II. LITERATURE REVIEW

Alternative fuel is any material or substance, other than petroleum (oil), which is consumed to provide energy to power an engine. The need for the development of alternative fuel sources has been growing due to concerns that the production of oil will no longer supply the demand. Some alternative fuels are biodiesel, ethanol, chemically stored electricity (batteries and fuel cells), hydrogen, methane, vegetable oil, wood, and natural gas.

Natural gas is an organic compound that is found deep within the earth. It is a fossil fuel formed over millions of years of geological pressures and changes. Natural gas is primarily methane comprised of hydrogen and carbon. It is a safe fuel source that is commonly used in homes and businesses for heating, lighting and cooking (McKenzie, 2006).

Natural gas is an ideal fuel source for many reasons, including safety. Natural gas is lighter than air. This means that it will not puddle (like gasoline) or sink to the ground like propane, which is heavier than air. Instead, natural gas will rise and dissipate in the atmosphere. Natural gas also has a higher ignition temperature. This means that it is much harder to ignite. Also the storage systems used for compressed natural gas are infinitely stronger that the gasoline tanks found on cars and trucks today (McKenzie, 2006).

2.1. Compressed Natural Gas

Compressed natural gas or CNG is natural gas under pressure which remains clear, odorless, and non-corrosive. Although vehicles can use natural gas as either a liquid or a gas, most vehicles use the gaseous form compressed to high pressures at 3000 to 3600 pounds per square inch (California Energy Commission, 2006). CNG is a domestically available, economical, clean burning, alternative fuel source for vehicles. It consists mostly of methane and is drawn from gas wells or in conjunction with crude oil production. An odorant is normally added to CNG for safety reasons (US Department of Energy, 2002).
2.1.1. Affordability

The CNG market is more stable than the gasoline market. CNG generally costs 15 to 40 percent less than gasoline or diesel. CNG requires more frequent refueling, however, because it contains only about a quarter of the energy by volume of gasoline (US Department of Energy, 2002).

2.1.2. Performance

Based on properties table of fuels (Appendix 5), octane rating for CNG is higher than that for gasoline; in a dedicated engine, a CNG vehicle’s power, acceleration, and cruise speed can be greater than that of a gasoline-powered vehicle. In addition, due to the cleaner burning characteristics of natural gas, CNG vehicle engines can run more efficiently than a gasoline-powered vehicle, thereby extending the life of the vehicle. In heavy-duty vehicles, CNG engines are also generally less noisy than diesel engines (US Department of Energy, 2002).

2.1.3. Safety

Although CNG is a flammable gas, it has a narrow flammability range, making it an inherently safe fuel. Strict safety standards make CNG vehicles as safe as gasoline-powered vehicles. In the event of a spill or accidental release, CNG poses no threat to land or water; it is nontoxic. CNG also disperses rapidly, minimizing ignition risk relative to gasoline. Natural gas is lighter than air and will not pool as a liquid or vapor on the ground. Nevertheless, leaks indoors may form a flammable mixture in the vicinity of an ignition source. CNG is primarily methane, however, which is a greenhouse gas that could contribute to global climate change if leaked. Methane is slightly soluble in water and under certain environmental conditions (anaerobic) does not biodegrade; if excess amounts accumulate, the gas can bubble from the water, possibly creating a risk of fire or explosion. Natural gas also has a higher ignition temperature. This means that it is much harder to ignite. Also the storage systems used for compressed natural gas are infinitely stronger than the gasoline tanks found on cars and buses today. Reported incidences of bus fires are related to engine failures, not the use of natural gas. Natural gas buses have onboard gas detectors and other safety
devices, such as tank safety valves that allow fuel flow only when the engine is keyed on. Also, the tanks must be inspected and approved by the Department of Transportation after certain periods of use.

### 2.1.4. Process for Powering Vehicles

Natural gas is compressed and enters the vehicle through the natural gas dispenser or fill post. It flows into high-pressure cylinders that are located on the vehicle. When the driver steps on the accelerator, the natural gas leaves the on-board storage cylinder, passes through the high-pressure fuel line and enters the engine compartment. Gas then enters the regulator, which reduces pressure from up to 3,600 psi to approximately atmospheric pressure. The natural gas solenoid valve allows natural gas to pass from the regulator into the gas mixer or fuel injectors. Natural gas mixed with air flows down through the carburetor or fuel injection system and enters the engine's combustion chambers.

### 2.1.5. Emission Characteristics

Actual emissions will vary with engine design; these numbers reflect the potential reductions offered by compressed natural gas, relative to conventional gasoline.

- Reductions in carbon monoxide emissions of 90 to 97 percent, and reductions in carbon dioxide emissions of 25 percent.
- Reductions in nitrogen oxide emissions of 35 to 60 percent.
- Potential reductions in non-methane hydrocarbon emissions of 50 to 75 percent.
- Fewer toxic and carcinogenic pollutants and little to no particulate matter produced.
- No evaporative emissions in dedicated engines (such as those associated with gasoline or diesel).

### 2.2. Geographic Information System

GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically
referenced information. A geographic information system (GIS) can link information (attributes) to location data, such as people to addresses, buildings to parcels, or streets within a network. Then layer that information to give a better understanding of how it all works together.

### 2.2.1. Three Views of GIS

A GIS is most often associated with a map. A map, however, is only one way you can work with geographic data in a GIS, and only one type of product generated by a GIS. This is important, because it means that a GIS can provide a great deal more problem-solving capabilities than using a simple mapping program or adding data to an online mapping tool (Berry, 1995).

A GIS can be viewed in three ways:

1. **The Database View**: A GIS is a unique kind of database of the world—a geographic database (geodatabase). It is an "Information System for Geography". Fundamentally, a GIS is based on a structured database that describes the world in geographic terms.

2. **The Map View**: A GIS is a set of intelligent maps and other views that show features and feature relationships on the earth's surface. Maps of the underlying geographic information can be constructed and used as "windows into the database" to support queries, analysis, and editing of the information. This is called geovisualization.

3. **The Model View**: A GIS is a set of information transformation tools that derive new geographic datasets from existing datasets. These geoprocessing functions take information from existing datasets, apply analytic functions, and write results into new derived datasets.

### 2.2.2. Representation of Geographic Phenomena

GIS supports such study because it represents phenomena digitally in a computer. GIS also allows visualizing this representation in various ways. Geographic phenomena exist in the real world: for true example, one has to look outside the window. In using GIS software, we first obtain some computer representations of these phenomena – stored in memory, in bits and bytes – as
faithfully possible. This is where we speak of spatial data. We continue to manipulate the data with techniques usually specific to the application domain, for instance, in geology, to obtain a geological classification. This may result in additional computer representations, again stored in bits and bytes. For true examples of this representation, one has to look into the files in which they are stored. One would see the bits and bytes, but very exciting this would not be. Therefore, we can use the GIS to create visualizations from the computer representations, either on-screen, printed on paper, or otherwise.

Figure 1. Representation of Geographic Phenomena (de By, 2000)

Geographic phenomena can be named, described, georeferenced (a coordinate system with well-defined origin and orientation of the three orthogonal, coordinate axes—spatial reference system), and assigned a time or interval. Type of Geographic data:

a. Continuous data
Continuous data, or a continuous surface, represents phenomena where each location on the surface is a measure of the concentration level or its relationship from a fixed point in space or from an emitting source. Continuous data is also referred to as field, nondiscrete, or surface data. One type of continuous surface data is derived from those characteristics that define a surface, where each location is measured from a fixed registration point. These include elevation (the fixed point being sea level) and aspect (the fixed point being direction: north, east, south, and west).
b. Discrete field

Discrete data, which is sometimes called categorical or discontinuous data, mainly represents objects in both the feature and raster data storage systems. A discrete object has known anisotropically the coordinate and definable boundaries. It is easy to define precisely where the object begins and ends. A lake is a discrete object within the surrounding landscape. Where the waters edge meets the land can be definitively established. Other examples of discrete objects include buildings, roads, and land parcels. Discrete objects are usually nouns.

2.2.3. Spatial Reference

The geometry and motion of objects in 3D Euclidean space are described in a reference coordinate system. A reference coordinate system is a coordinate system with well-defined origin and orientation of the three orthogonal, coordinate axes. Usually it refers to such a system as a Spatial References System (SRS).

To represent parts of the surface of the Earth on a flat paper map or on computer screen, the curved horizontal reference surface must be mapped onto the 2D mapping plane. The reference surface is usually an oblate ellipsoid for large-scale mapping, and sphere for small-scale mapping. Mapping onto a 2D mapping plane means assigning plane Cartesian coordinates \((x, y)\) to each point on the reference surface with geographic coordinates \((\Phi, \lambda)\).

A map projection uses mathematical formulas to relate spherical coordinates on the globe to flat, planar coordinates. Different projections cause different types of distortions. Some projections are designed to minimize the distortion of one or two of the data's characteristics. A projection could maintain the area of a feature but alter its shape. In the graphic below, data near the poles is stretched.

Any map projection is associated with distortions. There is simply no way to flatten out a piece of ellipsoidal or spherical surface without stretching some parts of the surface more than others. Some map projections can be visualized as true geometric projections directly onto the mapping plane, or onto an intermediate surface, which is then rolled out into the mapping plane. Typical
choices for such intermediate surfaces are cones and cylinders. Such map projections are then called azimuthal, conical, and cylindrical, respectively.

Figure 2. Map Projection (ESRI, 2005)

There are many supported map projection, in this case Universal Transverse Mercator (UTM) is applied. This system is a specialized application of the Transverse Mercator projection. The globe is divided into 60 north and south zones, each spanning $6^\circ$ of longitude. Each zone has its own central meridian. Zones 1N and 1S start at -180° W. The limits of each zone are 84° N and 80° S, with the division between north and south zones occurring at the equator. The polar regions use the Universal Polar Stereographic coordinate system.

2.3. Spatial Data Analysis

de By (2000) defined that spatio-analytic capabilities distinguish GIS from other data processing systems. These capabilities use the spatial and non-spatial data in the spatial database to answer questions and solve problems. The principal objective of spatial data analysis is to transform and combine data from diverse sources/disciplines into useful information, to improve one’s understanding or to satisfy the requirements or objectives of decision makers. A GIS application deals with only some delineated, relevant slice of reality, termed as the universe of discourse of the application.
Application models used for planning and site selection are usually prescriptive. They involve the use of criteria parameters to quantify environmental, economic and social factors. The model enumerates a number of conditions to be met. In predictive models, a forecast is made of the likelihood of future events, which may be pollution, erosion, or even landslides. Such a model involves the expert use of various spatial data layers, either raster-or vector-based, and their combination in a methodically sound way to arrive at sensible predictions (de By, 2000).

2.3.1. Proximity Computation

In proximity computations, geometric distance is used to define the neighbourhood of one or more target locations. The most common and useful technique is buffer zone generation. The principle of buffer zone generation is simple, which one or more target location is selected, and then the area around them determined, within a certain distance (de By, 2000).

In some case studies, zonated buffers must be determined, for instance in assessment of traffic noise effects. Most GIS support this type of zonated buffer computations. In vector-based buffer generation, the buffers themselves become polygon features, usually in a separate data layer, that can be used in further spatial analysis. Buffer generation on raster is fairly simple function. The target location or locations are always represented by a selection of the raster’s cells, and geometric distance is defined, using cell resolution as the unit. The distance function applied is the Pythagorean distance between the cell centers.

2.3.2. Network Analysis

A completely different set of analytic functions in GIS consists of computations on network. A network is a connected set of lines, representing some geographic phenomenon, typically of the transportation type. The ‘goods’ transported can be almost anything: people, cars and other vehicles along a road network, commercial goods along a logistic network, phone calls along a telephone network, or water pollution along a stream/river network (de By, 2000).
Network analysis can be done using either raster or vector data layers, but they are more commonly done in the latter, as line features can be associated with a network naturally, and be given typical transportation characteristics like capacity and cost per unit. One crucial characteristic of any network is whether the network lines are considered directed or not. Directed networks associate with each line a direction of transportation; undirected networks do not. In the latter, the ‘goods’ can be transported along a line in both directions (Aronoff, 1989).

For many applications of network analysis, a planar network, i.e., one that is embeddable in a two-dimensional plane, will do the job. Many networks are naturally planar, like stream/river networks. A large-scale traffic network, on the other end, is not planar: motorways have multi-level crossings and are deal with computationally, as they have simpler topological rules. Not all GIS systems accommodate non-planar networks, or can do so only using trickery (de By, 2000).

Burrough and McDonnel (1998) explain that various classical spatial analysis functions on networks are supported by GIS software packages. The most important one is optimal path finding. Optimal path finding techniques are used when a least-cost path between two nodes in a network must be found. The two nodes are called origin and destination, respectively. The aim is to find a sequence of connected lines to traverse from the origin to the destination at the lowest possible cost.

The cost function can be simple: for instance, it can be defined as the total length of all lines on the path. The cost function can also be more elaborate and take into account not only length of the lines, but also their capacity, maximum transmission (travel) rate and other line characteristics, for instance to obtain a reasonable approximation of travel time. There can even be cases in which the nodes visited add to the cost of the path as well. These may be called turning costs, which are defined in a separate turning cost table for each node, indicating the cost of turning at the node when entering from one line and continuing on another.
2.3.3. 3D Data Structures

de By (2000) explain that the data structures used for representing 3D objects have largely evolved from theoretical work done in the fields of geometry and solid modeling. Much of this work is in use in computer-aided design and manufacturing (CAD/CAM) systems, for industrial design purposes.

Not all of these representations have been used for modeling in 3D GIS in practice, for applications such as mining and site investigation, two different approaches are followed, namely geometric modeling and volumetric modeling. These two approaches differ significantly in associated file size, ease of manipulation and interactive editing and visualization capabilities, as is the case with vector and raster approaches in 2D GIS. Geometric models result in smaller file size, and are easier to view and manipulate interactively. Volumetric models are important for applications interested in variations in internal properties of solid objects. In addition, it is generally much easier to computationally combine and intersect objects using volumetric models.

2.3.4. 3D Data Capture

Aronoff (1989) explain that many aspects of 3D data capture are similar to the approaches used in 2D GIS, with some additional procedures being necessary to ensure all data are correctly georeferenced. Examples of the procedures used for 3D data capture, are summarized below:

a. Topographic contours

The (constant) contour elevation is treated as a coordinate value for 3D georeferencing, as opposed to 2D GIS where it is regarded simply as a numeric attribute. Such data can be captured using conventional digesting tablets. The main procedural difference is that each reference point used for orienting the map on the digitizer has three coordinate values, and each contour will be assigned a z-value, which indicates its position relative to the reference plane.

b. Automatic generation of triangulated surfaces

c. Extrusion of 2D polygons

d. 3D Interpolation
2.4. **Analytical Hierarchy Process**

Analytical Hierarchy process (AHP) is a quantitative method for ranking decision alternatives by developing a numerical score to rank each decision alternative based on how well each alternative meets the decision maker’s criteria (Russell and Taylor, 2003). AHP can be used to determine the relative weights among decision elements for GIS-based Suitability and Routing models. In its many other applications AHP is used to select the best single alternative that best matches decision criteria (decision-making models).

The process involves 1) identifying the decision elements, 2) recording relative importance of those elements, 3) construction of an importance table and 4) implementing a simple mathematical solution. The decision elements are identified by group interaction and discussion. A scale from 1= equally important through 9= extremely important is used to record the relative level of importance for the pairwise combinations of the decision elements. Each member of the group first orders the decision elements to be compared so the statement “<element A> is preferred over <element B>” is correct, and then records the appropriate rating value (1 to 9) for the strength of the opinion. The number of pairwise combinations is calculated by #Pairs= (N * (N – 1) / 2), where N is the number of decision elements (Saaty, 1992).