SDI). Here we will discuss the place and role of a GIS in hazardous locations management, which is derived from other activities and our experiences.

1- Introduction

An overall study of rapid growth emerges in Geospatial Information Systems (GIS) concepts and technology utilization by different management processes illustrate that there are some common and important gaps and aims in their tasks, which GISs are recognized to be able to fulfill them. These gaps are lack of enough certainty in effective decision-makings lead us toward the sustainable development as the common aim. Sustainable development is known as coordinated development in environmental, social and economical areas. Effective decision-making provides the required framework for sustainable development as it handles all the effective factors with minimum changes and distortion of natures in an analytical problem solving process. Therefore, understanding the nature of the factors and their relationships is the main prerequisite of any effective decision making process which is known as Multi Criteria Decision making (MCD).

MCD technique includes the clarification of all the factors and their relationships, which provide the required framework for factors prioritization regarding their effectiveness level in results. Then, the decision-maker can define dominant factors, which are determinant

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elements in a MCD process. Decision-making quality control processes lead decision makers toward gaining the maximum required effectiveness from their decisions through resources analyze (Figure 1). The main issue in MCD process is the nature and relationships of inconsistency and ambiguous factor comprehension [1, 2]. These ambiguities are intensified dealing with real world phenomena in spatial activities because of the high level of complexity, and uncertainty existence.

Here, extraction of a common relationship among the factors is recognized as one of the effective ways could be applied for this challenge. Considering the fact that each development activities carry out in a spatial domain can lead us to study and use the spatial factors of activities as the required common relationship. The experiences have confirmed that we could define these spatial factors as the required framework assures the effective

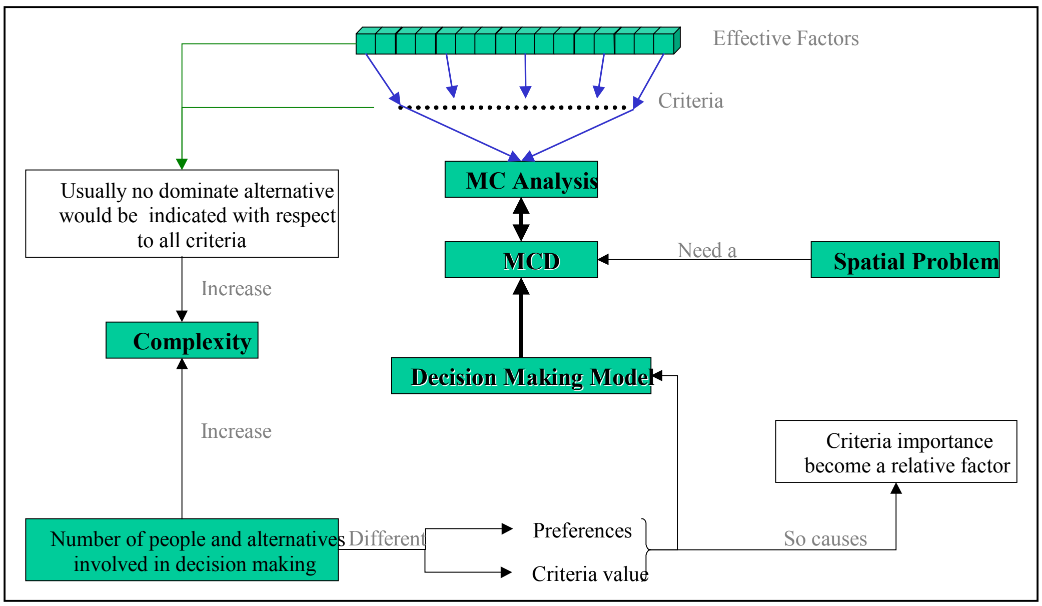

Figure 1: Multi-Criteria Decision Making Process

decision-making and management required for the sustainable development [2].

Understanding these facts in science and technology domain became the incentive of emerging a widespread spectrum of dynamic concepts and systems support spatially MCDs. This rapid development allocated a vast majority of markets to itself (34 billion dollar and 20% growth rate per year)[3]. Therefore, managers are convinced to use these technologies, understanding their needs.

Here, familiarization with GIS as an innovation and the process used for innovations diffusion is very important. Figure 2 provides general steps required for innovation diffusion considering the specific issues of GISs[4].

2- Methodology

Regarding the previous section, the following systematic procedures are considered, emphasizing on the initial phase of GIS utilization, problem recognition and definition of components and relations position contributing all stakeholders to certificate the required results [1, 5, 6]:

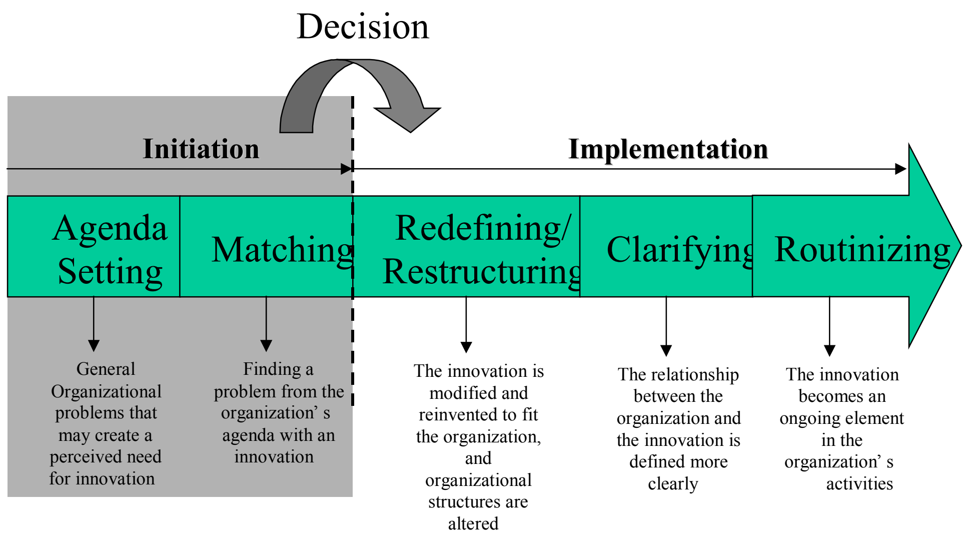

Figure 2: GIS Diffusion as an Innovation

- *Problem and aims definition*; As a general view excluding any GIS related issues and concepts represented by managers (and stakeholders) resulting in an adjudication of desired aims, limitations, inputs and outputs.
- *Effective factors definition*; Regarding their role in realization of:
  - Expected needs (managerial/stakeholders view)
  - System requirements (GIS specialist view)
  - Further system development needs (Mix View)
- *Clarification of factors spatial nature*; definition of spatially related factors, their nature and level of corporation can be categorized as:
  - Fundamental spatial factors: Regarding as vital spatial infrastructures and frameworks required as a core (the least) for system utilization.
  - Complementary spatial factors: Interact with fundamental spatial factors for optimum development and completion of system applications.
- *MCD issues definition*; achievement of above-mentioned procedures and study of their dominant nature.
- *Relationships definition and System placement modeling*; an overall model which could emerge an integrate view of all the steps carried out here.

Systematically, these procedures result in development of a conceptual framework for the problem and system, which is known as conceptualization.

3- Prototype

The above-mentioned methodology is used here in a prototype as identification and prioritization of hazardous locations management, which is discussed in the remaining parts.

3-1- Problem and aims definition

Hazardous location is a road section, which is potentially capable of happening hazards in a time interval because of some factors and condition existence. Hazardous location management is the process of registration, evaluation, prioritization and planning of these locations [7]. These aims can be detailed as:

- Increasing the rest and safety level in any road related activities by declaration and elimination of road problems and defects;
- Detailed, accurate and up-to-date evaluation of road accidents costs and losses which is used by policy makers and managers and for presentation of acceptable results to clarify society viewpoint as an important factor in gaining supports for long-term sustainable roads security development;
- Providing the possibility of decision-making and effective management for hazardous locations and their related issues prioritization and refinement considering the limited resources available in management process;
- Development of a dynamic, flexible and reliable infrastructure certificates the long-term realization of management aims in this domain.

3-2- Effective factors definition

Hazardous locations identification and prioritization carried out using Road Safety Assessment (RSA) method integrated with risk engineering theory briefly presented here:
The above-mentioned approach initially applied a set of checklists contained questions about key issues and effective factors in hazardous location identification and prioritization process. Then, the defects frequency and severity and exists problems are identified in road sections and the risk quantity defined using a Quantified Risk Assessment method (QRA)[1] as shown below:

$$Risk = \sum_{i=1}^{n} f_i \times S_i$$

Where,

f_i is the frequency for the i^{th} defect; and

S_i is the severity for the i^{th} defect.

Finally, a descending exponential function derived for the desired risks, the Safety Index (SI) calculated for the road sections and used as the base for the prioritization process.
Using the classification presented for effective factors definition in methodology we will have [8, 9]:

- Road elements; includes geometric design components, road furniture, signs and marks, pavement conditions and road environment;
- Operation conditions: includes level of service (traffic), natural hazards and roadside hazards, accidents (required spatial and attribute data e.g. their location, rate and severity);
- Environmental conditions: includes topography, climate and population density information;
- Lineage: includes the road authorities, road type and application, accomplished measurements and other information of projects (e.g. construction and improvement costs).

3-3- clarification of Factors spatial nature

As defined here, this road hazardous location management is limited to the management of rural roads, which imposes some specific spatial natures to defined factors.

Studying the spatial elements in these categories, rural roads and position of accidents are considered as fundamental factors and other as complementary factors (e.g. road condition and environment). Also the road plan (road geometry design) plays a more infrastructural role than accidents position so it's considered as the main dominant factor.

Scale is an important specification used in spatial element nature recognition and utilization, which is defined their precision, accuracy and usage. Considering the concepts of spatial data integration, the dominance of minimum precision of contributed spatial factors in applications and the least precision in this prototype that belongs to the accidents position (usually created by police personnel) the dominant precision will ranges from 100m (the vehicle kilometer counter precision) to 15m (GPS precision in kinematics mode). Then, the scales has to be selected between 1:500,000 to 1:100,000[7]. In this prototype the medium scale 1:250,000 have been considered for the dominant scale. Therefore, these conditions are defined:

- Route factor; which have to be considered as line features (defining the road centerline) in each direction. Also the limited length sections (e.g. Ramps) don't required to be surveyed precisely and can be shown simply by a line or point features.
- Route accidents factor; which have to be considered as line or point features, which will be transferred to route s using dynamic segmentation for lines and points.

Also, other complementary factors have to be defined as point, line or polygon features as they defined.

As shown, most of the factors defined in this prototype are spatial factors, which show the spatial nature of hazardous location management activities and emerge required brilliant justifications for the need for GIS utilization in this domain.

3-4- MCD issues definition

Considering the previous steps as inputs for MCD process (Figure 1), we have defined the following issues:

- Sources and factors analysis; in this process we studied the fitness for use parameters of different sources and factors using the specified scale and the spatial specification of defined dominant factors. Besides, evaluations were extended to issues such as attribute accuracy, logical consistency (topology), completeness, and Updateness (as defined in SDTS).
- Applying decision-making models; analytical models, which provide the required results for decision-makings, are applied here using the defined factors. Some of these models used for this prototype are as follow[5, 7]:
    - Display and Query Models.
    - Vector analysis Models
        - Overlay analysis: Used for factors integration as a unique analyzable dataset.
        - Proximity analysis: Used for the relative distances between factors features in defined areas (e.g. The distance of facilities from the neighbors' routes).

        ▪ Spot/Intersection analysis: Used for the study of accidents in a point or an intersection.
        ▪ Strip Analysis: Used for the study accidents along a section of the routes.
        ▪ Cluster analysis: Used for the study of accidents clustered around part of the routes such as bridges, tunnels and railway-route intersections.
    o Network Analysis Models; these models support the dynamic and directional analysis which could sweep the routes as:
        ▪ Sliding-Scale Analysis: Used for definition of parts of route contains many accidents and losses. This analysis, despite other, is not limited to on parts of route and can sweep the routes in defined parts and in different direction.
        ▪ Corridor Analysis: Used for the definition of accident accumulation centers in a specific corridor of route.
    o Cell-Based Models; utilization of continues and spread spatial factors like weather condition, pollutions and etc. which is applicable using these models and can handle location/allocation analysis.

3-5- Relationships definition and System placement modeling

Considering the above-mentioned detail, the diagram presented in figure 3 defines the relationship and system placement model for this prototype.

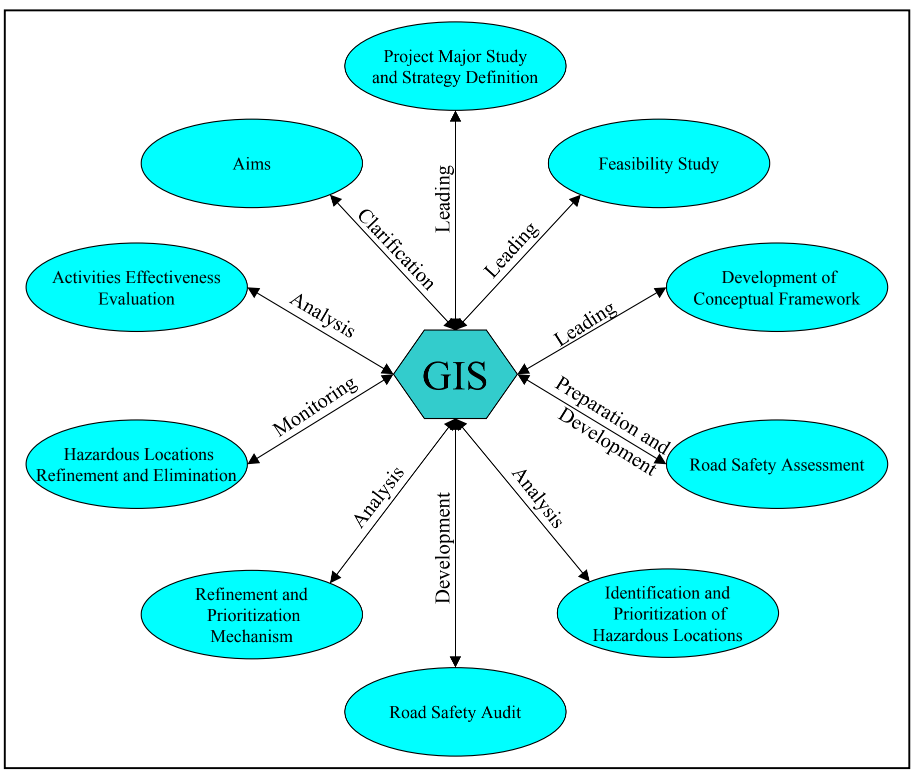

Figure 3: GIS Placement in Hazardous Location Management Process

4- Conclusion

The main results revealed from this research are focused on the clarification of manager's incentives and needs moving toward understanding GIS concepts, as a most required management decision support system through a logical and systematic process. This initial process, which mentioned as conceptualization, realizes this aim through creating a conceptual framework supports the dynamic and effective interaction between Managers, GIS analysts and other stakeholders.

Besides, hazardous location management prototype, presented here, emerged high potential spatial capabilities, which have made it more susceptible for effective use of GIS as an innovative technology and increase GIS diffusion activities in other themes.

Considering the prototype providing the models and analysis mentioned as pilot project has realized most of the defined aims in Iranian roads authority organizations.

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