

# Providing Intelligent Spatial Decision Support using Expert System and Web Technologies

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## EXTENDED ABSTRACT

Integrating GIS and web technologies with expert systems can provide valuable real-time spatial decision support. Traditional decision support systems (DSS) lack expert knowledge and are mostly PC-based software components. The benefits of the traditional DSS can be further leveraged by embedding expert knowledge and implementing the DSS using web-based technologies. Embedding expert knowledge with the DSS provides intelligent decision support rivaling a human expert, and implementing the intelligent DSS over the web provides many advantages, such as anytime-anywhere access, no distribution costs, ease of use, and centralized data storage. This paper discusses implementing one such architecture for snow removal operations planning that integrates GIS, expert systems, and web technologies.

Providing speedy and cost-effective snow removal management during winter months is overwhelming for local government personnel. Considering the massive costs of snow removal operations and their importance, it is essential that snowplowing operations be planned carefully and efficiently to minimize costs and provide a quick response. However, existing methods for snowplowing planning operations are mostly handled manually. For example, resource allocation and management is done without the help of analytical tools for optimization, and routing is often done without considering the least costly snowplow. To overcome these disadvantages, researchers have developed stand-alone, PC-based systems for planning snow removal operations. While manual methods often result in non-optimal resource allocation, increased deadhead time, and inefficient routing, the stand-alone systems lack advanced mapping capabilities or decision support and are often difficult for novice computer users. Thus, most agencies involved in snowplowing do not use any substantial analytical tools or methods before planning snowplowing to reduce costs and maximize the effectiveness of snowplowing operations. Also, there is no integrated use of weather information that could alert snow removal crews and provide scenario-based decision support. Therefore, significant need exists for developing an intelligent spatial decision support system (ISDSS) and a set of analytical tools for snow removal planning operations while providing ease of use for such a system.

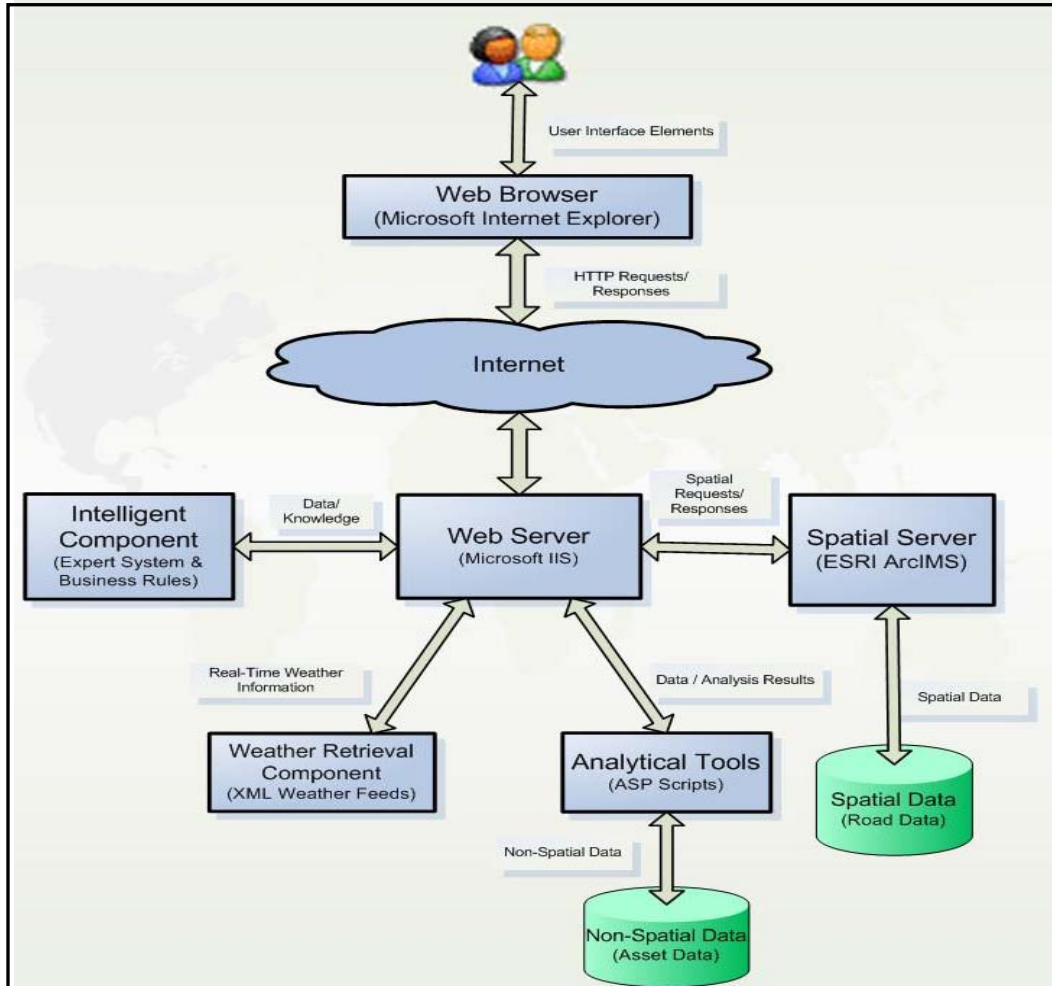
The web-based ISDSS the authors developed integrates an intelligent software component with geo-spatial and analytical techniques for providing real-time decision support for planning snow removal operations. The system achieves the objectives of providing intelligent decision support by including

expert knowledge on snow removal operations within the system. Further, the real-time weather information accessed from the internet, along with expert knowledge, helps in making real-time decisions based on different weather conditions. To provide ease of use, the user interface components, such as the toolbars, layers, and the map, were adapted to emulate the look and feel of standardized GIS software like ArcGIS. The current prototype has capabilities such as a user-friendly interface, powerful analytical tools for effective management and optimal allocation of resources (e.g., material, vehicles, and drivers), efficient routing, easy inventory management and analysis, an integrated real-time weather system, and expert knowledge. This system is capable of streamlining various tasks involved in planning snow removal operations and helps cut costs by increasing the efficiency of snow removal procedures.

The methodology for developing the ISDSS comprised the following four steps: (1) knowledge elicitation, (2) web-based GIS system design, (3) intelligent software component development, and (4) GIS and intelligent software component integration. The expert knowledge on snow removal procedures was gathered from snow removal officials for the Iowa DOT in Waterloo, IA, and street department officials in the cities of Cedar Falls and Waterloo, IA. Through a series of direct interviews, information on various standard operating procedures for snow removal was gathered. This knowledge was then embedded into the system to be referenced during spatial data analyses and decision making. Expert knowledge is crucial for arriving at an advised decision, and thus the system designed will be able to replicate human knowledge. A website was then designed containing the GIS-based road information of the study area of Black Hawk County, IA, in the form of shapefiles. These shapefiles were converted into a form suitable to be published on the web. The website also provides a way to perform various road data analyses, such as route creation and assigning material to routes. From the website, live weather data can be read and scenario-based analyses can be performed. There is also a provision for managing resources such as materials, drivers, and vehicles. In this way, the website integrates the GIS-based analytical and routing tools and weather data into a single interface, providing intelligent decision support.

The system uses ESRI ArcIMS ActiveX Connector, ArcIMS Route Server Extension, and related web technologies such as ASP, JavaScript, HTML, XML, and RSS. Figure 1 depicts the architecture that integrates the intelligent component (expert system) with spatial and non-spatial tools, providing a web-based interface. The ArcIMS ActiveX Connector was customized to provide mapping and analytical tools for snow removal tasks, such as routing, resource allocation, and inventory analysis. The ArcIMS route server extension was configured and customized to route efficiently between the snowplowing station and routes. Expert knowledge is encoded as “business rules” using Rule Machines’ Visual Rule Studio, and is integrated as a dynamic link library into the system. RSS technology using XML weather feeds was used to read live and forecast weather information. The weather information in conjunction with the expert rules provides intelligent decision support for efficient routing, optimal resource allocation, and inventory control. Important features of the system include optimized route creation to reduce deadhead time, provision of pre-defined routes used by the DOT to avoid creating routes manually, embedded real-time weather data, efficient resource management and allocation, inventory analysis, and visual feedback on routes. The sample test runs show that the system effectively plans snow removal based on live and forecast weather data, and thus can improve snowplowing efficiency and cut costs.

The intelligent software component implemented for the current system is an expert system. This expert system helps in decision making by using a set of rules and reading real-time weather data. The expert system can use the current and forecast weather data to advise decisions regarding the shortest paths, prioritized routes, and optimal resource allocation. The expert system was designed using knowledge gathered from snow removal experts in Cedar Falls and Waterloo, IA, as well as the Iowa DOT. These rules were encoded as business rules in the form of a set of conditions resulting in a set of actions. These rules were then embedded into the system. Once the system prototype was implemented, it was demonstrated to county and city officials. Their feedback was sought to improve and refine the system.



**Figure 1. Integration of expert system and web-based tools for intelligent spatial decision support**

In summary, integrating web technologies with expert systems helps provide intelligent decision support for spatial problems. This paper provides a proof-of-concept by developing an application that provides decision support for snow removal operations. This system integrates the expert knowledge on snow removal operations and web-based technologies to provide a user-friendly interface and analytical tools for snowplowing operations. Systems like these are capable of advised decision support through a web-based interface, thus facilitating ubiquitous access and ease of use. Future improvements for this research include utilizing ArcGIS Server 9.x and ArcObjects for realizing advanced analysis capabilities, utilizing individual road segment weather information, adding an intelligent software agent to manage resources and weather conditions, and providing advanced inventory analysis.

Note: This research was still in progress at the time of publication; contact the lead author above for more information.