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Optimum Highway Design and Site Location Using Spatial Geoinformatics Engineering

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Abstract

The current road or highway design systems are not conceived for making computer-aided design judgments such as automated generation of alternative grade lines, optimizing the number of curves, land cover and land use consideration, minimizing the volume of cut and fill, optimizing intersection with existing networks and infrastructure, the best fitting vertical alignment for minimizing the total road costs, or consider environmental impact or land cost.

Spatial satellite remote sensing data were used to derive a GIS (Geographic Information System) model combined with a three dimensional road design model which was then used as a decision support tool. The combination of different types of data is to compose a product with optimum characteristics that may be valuable in the preliminary route location studies and provides a designer with a quick evaluation of alternative road paths.

In the model, initial trial corridors were investigated. Several paths within each corridor were studied to choose the best path within each corridor.

The criteria in the methodology section were used in the comparison process. Routes are generated by "tracing" the possible paths using computer cursor on a 3D model of the terrain (DEM). Based on high-resolution Digital Elevation Model (DEM) data generated using ArcGIS package, corridors are selected by integrating in the process, all factors which may affect selecting the optimum route corridor such as land use and land cover, geology, soil, number of crossing with valleys, number of crossing with existing roads, number of vertical alignment, length, optimal slope, with the lowest total costs, while conforming to environmental requirements.

The development of the road design model incorporating powerful computer, high resolution spatial remote sensing data, advanced geoinformatics technologies, improved modern optimization techniques, and environmental considerations will improve the design process for highways and roads.

Keywords: Geoinformatics; Geographic information systems; Satellite remote sensing; Cartography

Introduction

The road network is an important component of the infrastructure in every country. Therefore, up-to-date and accurate information on the land cover, land use, topography and road network is of vital importance. Today, short up-date-cycles and high quality GIS are requested. One means to satisfy these demands is to make use of satellite remote sensing imagery for automated roadway and highways design.

Highways and modern roads are part of the facilities and infrastructure that makes up the spinal cord of modern society.

GIS provides a valuable tool in the process of planning and design of highways. To obtain an optimum highway route alignment which is economical, suitable and compatible with the environment, various types of data have to consider simultaneously [1].

Every route-surveying project involves economic problems both large and small. By far the most important question is whether or not to construct the project. Essentially, this decision is based on a comparison of the cost of the enterprise with the probable financial returns or social advantages to be expected. In some cases the question can be answered after a careful preliminary study without field work; in others, extensive surveys and cost estimates must first be made.

However simple or complex the project may be, it is rarely possible for the engineer alone to answer this basic economic question. To his studies must be added those of the persons responsible for the financial and managerial policies of the organization. In the case of a public project the broad social, environmental, and political objectives also carry weight. The engineer responsible for conducting route surveys is not solely a technician [2]. In addition to his indispensable aid in solving the larger economic problems, he is continually confronted with smaller ones in the field and office. For example, the relatively simple matter of deciding which of several methods to be used in developing a topographic map of a strip of territory is, basically, an economic problem that involves survey, terrain, and equipment and personal available.

Handling and managing this large amount of data manually, is not easy. It is here GIS comes to help, because of its inherent property of handling large bulk of spatial data, non-spatial data and its analysis. Remote sensing images of the study area were used as the source (spatial data). Various collateral data from various offices was collected to be used as non-spatial data. These images were used to prepare the digitized formats required for the GIS techniques. Using the Resistance concept (such as areas suitable for the new alignment were assigned

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a low resistance value, whereas the areas not suitable for the new alignment were assigned a high resistance value) the data was prepared for analysis [3].

Route selection has two distinct phases: regional study and detailed route selection. Regional study identifies broad, feasible corridors. These corridors are wide, elongated land areas selected for broad resource capabilities, uses and potential impacts.

One or more corridors are selected for a detailed evaluation of their potential for routes on the basis of the best balance between the biophysical, socioeconomic and engineering components. Detailed route selection, carried out in greater detail, selects one or more routes within the preferred corridor(s) selected by regional study. The components of route selection are analyzed in detail for each selected corridor according to the potential impacts that must be avoided and those that can be suitably mitigated.

Remote sensing data and techniques and geographic information systems (GIS) provide efficient methods for analysis of land use issues and tools for land use planning and modeling. Understanding the driving forces of land use development in the past, managing the current situation with modern GIS tools, and modeling the future, we are able to develop plans for multiple use of natural resources and nature conservation. Satellite remote sensing data is usually the most accurate and up-to-date “map” available [4]. Especially with fast growing towns and cities, it is practically the only method that can follow up the urban growth. When the satellite image is rectified to a coordinate system, a satellite map can be produced – but a whole lot of other techniques, processes and models can be used for different planning and analysis purposes. Together with aerial photography, satellite remote sensing data forms the base for land use mapping and planning. With modern geographic information systems, flexible geographic databases can be created for land use issues [5].

Conceptual studies and preliminary roadway design

The preliminary design phase involves developing the engineering design and evaluation in collaboration with the various functional disciplines including right-of-way, surveys and mapping, environment, safety, highway design, pavements, hydraulics, geotechnical, structural design, and construction, to support the identification of a preferred alternative and the decision-making process as described in Section 3.4. This phase may include developing multiple alignment configurations, roadway templates, pavement structures, roadside features or other alternatives for evaluation.

The preliminary design is typically developed to approximately the 30 percent level of design detail using substantial additional engineering data, information and input to supplement the information gathered during the conceptual studies phase. This phase typically includes identification of a detailed scope of engineering activities, estimated costs, and a project delivery plan for implementing the proposed project and achieving the project objectives on schedule and within budget [6].

The existing geometric elements of a roadway are used to describe in conventional engineering terms the physical, structural, safety and operational characteristics of a facility. While many elements of design (e.g., stopping sight distance, grades, horizontal/vertical alignment, super elevation) must be established to develop a highway design, only a few controlling elements are essential to evaluate it at the conceptual stage.

Roadway width (i.e., lanes, shoulders), design speed, surfacing type and alignment location, or new corridor location, if applicable, are the main criteria for studying highway alternatives.

Design standards include the geometric design standards and other technical standards. Geometric design standards relate to the functional classification of highways, types of users, traffic density and character, design speed, capacity, safety, terrain, and land use. Design of the overall highway should be done to a consistent standard [7]. Evaluate the route between major termini to maintain a uniform approach to the major design features of an overall route that may be improved in stages on a project-by-project basis. Identify contextual features and qualitative aspects of each project early in the design process, before design standards are selected, and consider them throughout the design process. Proposed highway improvement alternatives are principally described by the preliminary design standards.

Geometric design is the development of the surface dimensions of a highway such that its form will meet the functional and operational characteristics of drivers, vehicles, pedestrians and other users. The geometric design includes the facility’s location, alignment, profile, cross section, intersections and shape of the roadside [8]. The geometric form and dimensions should reflect the user’s desires and expectations for safety, mobility, comfort, convenience and aesthetic quality. It should do so with compatibility and sensitivity to the terrain, land use, roadside and community development, natural and cultural environment, and with consideration for cost and economic efficiency. A consistent approach to geometric design matches and reinforces expectations of the user, which is important to guide the full range of drivers and conditions including drivers that are unfamiliar, older, inexperienced, distracted, inattentive, tired or impaired. A consistent approach also addresses the safety and other needs of pedestrians and bicyclists, and their interactions with motor vehicles [9].

The determination of applicable highway standards is intended to cover broad classifications of highway facilities. However, each project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities of the site are unique factors that must be considered with determination of design criteria for each highway project. The applicable standards provide flexibility in the selection of highway design criteria, which requires decisions on the part of the project design team and stakeholders. The standards allow designs to be tailored to the particular situations encountered in each highway project. Often, the flexibility within the range of criteria provides enough flexibility to achieve a balanced design that meets both the objectives of the project and is sensitive to the surrounding environment and context. In some instances, the criteria may not provide sufficient flexibility to adequately protect essential resources or values. For these cases a design exception process is provided to recognize the need for an exception to the standard, evaluate the consequences and risks, and develop mitigation [10].

Highway location

Location of proposed highway is an important first step in its design. Particular location is based on: topography, soil characteristics, environmental factors such as noise, air pollution and economic factors.

Surveys techniques usually involve measuring and computing horizontal and vertical angles, vertical heights (elevations) and horizontal distances. Data from surveys are used to produce maps with contour lines and longitudinal cross sections. Highway surveys encompass: ground surveys, remote sensing, aerial photographs, computer graphics, positioning, leveling, and as-built control [11].

Four different faces for the location of a highway:

Office study (existing information): Obtain available data relating to the following: topography, geology, climate and traffic volumes social and demographic, land use and zoning patterns, environmental issues (wildlife, historic and archeological sites, effects on air, noise and water pollution). Economic (unit costs for construction and trends of agricultural, commercial and industrial activities) Preliminary analysis will identify un suitable sites for the highway such as sites of archeological importance [12].

Reconnaissance survey: Identify several feasible routes using aerial photographs and remote sensing satellite images, and taking into account the following: Terrain and soil conditions, Serviceability to industrial and populated areas, crossing of other transportation facilities (rivers, railroads or other highways), and Directness of the route.

Preliminary location survey: Feasible routes are set as closely as possible and preliminary vertical and horizontal alignments determined. All feasible routes are evaluated for economics and environmental impact.

Final location survey: Detailed layout of selected route. Final horizontal and vertical alignments determined and final positions of structures (bridges, tunnels etc.) located, Set out of points of intersection (PI) of straight portions of the highway and fit horizontal curves between them.

Objective

In this paper we use Satellite Remote Sensing Imagery to estimate the Land cover, the land use, the Topography and the rates of urban growth for the area of study and to estimate also many other aspects of land cover change, including urbanization, which are poorly measured but of critical importance to the human occupants of Earth. Similar uncertainties surround agricultural production, fresh water resources and other land uses. Surface terrain information is merged in a GIS to economically locate new or relocate existing transportation facilities. Terrain information is used both to construct and evaluate alternative routes and to create final design plans that optimize alignments and grades for the selected alternative [13].

One of the main objectives of the research was to determine whether high resolution satellite remote sensing data were of sufficient accuracy for use in highway location studies.

Satellite remote sensing imagery for highway location

Currently, field surveying and aerial photogrammetry are the methods used by to acquire this data. Both methods are time and resource intensive since they require significant data collection and reduction to provide the level of detail necessary for facility location. In addition, these methods are limited by environmental factors, such as weather. Photogrammetric data collection is most constrained by these factors. Collection of the appropriate aerial imagery is often constrained to early spring or late fall so that data collection occurs under leaf-off conditions and the appropriate sun angle (above 30 degrees) with cloud-free skies. These requirements severely limit the available window during which imagery can be acquired, especially in northern climates. With conventional surveying, data collection occurs almost entirely in the field and may require that data collection personnel locate on or near heavily traveled roadways [14].

Additionally, because of extensive in-field data collection, its use is impractical for sizeable projects. Field data collection for photogrammetry is less onerous, but once aerial imagery are obtained, a significant amount of processing is necessary before any useful terrain information is available. The result is the passage of a significant amount of time between project inception and final route selection, construction, and completion. To reduce the time required to plan and design highway projects, highway agencies have begun to streamline processes. In order to meet the extensive data requirements for environmental assessment and final design, some agencies have chosen to collect and process more terrain data and imagery products than they will ultimately need, in order to be able to rapidly respond to changing location decisions. While facilitating a smoother, faster planning process, the additional data collection and processing is expensive and time consuming. For example, a highway bypass study may require as many as 18 months of photogrammetric processing. The existing process requires early collection and processing of data to support final design. However, only the final design stages of project development may require the accuracies provided by conventional photogrammetric processing.

Once final alignment decisions are made, photogrammetric control and processing could be limited to an area perhaps one-fifth or smaller than the original location corridor. This scale of photogrammetric work could be completed in a short time at a much-reduced cost. In order for these savings to be realized, engineers and planners must be able to use the products and resulting designs must be of sufficient accuracy. This report discusses such a use of Satellite Remote Sensing data in the preliminary planning stages of highway corridor studies.

Digital image segmentation

Generals: The resolution of images provided by the satellites increases every day. Some years ago, these images had a resolution of dozens of meters. The measured luminance of one pixel was representing the mean of luminance of several ground objects. Now the new satellites reach sixty centimeters of resolution, increasing the level of detail by a factor ten. With such images we can consider that each pixel is part of a single object. Thus, the heterogeneity of images has dramatically grown.

Satellite images are mainly used in geographic information systems (GIS). Their classification is very useful for cartography. With low resolution satellite images, the intensity of the pixels is enough to individually classify each of them. On the contrary, high resolution image classification is more difficult. The increasing complexity of the scenes raises the level of details [15].

For example a tree in a field or the shadows of the objects is visible, and the contextual information of the pixels becomes essential for a good classification. The existing GIS classification software generally use the same methods for low and high resolution images.

If satisfactory results can be obtained with low resolution shots, the electiveness of this software for high resolution images is questionable. To ensure a good accuracy, manual classification is sometimes preferred to automatic methods.

The extraction of information on the land cover from remote sensing data has for long been driven by the use of the spectral dimension of the image alone. This approach, based on the consideration of the spectral distance and the decision criterion, proved to be satisfactory for the classification of medium and high resolution images (> 10 m resolution). Given the strong heterogeneity of the spectral information induced by the current very high resolution images (up to 0.5 m resolution), the pixel by pixel approaches of image classification are no more satisfactory. Solutions are brought by the contextual approaches, considering the pixel neighborhood. The segmentation acts as a homogenization factor, strengthen the discriminating ability of the classification.

Moreover, spatial features are calculated for each homogeneous region, supplementing the spectral features to be considered by the classifier.

The improvements of satellite imaging then require new classification methods. Some classifiers were recently developed for biomedical imagery or industry, but are still uncommon in remote sensing. Moreover in biomedical imagery a pre-processing step, the segmentation, is often added. Its aim is to divide the image into homogenous regions in order to extract contextual features. All these new methods are not fully exploited in remote sensing [16].

The segmentation is a process which extracts the outline of the ground objects by defining homogenous regions. Most of the methods only use the intensity of each pixel to define the regions, but produce very noisy segmentations, particularly with the high resolution satellite images. Some algorithms now include contextual information in the process to reduce the heterogeneity of the segmentations. In some of them textural information extracted from the image is also used.

The segmentation step is generally made up of three parts:

- The first part is the pre-processing, in which we select the features to use and eventually modify or re-scale the data. The pre-processing is very important for the following steps. The effectiveness of the segmentation depends on this stage. Moreover, if it is not properly performed, the segmentation may fail. This preprocessing is made up of two parts: feature selection and re-scaling methods. Each part will be discussed in this section.
- The second is the initialization of the segmentation algorithm, if needed. The initialization is very critical because the GHMRF algorithm is only able to converge to a local minimum. The quality of the segmentations can then be strongly affected by a wrong initialization. The most used method is to give aleatory values to the parameters of the components. However, to ensure the best segmentation results, the user has to run several times the algorithm and select the best experiment. We suggest another initialization method consisting of two steps: first the k-means algorithm to estimate the parameters of the components. Then, in order to speed up computing time, we suggest running the FGMM with equal α weights.
- Finally the third part is the segmentation itself.

The Gaussian Hidden Markov Random Field (GHMRF) algorithm:

Let us suppose that we have a density function p (x|Θ) that is governed by the set of

parameters Θ. In our case, we assume the following probabilistic model:

$$p(c\mid\Theta)=\sum_{k=1}^{M}(\alpha_k p_k(x\mid\Theta_k))$$

Where the parameters $\Theta=(\alpha_1,\ldots,\alpha_M,\theta_1,\ldots,\theta_M)$ such that $\sum_{k=1}^{M}\alpha_k=1$

, and each p_k is a probability density function characterized by θ_k. We then have M component densities weighted by M coefficients θ_k.

Let X = {$x_1,\ldots,x_N$} be a set of supposedly drawn from this distribution. The log-likelihood of the data is given by:

$$\log(\xi(\Theta\mid X))=\log\prod_{i=1}^{N}(p(xi\mid\Theta))=\sum_{i=1}^{N}\log\sum_{k=1}^{M}(\alpha_k p_k(x_i\mid\Theta_k))$$

This likelihood is difficult to optimize because we have to compute the logarithm of a sum. However, by considering X as incomplete data and supposing that there is a set of data $yi\in\{1,\ldots M\}$ whose values indicate which probability density function p generated each x_i, we can simplify this equation. Let us then suppose that $yi\in\{1,\ldots M\}$ for each i and that y_i = k if the sample i was generated by the distribution k. Knowing the data Y, the likelihood becomes

$$\log(\xi(\Theta\mid X,Y))=\sum_{i=1}^{N}\log(P(x_i\mid y_i)P(y_i))=\sum_{i=1}^{N}\log(\alpha_{yi}p_{yi}(x_i\mid\theta_{yi}))$$

which can be optimized given a particular form of the component densities. The problem is that we do not know the data set Y. However, if we assume that Y is a random vector we can proceed. Let us first choose an arbitrary set of parameters $\Theta=(\alpha_1,\ldots,\alpha_M,\theta_1,\ldots,\theta_M)$. Given Θ_g, we can easily compute $p_k(x_i\mid\theta_k)$ for each i and k. The mixing parameters k can be thought of as prior probabilities of each mixture component. By using Bayes's rule, we can compute:

$$p(y_i\mid x_i,\Theta^g)=\frac{\alpha_{yi}^g p_{yi}(x_i\mid\theta_{yi}^g)}{p(x_i\mid\Theta)}=\frac{\alpha_{yi}^g p_{yi}(x_i\mid\theta_{yi}^g)}{\sum_{k=1}^{N}\alpha_k^g p_k(x_i\mid\theta_k^g)}$$

The hidden Markov random fields theory asserts that the total image information can be reduced to the local neighbourhood information for each pixel. The local spatial information is then taken into account and is represented by $p_k(x_i\mid\theta_k^g)$ which is the probability that the pixel i was generated by the component yi knowing the classification of its neighbourhood. This information is used to replace the weights α_k previously defined as prior probabilities. This function can take several forms, we chose the most used and the more intuitive one, that is

$$p(y_i\mid y_{Ni})=\frac{e^{\beta V_{i,yi}}}{\sum_{k=1}^{M}e^{\beta V_{i,k}}}$$

$V_{i,k}$ represents the number of neighbouring pixels generated from the component k. β is a constant which defines the importance of the neighbourhood. The neighbourhood size is defined by the user.

Satellite high resolution image classification

Principle of classification: The basic principle of the classification is to assign a label to each instance, which is for remote sensing images either a pixel or a region. Each label corresponds to a class having its own properties. The algorithm that assigns these labels is called classifier. The classifier, which can be supervised or not, uses extracted features from the data to choose the labels.

Each region must be characterized by some values to perform a classification that is why we need to extract features from these regions [17].

The following part will present the features that we extracted. Let *r* be a region of the segmented image and Pr = $p_{1,r},\ldots p_{k,r}$ be the set of pixels of size K belonging to the region r. $I_{p,b}$ is the intensity of the pixel p in the band b.

The intensity is defined as the mean of the intensity of the pixels belonging to the same region. With multi-spectral data the mean can be computed on each band. The mean intensity for a region r in the band b is given by

$$Ratio_{R,PIR,r} = \frac{I_{mean,r,R}}{I_{mean,r,PIR}}$$

Two features can also be interesting when using multi-spectral data: the red-infrared and red-green ratios. The first one is useful to detect the wooded areas, since vegetation has a low intensity in the red band but is very sensitive in the near infrared band. The second one can be helpful in the recognition of some farming areas.

$$Ratio_{R,PIR,r} = \frac{I_{mean,r,R}}{I_{mean,r,PIR}}$$

and the red-green ratio is given by

$$Ratio_{R,G,r} = \frac{I_{mean,r,R}}{I_{mean,r,G}}$$

The standard deviation of intensity is given by

$$I_{std,r,b} = \sqrt{\frac{\sum_{i=1}^{K}(I_{pi,r,b} - I_{mean,r,b})^2}{K}}$$

Classifiers: There is a wide range of classifiers. It is beyond the scope of this work to describe all of them in details. That is why we will first present an overview of some of the most known classifiers. Next, the advantages or disadvantages of each classifier will be discussed. Finally the classifiers that we used in our study will be presented.

Note that we make the difference between unsupervised classifiers, which only need samples to perform automatic classification, and supervised classifiers, which have to be trained with a set of samples whose labels are known, called the training set [18].

Unsupervised classifiers include,

- K-means algorithm: This starts with arbitrary clusters in the feature space, each of them defined by its centre. The first step consists in assigning the nearest cluster to each sample. In the second step the centers are recomputed with the new clusters. These two steps are repeated until convergence.
- Finite Gaussian Mixture Model: The model can also be applied to the classification step. In this case each component of the created mixture corresponds to a label.

Supervised classifiers include,

- Finite Gaussian Mixture Model: This is the supervised version of the FGMM. In the first step, the distribution of the training instances for each class is approximated with a mixture of Gaussian probability density functions. Then for each testing sample the best distribution in terms of maximum likelihood is selected and the corresponding label is assigned to the sample.
- The second classier is the Mahalanobis Distance. For each class the mean and the covariance matrix are computed according to the training instances. Then for each testing sample we compute the Mahalanobis Distance to each class. The nearest class is then assigned to each testing sample.
- The third classifier is the K-nearest Neighbours. For each testing sample we search the K nearest training instances and the most represented label among these instances is selected.
- Neural network. This is a classifier which tries to find nonl inear separating surfaces in the feature space.
- Support Vector Machine. The basic principle of a support vector machine in a two- class case is to locate a linear hyper plane that maximizes the distance from the members of each class to the optimal hyper plane. As it is sometimes not possible to separate classes with a linear hyper plane without misclassification, the support vector machine tries to find the optimal nonlinear transformation to apply to the data in order to find a linear separating plane without misclassification. Finally, each testing instance is transformed and the class is chosen depending on which side of the hyper plane this instance lies. This can be easily extended to multi-class cases.

Unsupervised FGMM: The FGMM assumes that the data are generated by Gaussian distributions, each of it characterized by its centre μ, its covariance matrix Σ and its prior probability α. This algorithm is implemented as follows:

1. Initialization of parameters θg
2. For each component k of the mixture, compute

$$p(k \mid x_k, \theta^g) = \frac{p_k(x_r \mid \theta_k^g)\alpha_k^g}{\sum_{r=1}^{M} p_k(x_r \mid \theta_k^g)\alpha_k^g}$$

$$\alpha_k^{new} = \frac{\sum_{r=1}^{R} p(k \mid x_r, \theta^g)}{R}$$

$$N_k^{new} - \frac{\sum_{r=1}^{R} x_r p(k \mid x_r, \theta^g)}{\sum_{r=1}^{R} p(k \mid x_r, \theta^g)}$$

$$\sum_k^{new} - \frac{\sum_{r=1}^{R} p(k \mid x_r, \theta^g)(x_r - \mu_k^{new})(x_r - \mu_k^{new})^T}{\sum_{r=1}^{R} p(k \mid x_r, \theta^g)}$$

3. Repeat step 2 until convergence of Θ^g.
4. For each sample x_r compute the corresponding label lr given by

$$I_r = \arg\max_k (p_k(x_r|\theta_k))$$

For the classification step, the number of components is simply equal to the number of classes that the user needs to extract from the satellite image. As for the GHMRF algorithm used for the segmentation step, the initialization is very critical because the FGMM is only able to converge to a local minimum. We also suggest using the k-means algorithm to approximate the components of the mixture. The stopping criterion is fixed around 0.1 percent.

Methodology

In this study we will present and apply a methodology for the use of Satellite Remote Sensing Imagery to feed the latest computing and information technology trends Geographic Information Systems (GIS). Precise Stereo-models were derived from SPOT imagery by mathematical modeling between space images and the imaged area. Photogrammetric techniques were also used to derive from stereo-models, Digital Elevation Models.

Detecting change in urban areas is not only of academic interest, because it serves as the major data source for strategic planning and analysis in urban areas [19]. In addition, to get information of the current situation, the need to move from 2.5D or 3D representations of urban areas into 4D-that is, including time is clear. In order to understand the dynamics of an urban area, it is very important to take into consideration the urban growth rate as well.

Finding patterns in the formation of informal settlements might give valuable clues for the planners to learn from the mistakes made in the past. When no other data is available for this kind of analysis, one solution is to use remote sensing imagery as the primary data source, and GIS (geographic information systems)

To measure rates of urban growth, we use differences in NDVI between subsequent images, filtered through a land-cover classification derived from the later image to remove effects of agricultural variability. We first calculate NDVI for each image [20]. For Landsat TM, NDVI is defined as (band4-band3)/ (band4+band3), while for MSS it is defined as band4+band2/band4-band2. NDVI images from subsequent dates are then subtracted, producing a map of DNDVI in which positive values represent 'greening' (increased vegetation) and negative values represent 'browning' (decreased vegetation). We then pick a threshold DNDVI value by visual inspection to distinguish true urban growth (large negative DNDVI) from noise (small negative DNDVI). Typically, threshold values are found within recently-developed residential areas where the spatial pattern of roads clearly indicates growth but the introduction of landscaping typically modulates DNDVI values.

Study site and data

Our study comprises the urbanized portion of Amman Metropolitan Area, including all the suburbs considered within the Greater Amman Municipality.

Amman region presents a particularly interesting laboratory for studying urban growth. The region has developed rapidly since the Second Gulf War.

According to the Greater Amman Municipality, the city's population is expected to surpass the six million mark by 2025. This assessment is based on examining Amman's growth patterns during its modern history and projecting these patterns over the next decade and a half [21]. The history of modern Amman dates back to the 1870s, when it was resettled after being deserted for centuries. As late as the 1920s, it only had about 5,000 inhabitants, but since then, the city's population has grown spectacularly to reach its current level of about 2.5 million. Its growth has been fueled not only by high levels of natural population increase, but also by migration from other parts of the country and from neighboring countries.

Whenever it seemed that Amman's growth would revert to more manageable levels, developments in the opposite direction would take place, particularly regional crises that result in the movement of a few hundred thousand people into Jordan, with most settling in Amman [22]. One manifestation of this growth pattern is that the city's population growth has not been evenly distributed over the years, but has experienced sudden spurts connected to the 1948 and 1967 Arab-Israeli wars, the 1990 - 1991 Gulf War, and the instability affecting Iraq over the past five years or so.

If Amman's population rises to exceed six million by 2025, this would translate into an average yearly projected growth of over 6%. Jordan's natural population increase of about 2.3% accordingly would account for less than half that growth, while most of it would result from migration, either from other parts of Jordan or from outside it.

The vast majority of this development occurred in outlying suburban regions. Economically, Amman commercial base depends on the private sector [23].

To generate our Models of growth in Amman area, we obtained Landsat scenes from 2008, and 2011. All scenes were imaged during the regional growing season to minimize seasonal variability. All the scenes were mapped by the use of Multi-date Landsat Thematic Mapper (TM).

DEMs were generated from, SPOT XS and panchromatic images 2008 after being resamped in epipolar geometry. Aerial photographs and Large Scaled Topographic maps served as ground truth.

Criteria for creation of highway corridor alternative

When planning new alignments, designers examine existing roadway alignments to determine how much, if any can be saved and incorporated into alignment alternative. It is cost feasible to utilize portions of existing facilities wherever possible. Financial savings are derived from reduced engineering requirements for planning and design, property acquisition, and construction costs.

The main consideration in the location of alignment alternatives is minimal disruption to private property. Essentially, the designer begins developing alternatives by laying out tangents that avoid passing through the middle of areas such as farm fields. When laying out an alignment, a designer seeks to follow property lines rather than transect property [24].

Public input is also sought and considered when examining areas through which alignments may be located. This input allows designers to understand property owner's concerns. It also allows the opportunity for disputes to be settled during the early stages of development. Another area considered by designers is accessibility, which refers to how existing properties will access the new alignment. Properties must remain accessible to owners, but at the same time, access from the new facility is often controlled to some extent. Most often, for a specific project, access point locations (e.g., driveways) are to be spaced a specified distance apart.

The function of a facility after its construction is another concern. An alignment that will be more costly to maintain is an alternative that is not as attractive as one with minimal maintenance costs. Terrain is relevant when determining alignment; alignments through more rugged terrain require more extensive maintenance than those traversing more level areas.

Once designers have a rough idea of where an alignment will be located, based on the other considerations listed previously, they begin to consider terrain. Whenever possible, level terrain is followed for an alignment, while rugged terrain is avoided if possible. If there are no other alternatives to locate an alignment, then cuts and fills will be employed. In this case, the goal is to balance cut and fill locations to minimize the amount of borrow required for a project. Care must be taken when utilizing cuts and fills to prevent adverse effects from occurring in areas outside the project boundaries. For example, fill used for the approaches to a river crossing could result in flooding in another location downstream [25].

A number of alternative corridors may be created for a project. However, it is impractical to present a large number of alternatives to the Transportation Commission for comparison and consideration. Consequently, the corridor development section meets as a group and narrows down the number of alternatives. Using past experience and engineering judgment, the corridor development section eliminates less attractive alternatives. A number of factors may limit an alternative's attractiveness including property acquisition issues. The most feasible alternatives are selected and presented to the commission [26].

Results

Classification

The pre-processing for the SPOT and Landsat images is completed and the data are ready for the classification and change detection phases. The land cover classes for which the training areas and test areas were collected in the field. Each image will be classified into these classes. The preliminary results from the interpretation of the airborne and satellite remote sensing data are shown below [27]. The area was classified into twelve classification categories as shown in the second column of the table 1. The third column shows the number of pixels for each category which is proportional to the area. And the fourth and last column represents the percentage of each one of the twelve categories with respect to the total area to be studied. As the Figure 1 shows, grassy areas had the highest share (44.3%), followed by cultivated areas (13.0%). Plowed area represented 11%, residential area is accounted only for 4.2% Stone mountain represented 9.5%, distorted area counted for 8.1%, Natural forest is accounted for 6.8%, water surfaces accounted for only 0.1% of the area, while unclassified areas represented 2.0%, Short-day plant represented 1% and vacant land accounted for 1%.

In order to assess the classification accuracy after the "supervised with training area method of classification" was applied, the confusion matrix is calculated. This matrix was calculated after combining all classification categories to reveal the relationship between known reference data (ground truth) and the corresponding data obtained from the automated classification (classification based on satellite and topographic data) [28]. The training set pixels that were classified into the proper land cover categories are located along the major diagonal of the matrix. All non-diagonal column and row elements

Class No.	Class Type	Area in Pixels	% of Total Area
1	Natural Forest	1227808	6.8
2	Distorted area	1462541	8.1
3	Stone Mountain	1720528	9.5
4	Plowed areas	1976392	11.0
5	Grassy areas	8025201	44.3
6	Cultivated areas	2352270	13.0
7	Residential Areas	749947	4.2
8	Water Surfaces	7395	0.1
9	Unclassified	362417	2.0
10	Short-day Plant	168343	1.0
11	Cemetery	15429	0.1
12	Vacant Land	57880	0.4
	Total Area	16778906	100

Table 1: Classification results.

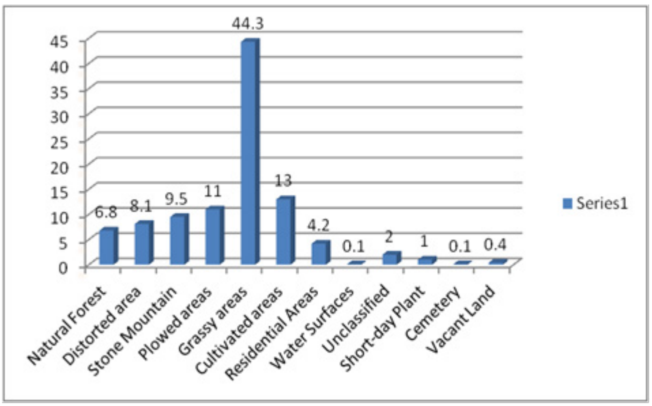

Figure 1: Classification results of the study area: The x-axis represents the categories and the y-axis the area of each category in percentage with respect to the total area.

represent omission (exclusion) and commission (inclusion) errors, respectively. Based on the matrix, the overall accuracy was 96.2%.

While producer's accuracy exceeding 96% for natural forest, residential area, water surfaces, cemetery and vacant land; it doesn't exceed 88 % for distorted area and stone mountain.

Users' accuracy exceeding 96% was obtained for natural forest, residential area, water surfaces, cemetery and vacant land; it doesn't exceed 92 % for distorted area and stone mountain and short-day plants.

KHAT Statistic was also calculated from the error matrix. A KHAT value of 94.0% was obtained which was a little less than the overall accuracy (96.2%). The difference is justified since each measure incorporates different forms of information from the error matrix [29]. The KHAT value of 94.0% shows that there are some miss-registration, and consequently interpretation errors, data entry errors, some changes in land cover between the date of registration of the classified images and date of the reference data.

The location process is identification of alignment alternatives. Alternatives are specific transportation improvement options that could be used to satisfy project needs. For smaller and/or rural projects, these alternatives might be different cross sections and alignments. In larger urban areas, alternatives might include non-highway options (transit, travel demand management, etc.). The goal of this study is to develop alternatives that are in balance with the communities that they will serve and integrated into the surrounding environment. When developing alternatives, elements such as cultural and sensitive environmental features are avoided, as well as adverse terrain and other physical features that would require costly engineering solutions. It is important to note that precise terrain mapping is not required in this phase, but rather, only when the project moves into the final design phase [30].

Once potential alternatives have been identified, an evaluation is made to narrow the list, which will be carried into the detailed evaluation phase. Evaluations are made using information gathered during previous phases of the process. The evaluations are made

$$\bar{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$$

by qualified engineers, planners, and environmental specialists. Evaluation criteria are developed by the study team and are unique to each project. Once evaluations are completed, alternatives are compared, and less desirable or feasible alternatives are dismissed.

Road linear network: SPOT images allow a satisfying identification and restitution of highways and main roads. Interchanges are also readable on metric models. Narrow roads are sometimes visible, according to the context of their surroundings.

Hydrographic network: with panchromatic SPOT images, only about 87% of linear features can be restored, whereas lakes are easily identified [31].

All features greater than 2.5 m in dimension were 100% recognizable on panchromatic

SPOT images and 1.2 m on aerial photographs.

The combination product of topographic information, aerial photographs and data derived from satellite imagery classification in addition to the DEM calculated from SPOT images was used to study three corridors surrounding the Greater Amman Area to select the optimal path for a proposed ring road.

Several alignment alternatives within each one of the two corridors were studied to choose the best alternative possible. Then, the three best paths were compared to choose the optimal one which satisfies better the design standards. The standard criteria were used in the comparison process.

Multi-Objective Assessment of Alternatives

The method starts with a matrix of responses of different alternatives on different

objectives: x_{ij} where x_{ij} is the response of alternative j on objective i, i=1,2,…,n as the objectives, j=1,2,…,m as the alternatives [32].

This method goes for a ratio system in which each response of an alternative on an objective is compared to a denominator, which is representative for all alternatives concerning that objective. For this denominator the square root of the sum of squares of each alternative per objective is chosen

$$\overline{y_j} = \sum_{i=1}^{i=g} S_i \overline{x_{ij}} - i = \sum_{i=g+1}^{i=n} S_i \overline{x_{ij}}$$

With:

x_{ij} - is the response of alternative j on objective i,

j = 1, 2 ..., m; m the number of alternatives,

i = 1, 2 …, n; n being the number of objectives,

x_{ij} - a dimensionless number representing the normalized response of alternative j on objective i. These normalized responses of the alternatives on the objectives belong to the interval [0; 1].

For optimization these responses are added in case of maximization and subtracted in case of minimization:

$$\overline{y_j} = \sum_{i=1}^{i=g} S_i \overline{x_{ij}} - i = \sum_{i=g+1}^{i=n} S_i \overline{x_{ij}}$$

With: i = 1, 2,…, g as the objectives to be maximized,

i = g+1, g+2,…, n as the objectives to be minimized,

s_i is introduced as a significance coefficient for the i-th objective,

yi is the normalized assessment of alternative j with respect to all objectives.

In this formula linearity concerns dimensionless measures in an interval [0; 1]. An ordinal ranking of y_j shows the final preference of the alternatives [33].

Optimization technique with discrete alternatives was used for ranking of alternatives in the case study. The results of multi-objective analysis are presented in Table 2.

When ranking of alternatives assessment is based on the objectives described in the first column of Table 2, the following rank of alternatives would be obtained (starting with the best alternative): 2-3-1.

Evaluation of the potential contribution of satellite remote sensing data in highway location studies

To reduce the time required to plan and design highway projects, highway agencies have begun to streamline processes. In order to meet the extensive data requirements for environmental assessment and final design, some agencies choose to collect and process more terrain data and imagery products than they will ultimately need, in order to be able to rapidly respond to changing location decisions. While expediting the planning process, additional data collection and processing is expensive and time consuming [34]. The ability to collect and deliver terrain products in a timely manner through the use of Satellite Remote Sensing Data presents an opportunity to minimize data collection costs, while meeting the current needs of highway agencies.

The accuracy evaluation obtained here indicates that Satellite Remote Sensing Data cannot replace photogrammetric data in the final design stages of the highway location and design process.

Photogrammetric data are still required to produce highly accurate terrain models, as well as additional data, such as break lines.

Criteria	Normalized Weight (First Alternative)	Normalized Weight (Second Alternative)	Normalized Weight (Third Alternative)
Path Length	0.371	0.270	0.359
Length of Slopes Exceeding 13%.	0.434	0.265	0.301
Number of Intersections With Highways.	0.340	0.300	0.360
Intersections With Secondary Roads.	0.388	0.302	0.312T
Number of Intersections With Railways.	0.333	0.333	0.333
Number of Intersections With Wadis.	0.276	0.342	0.382
Land Use	0.333	0.333	0.333
Number Of Vertical Curves Required.	0.466	0.255	0.279
Benefits.	0.390	0.286	0.324
Average Weight	0.370	0.298	0.331

Table 2: Normalized weights for the best three alternative alignments.Normalized weights for the best three alternative alignments.

However, these limitations do not entirely prevent Satellite Remote Sensing Data from being utilized in the location and design process. The true potential of this type of data in the process appears to be a supplemental form of data collection to photogrammetry [35]. Satellite Remote Sensing Data could be collected for large area corridors, providing designers with the terrain information necessary to identify favorable alignments at earlier stages. Once such alignments have been identified, detailed photogrammetric data could then be produced for a lesser area.

Conclusion

Satellite Remote Sensing data and techniques and geographic information systems (GIS) provide efficient methods for analysis of land use issues and tools for land use planning and modeling. Understanding the driving forces of land use development in the past, managing the current situation with modern GIS tools, and modeling the future, we are able to develop plans for multiple use of natural resources and nature conservation.

In this paper we use Satellite Remote Sensing Imagery to estimate the Landcover, the Landuse, the Topography and the rates of urban growth for the area of study and to estimate also many other aspects of land cover change, including urbanization, which are poorly measured but of critical importance to the human occupants of Earth. Similar uncertainties surround agricultural production, fresh water resources and other land uses. Surface terrain information is merged in a GIS to economically locate new or relocate existing transportation facilities. Terrain information is used both to construct and evaluate alternative routes and to create final design plans that optimize alignments and grades for the selected alternative [36].

Using advanced remote sensing technologies, modern optimization techniques, and high- resolution DEM data has significantly improved the designer efficiency in designing preliminary highways in the office. In this study, an alternative alignment optimization model was developed as a decision support system. Using this model, a designer can quickly evaluate alternative alignments and locate the best path with minimum total road cost.

The results from the case study were instructive in presenting how a decision support system equipped with interactive features, advanced GIS and remote sensing technologies, and environmental considerations can improve the preliminary highway location and consequently the design process for highways.

It provides a road designer with a number of alternative alignments to evaluate quickly and systematically.

While Satellite Remote Sensing data is not capable of replacing photogrammetric data in the final design of alignments, such data may prove useful in expediting the location process. With Satellite Remotely Sensed terrain information will be available to designers [37].

Preliminary research suggests that Satellite Remote Sensing data is best suited for providing designers with general terrain information early in the location process to identify final corridors where more intensive photogrammetric work can be performed. In this manner, the utilization of this type of data collection could produce time and cost savings by allowing expedient data collection to occur on a large corridor scale, with only limited areas being mapped by more time consuming and costly means.

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