Final Report 1998-07U

Research

Automated Route Planning and Optimizing Software

Local Road Research Board

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16. Abstract (Limit: 200 words)

This report presents the results of a study of automated route planning and optimizing software to be used by Mn/DOT Metro Division and by Hennepin County for snow plow and for snow and ice control logistical planning. The study has:

1. Produced a uniform set of specifications for the two agencies;

2. Identifyed and analyzed a large number of commercially available software simulation packages for route and logistical planning;

3. Prepared recommendations on how to proceed with the project with a detailed analysis of their advantages and shortcomings.

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Automated Route Planning and Optimizing Software

Final Report

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1 Executive Summary

Mn/DOT and Hennepin County share snow and ice removal responsibilities for common geographical areas. The main goals of this research are:

1. to identify a uniform set of specifications for the two agencies for the simulation software;
2. to survey and analyze existing software, and assess its potential usefulness for optimizing snowplow routing, minimizing duplication of travel and resources, and improving the localization of new facilities such as truck stations;
3. to make detailed recommendations on how to proceed with the project.

The study conducted has satisfied all the goals by

1. producing a uniform set of specifications for the two agencies;
2. identifying and analyzing a large number of software simulation packages for route and logistical planning;
3. preparing detailed recommendations on how to proceed with the project with a detailed analysis of advantages and shortcomings.

The technology for simulation software has made great advances in the last few years. Powerful packages are now available on personal computers, with simple and easy to use interfaces. The benefits of using simulation software for snow plow routing appear to be substantial, in terms of better use of the facilities and equipment, more sharing of work among drivers and (potentially) among the two agencies, guidance in locating truck stations and in determining levels of logistical support, and overall increased automation of the snow removal process.

A final recommendation is made to proceed with the project by acquiring an existing simulation software package, TransCAD from Caliper, that satisfies the needs of the two agencies and that is a powerful tool for a variety of other transportation applications.

2 Introduction

Background

Mn/DOT and Hennepin County share snow and ice removal responsibilities for some geographical areas. Snowplow route planning tools can optimize routing, minimize duplication of travel and resources, and improve the localization of facilities such as truck stations.

There is extensive literature on route planning algorithms [1]. Specialized algorithms have been developed to minimize travel time in time dependent networks [2, 3], or minimize distance traveled, or other criteria. The benefits of route planning have often been described [4] but have not been widely used in the contest of snowplow routing. A notable exception is the CASPER system [5, 6, 7, 8] that is used by the Indiana Department of Transportation. A few municipalities have started experimental projects, such as those reported in [9]. Arc routing [10] differs from point-to-point routing because arc routing problems require finding an efficient way to travel over a set of links and perform operations while traversing the links. Examples of arc routing problems include meter reading, mail delivery, garbage pickup, street cleaning, snow plowing, etc.

Objectives

The major purpose of this project is to prepare detailed recommendations to Mn/DOT Metro Division and Hennepin County for development or acquisition of simulation software to be used in devising optimal snow plow route plans and in determining optimal truck station locations. This requires:

1. identifying a uniform set of specifications for the simulation software;
2. surveying and analyzing existing software;
3. making recommendations with benefit/cost analysis.

Each of the objectives of the research is covered in a separate chapter of this report.

3 Development of Specifications for Simulation Software

The goal of this part of the project is to develop detailed specifications for simulation software. The specifications have been developed from interviews with the two agencies, through a questionnaire that has been distributed to the two agencies, and from discussions with the Technical Advisory Panel. The set of specifications, shown in Table 1, is uniform for the two agencies.

SHOULD Weight: 1 = Low, 2 = Medium, 3 = High importance

Item	Description	Must/ Should	Weight
	GENERAL		
1.1	Run on IBM compatible personal computers	MUST	
1.2	Output for high resolution (SVGA) color monitors	MUST	
1.3	Run under MicroSoft Windows (3.1 or later)	MUST	
1.4	Work within at least one of the following networking environments: (a) Novell, (b) IBM LAN, (c) Windows NT	MUST	
1.5	Be compatible with non-proprietary database (ANSI SQL, ODBC, and OLE 2.0 compliant)	MUST	
	MAJOR FUNCTIONALITIES		
2.1	Plan snow plow routes that minimize the time required to obtain the level of service desired	MUST	
2.2	Plan snow plow routes that optimize the use of equipment, material, and stock piles	MUST	
2.3	Assist in identifying duplication of traveled routes among agencies	MUST	
2.4	Assist in locating and sizing new truck stations	MUST	
	PROGRAM OUTPUTS		
3.1	Sequential plan of roads to be plowed, in tabular form with accurate descriptions of map nodes	MUST	
3.2	Route timing, categorized as productive and non-productive times	MUST	
3.3	Length of plow route (pass miles/lane miles/centerline miles/time)	MUST	
3.4	Inventory of equipment used and their assignments to each plow route	MUST	
3.5	Inventory of spare equipment	MUST	
3.6	Maps showing just the routes, and complete maps	MUST	
3.7	Location of stock piles	MUST	
3.8	Truck station assignments for equipment	MUST	
3.9	Points at which re-supply is necessary and supply depot to go to	MUST	
3.10	Lists of equipment sorted by criteria such as station, route etc	SHOULD	3
3.11	Equipment operator information (driver, phone number etc)	SHOULD	3
3.12	Catalog of routes that require special attention	SHOULD	1

Table 1, Part I: Specifications for simulation software

SHOULD Weight: 1 = Low, 2 = Medium, 3 = High importance

Item	Description	Must/ Should	Weight
PROGRAM INPUTS			
ROAD INFORMATION			
4.1.1	Road maps (connections, lengths)	MUST	
4.1.2	Number of passes/segment	MUST	
4.1.3	Targeted time to complete all passes	MUST	
4.1.4	Materials and application rate needed (salt/sand/chem)	MUST	
4.1.5	Priority of road	MUST	
4.1.6	Time to service	MUST	
4.1.7	Truck speed (difficulty)	MUST	
4.1.8	Bridge locations	MUST	
4.1.9	Signalized intersections	MUST	
4.1.10	Interchanges (including design type)	MUST	
4.1.11	Average daily traffic	MUST	
4.1.12	Average rush hour traffic	SHOULD	2
4.1.13	Peak traffic and times of occurrence.	SHOULD	2
4.1.14	Traffic magnets (those small areas that have high ADT counts).	SHOULD	2
4.1.15	Default equipment to be used per segment	MUST	
EQUIPMENT INFORMATION			
4.2.1	Unit type, including truck, plow, and sander type, effective plowing width, sander calibration, brine tank (pre-wetting) equipped, etc.	MUST	
4.2.2	Location of originating shops.	MUST	
MATERIALS INFORMATION			
4.3.1	Inventory of commodities.	MUST	
4.3.2	Location of supply stock piles.	MUST	
TRAINING AND SUPPORT			
5.1	Create data bases importing data from Mn/DOT's base map in ARC/INFO	MUST	
5.2	Supply the same basic package to both agencies	MUST	
5.3	Customize and update the software	MUST	
5.4	Provide on site training	MUST	
5.5	Provide a training schedule indicating duration, scope, and expected computer proficiency level	MUST	
5.6	Provide training and support for customizations and updates	MUST	
5.7	Provide on site support during installation	MUST	
5.8	Provide telephone support at all other times	MUST	
5.9	Allow for multiple licensing agreements (including individual and site licenses)	MUST	

Table 1, Part II: Specifications for simulation software

4 Survey and Analysis of Existing Simulation Software for Snow Plow Routing, and Snow and Ice Control Logistical Planning

The goal of this part of the research project is to prepare a survey and analysis of existing software for snow plow routing and logistical planning. We have identified three companies (Graphic Data Systems, PSR Group, and Caliper) that have simulation software packages that meet many of the specification requirements, we have invited them to give a demonstration of their products, and we have then analyzed their products in detail. Other companies have been contacted but their products did not satisfy enough of the requirements, and so were not considered appropriate.

The results of our analysis are reported and summarized in Table 2. Table 2 indicates what requirements the three simulation software packages satisfy and compares their cost. The products are listed in the order in which the companies were invited to demonstrate their products.

4.1 gdsICE from Graphic Data Systems

Graphic Data Systems (GDS)
Convergent Group
6200 S. Syracuse Way, Suite 250
Englewood, CO 80111
Phone: (303) 741-8561
Fax: (303) 741-8578
E-mail: tucker@gdscorp.com

The product from this company that we have analyzed is called gdsICE. gdsICE has been developed under contract from the Indiana DoT, as an improvement of the original CASPER system that was developed by Purdue University under contract from Indian DoT. At this point, it is not completely clear who owns the rights to this software product, and, according to Larry Goode from Indiana DoT, negotiations are still under way.

Lawrence Miller and Jerry Fusuglio from GDS demonstrated their company software on September 16th in the EE/CSci building at the University of Minnesota. They brought an Alpha VAXstation and connected a high resolution monitor output to the CS department's overhead projection system. The presenters were not entirely familiar with their product, but they did demonstrate some of its major functionalities.

gdsICE works with gdsTransport, the main GIS engine used by GDS. While gdsICE meets many of the requirements, a major requirement that it does not meet (requirement 1.1) is that it runs on a VAX system, not an IBM compatible PC. gdsICE also does not run under any of the networking environments specified in requirement 1.4. Mr. Martin and Mr. Fusuglio stated that GDS was working on doing these things but no timetable was given.

gdsICE strives to balance routes, minimize deadhead travel and reduce the amount of time required to clear routes. All of these goals are agreeable with the requirements we have specified, but requirement 2.2 (to optimize the use of equipment, material and stock piles) is not specifically addressed. In the version used by Indiana DoT, there is only one stockpile per zone, and each route is planned assuming that re-loading is not necessary. Mr. Fusuglio stated that stockpile usage could be added to the software in a recent telephone conversation.

In subsequent telephone conversations with Mr. Martin and Mr. Fusuglio, they have stated that all the program output requirements that are not met can be added, through use of the database engine. They stated that all the input requirements that were not met in the current version of gdsICE could also be added, because the GIS engine that GDS uses can take any number of attributes, and can import data from many commercial databases (including ARC/INFO). The format used for data is based on the US Geological Survey Digital Line Graph (DLG), the database supported is Oracle.

One of the questions raised during the demo was why the optimization had to be iterated by hand; this seems to be due to the algorithm used for optimization (tabu search). The advantage of this algorithm over algorithms used in other packages is that it allows for multiobjective optimization (minimize deadhead time, minimize deviation for target service times, and maximize road class continuity).

Another question raised was whether it was possible to input constraints, such as forcing plows to work in tandem; there was no answer available at the meeting. The software assumes a single depot with multiple vehicles. The constraints used are: each arc must be serviced only as part of one route, routes must be continuous, routes should start and end at the depot, subtours are not allowed, route service times must be calculated based on whether the arc is being serviced or used to deadhead over.

Indiana DoT is actually using the software for approximatively 1/3 of the state, covering both urban and rural areas, with a prevalence of rural areas. Considering that the cost of a truck and

its operations is estimated at $144,000/year, and considering that by using the software 17 fewer trucks are needed, the savings amount to approximatively $1,500,000/year. Indiana DoT expects to be able to cover the entire state and so to increase the savings. Additional savings are expected from new algorithms being developed at Purdue that allow to reallocate road segments to counties.

A major problem with gdsICE is its cost. The cost of the gdsICE system would surely be more that $1,000,000, and less than $4,000,000, according to Mr. Martin, depending on how much "scrubbing" the data that we provide requires. He noted that the data base thus produced would be usable by other departments, and in Denver a permitting application data base was used for gdsICE. The package is mainly intended to be used by the entire state, as opposed to individual counties. The way the software is used in Indiana is on a central computer (an Alpha VAX 7000), that runs the software and provides the data for six district offices connected by dedicated 56Kbaud phone lines. Each route designer in the district uses a VAXstation 4000. The response time for farther away areas is quite slow, according to Larry Goode, mainly when large maps are displayed.

$300,000 would buy a "turnkey" package for one county/organization. This would include the software, customization, training and support. But this figure is highly dependent on GDS having a "look at the data". This look would cost $7,000-8,000 for a 4 day stay and airfare, and would involve interviews besides actually looking at the data.

$12,000 would buy one "seat", i.e. the license for gdsTransport on one workstation; no training is included. [Note that gdsTransport is not the same as gdsICE].

Cost of gdsICE (for each agency)		
6.1	Cost of a single user license	$300,000 (turnkey package for one county)
6.2	Cost of additional licenses	To be determined
6.3	Data conversion from Mn/DOT's base map	Included
6.4	On site training	Included
6.5	Additional on site support during installation	$8,000 for 4 days on site
6.6	Customization	To be determined
6.7	Annual support and maintenance	To be determined

4.2 GeoRoute Municipal from PSR Group

PSR Group

301 Moodie Drive, Suite 121

Nepean, Ontario, Canada K2H 9C4

Phone: (613) 820-6019

Fax: (613) 820-7281

PSR Group is a consulting company that is licensed by GIRO to sell the GeoRoute software. The product we are interested in, called GeoRoute Municipal, supports many of the GIS type planning operations that occur in municipalities, such as bus route, mail route, and garbage collection planning. Included is the capability to plan and optimize snowplow routes.

Paul Frigon of PSR came to the EE/CSci department on September 23rd to demonstrate their product. He brought a laptop computer (IBM compatible) and routed the output through the CS department's overhead monitor projector.

GeoRoute Municipal meets most of the major requirements, except that it doesn't run under Windows (requirement 1.2). It runs currently under OS/2, and Windows '95 is planned for future development, but no firm date is given. Oracle is supported but there is no mention of OLE compliance in any of the literature provided (requirement 1.5).

The software minimizes the time for completing the service required (requirement 2.1). Optimizing the use of equipment, material and stock piles (requirement 2.2) is not specifically addressed, but can be achieved iteratively, for instance by changing the service time to force the system to examine different routes.

Output requirements are either explicitly met (requirements 3.1 to 3.3 and 3.6 to 3.8) or their formats should be trivially customized (requirements 3.4, 3.5 and 3.10 to 3.11). Points at which re-supply is necessary and the supply depot to go to (requirement 3.9) may be added by using a refill activity, much like assigning coffee and meal breaks. Each truck would be assigned a supply depot and the duration of the loading activity would be included. The routing process would track the reduction of vehicle content, route the vehicle to the appropriate depot when it was empty, include the duration of the loading activity, and then, after refilling, reroute the vehicle back to the point where it left off.

GeoRoute's ability to import data from ARC/INFO allows it to receive all the inputs required.

There is no explicit mention that the inventories of commodities (requirement 4.3.1) can be input, and it is not clear if the traffic information (requirements 4.1.12, 4.1.13, 4.1.14) can be used in the optimization.

The cost of the package is approximatively as follows: $60,000 for a license, $10,000 for training, $2,000 for data conversion, $10,000 to $15,000 for additional implementation support, $10,000 for customization. There is a 15%/year charge for support and maintenance. Since two licenses would be needed for the two agencies, and the implementation support and data conversion will have to be done for both agencies, this will bring the total for the two agencies to approximatively $175,000.

Cost of GeoRoute Municipal (for each agency)		
6.1	Cost of a single user license	$60,000
6.2	Cost of additional licenses	$60,000 each
6.3	Data conversion from Mn/DOT's base map	$2,000
6.4	On site training	$10,000 (for the two agencies)
6.5	Additional on site support during installation	$15,000
6.6	Customization	$10,000 (for the two agencies)
6.7	Annual support and maintenance	15%

4.3 TransCAD from Caliper

Caliper Corporation
1172 Beacon Street
Newton, MA 02161
Phone: (617) 527-4700
Fax: (617) 527-5113
E-mail: webmaster@caliper.com
URL: http://www.caliper.com/default.htm

Caliper Corporation produces TransCAD for Windows, a GIS used to store display, manage, and analyze transportation data. The software was demonstrated by Graham Barrowman on October 18, 1996 in the conference room of CTS.

TransCAD supports Microsoft's Open Database Connectivity specification which can access many commercially available database management systems and spread sheet applications such as ORA-

CLE, SYBASE and INGRES. It also supports Microsoft's Object Linking and Embedding capability, allowing maps that are created and maintained by TransCAD to be linked and embedded within documents that are created by other OLE compatible applications. Included with the software is a GIS Software Development Kit (GISDK(TM)) that provides access to the full range of geographic data management and analysis functions, and supports the development of macro programs, custom user interfaces, and other extensions.

The software supports trip generation, trip distribution, traffic assignment, optimal site location, minimum cost distribution, routing with time windows, multi-vehicle routing, travel demand modeling, etc. The software comes with a large collection of data (U.S. streets with address range information for geocoding, USDOT files on highways, railroads, public transit, waterways and airports, etc). The system can also be interfaced to data collection tools including GPS.

Caliper has developed modules for arc routing problems (for applications such as garbage pickup, etc) and some modules for snow plow routes. The main features of TransCAD are its ability to do arc routing on a network of streets, solve shortest path problems, and handle time and distance optimization problems (by minimizing deadhead time or distance). TransCAD can create workload shifts and output text files with detailed directions that can be easily edited. It can also import data from GIS databases and will support as many attributes as desired for the links describing road sections. External devices such as GPS can be easily connected.

Output requirements are either already met (requirements 3.1 to 3.3 and 3.6 to 3.8) or should be trivially customized (requirements 3.4, 3.5 and 3.10 to 3.11). No explicit way is given on how to handle resupply of sand or chemicals (requirement 3.9).

TransCAD allows multiple passes of a truck on the same street, but it does not allow for multiple types of trucks (requirement 4.2.1). Truck features can be specified but the algorithms require that all vehicles from the same depot have the same capacity. Multiple depot applications can be run in a single pass (streets have to be assigned to depots in advance), shifts and truck routes can be computed easily. No explicit way is given to use traffic data (4.1.12, 4.1.13, 4.1.14).

For optimization purposes, penalties can be specified (for instance for left turns, or on specific segments, or on intersections). Penalties can also be expressed as constraints (e.g. the time to make a right turn from a secondary road into a primary road is greater that the time to make a turn from a primary to a primary road) in a natural and simple way.

TransCAD is mainly a toolkit, and can be extended by using a specially designed macro language

that is part of the package or by linking it to software written in other programming languages. This makes the package very flexible and relatively easy to customize.

The cost of the package is approximatively $10,000, with the cost decreasing with the number of packages acquired. On site training is available at $1,000/day + expenses. Some scheduled training is available in selected cities for $600 for 2 days of basic training. Additional support and customization are available from the company at a cost to be negotiated. Technical supports and upgrades for a year are included with the software, and available for subsequent years subject to a license renewal fee of $995/year.

Cost of TransCAD (for each agency)		
6.1	Cost of a single user license	$9,995
6.2	Cost of additional licenses	$8,995 (copies 2-5), $7,995 (6-15), $6,995 (16 and up)
6.3	Data conversion from Mn/DOT's base map	To be determined
6.4	On site training	$1000/day + expenses
6.5	Additional on site support during installation	To be determined
6.6	Customization	To be determined
6.7	Annual support and maintenance	$995/copy

4.4 Other products examined

Here we list other companies we have contacted that have products for snow plow route planning and optimization. None of the products listed here satisfies enough of the specification requirements, so we did not perform an in-depth analysis of their products as we did for the three companies listed above.

- Enera Inc.

  150 N. Michigan Av, Suite 1200

  Chicago, IL 60601-7594

  Phone: (312) 781-4263

  Fax: (312) 346-0683

  ENERA has developed the Winter Road Maintenance System (WRMS) to be used in Scandinavia and possibly Norway starting this year. WRMS runs in the WINDOWS environment

and has three modules: 1) a planning module (which includes the importation of road data), used to facilitate manual planning; 2) a call-out module for rapid communication to maintenance personnel and 3) a module for reporting road conditions and the status of assignments over the telephone.

ENERA demonstrated their system on August 19th at the Transportation building in St. Paul. Their GIS capability was shown to be adequate, but they had no software for snowplow route optimizing. They have expressed a keen interest in automating the planning of routes as part of this project, in support of another entity with expertise in route optimization.

- Orr Schelen Mayeron & Associates (OSM), Inc.
  300 Park Place East
  5775 Wayzata Boulevard
  Minneapolis, MN 55416
  Phone: (612) 595-5775
  Fax: (612) 595-5773

  OSM has expertise with GIS and could provide the GIS support for snow plow routing. They do not have any specific product that satisfies the requirements and do not plan on developing any product for routing. However, they have already used ARC/INFO for manual snow plowing optimization. The approach they propose is to use ARC/INFO for the GIS database, to set manually routes, and use ARC/INFO to compute deadhead time, given the desired level of service, priority, etc. as a result of optimizing routes, indications can be obtained on the location of truck stations and optimal boundaries between districts can be computed. The estimated cost of doing this for the two agencies is $20,000.

- Tech Master Group
  2210 Victory Parkway
  Cincinnati, Ohio 45206
  Phone: 1-800-332-5773

  Although this company has a product, SNOWMASTER, that appears to meet the requirements, they do not seem to be able to deliver any products at this time. It is not clear what the current state of the product is, the company does not appear interested (even after repeated phone calls they have not sent any material), and has a bad reputation among Depts

of Transportation (the Illinois DoT has informed us that they are no longer doing business with this company because of the company failure to satisfy a contract with them).

4.5 Products examined that do not meet minimum specification requirements

None of the products listed here allows for arc routing, so none of them is appropriate for snow plow routing, but we include them here for completeness.

Logistics Software

- CAPS LOGISTICS
  2700 Cumberland Parkway
  Atlanta, Georgia 30339-3321
  Phone: (770) 432-9955
  Fax: (770) 438-9630

  This is a software development firm specializing in the areas of transportation, distribution and logistics. Their flagship product, TOOLKIT, provides supply chain management (site location, customer assignment, open/close scenarios), vehicle routing and scheduling and shipment planning. No arc routing is available.

- CarteGraph Systems, Inc.
  1660 Embassy West Dr
  Dubuque, IA 52002-2245
  Phone: (319) 556-8120
  Phone: 1-800-688-3656

  Carte'Graph Systems Inc. produces software that is used mainly for pavement, signal, bridge and sign management. They have developed software for traffic management and inventory using dBase in Windows environments. Although not a true GIS solution, they plan to develop one soon that will be generic, such as Microstation or ArcView.

- Lightstone Group
  250 Old Country Road
  Mineola, NY 11501
  Phone: (516) 294-7505

Fax: (516) 294-5543

E-mail: info@lightstone.com

Lightstone Groups' Resources in Motion Management System (RIMMS) works in a Windows environment as a logistical planner. It has various functionalities to allow the user to see scheduled activity on a route, overview all activities scheduled for a route, and see the time each activity will occur. RIMMS incorporates user defined rules about conditions that need to be met to optimize logistical solutions, and can share data with other information systems. No arc routing is available.

GIS Software

- Environmental Systems Research Institute, Inc.

  380 New York St.

  Redlands, CA 92373

  Phone: (909) 793-2853

  Fax: (909) 783-5953

  E-mail: info@esri.com

  URL: http://www.esri.com

  Environmental Systems Research Institute, Inc. produces some of the most widely used GIS database tools, such as ARCVIEW, ARC/INFO, PC ARC/INFO, ArcCAD. BusinessMAP, MapObjects, SDE, etc. No logistical software is available directly from the company, but many other vendors build products using ARC/INFO.

- Geographic Designs, Inc.

  3738 Meru Lane

  Santa Barbara, CA 93105

  Phone: (805) 563-8300

  Fax: (805) 569-3084.

  Email: inquiry@geodesigns.com

  URL: http://www.geodesigns.com

  Their products are used almost exclusively for GIS file and data management, browsing, and querying GIS databases.

- GENASYS II INC

  The Genasys Building

  1501 South Lemay Avenue

  Fort Collins, CO 80524

  Phone: (970) 493-0035

  Fax: (970) 493-0966

  GENASYS has many products that deal with the display and manipulation of geographic data, but no products that perform routing or logistical analysis.

- Kositzky & Associates, Inc.

  1601 Greenbriar Pl. Ste J,

  Oklahoma City, OK 73159

  Contact: David B. Johnson

  Phone: (405) 692-1683, 1-800-893-1250

  Fax: (405) 692-1698

  E-mail: geoinfo@geowhiz.com

  URL: http://www.geowhiz.com

  Their software does point to point routing. They have expressed no interest in developing snow plow route planning packages, at this time. Note: They are looking into the fact that they and GIRO have products with the same name.

- SEI Information Technology

  Information Delivery Services

  150 North Wacker Drive, Suite 2150

  Chicago, IL 60614

  Phone: (312) 251-5120

  Fax: (312) 251-5130

  E-mail: mstearns@sei-it.com

  SEI produces EnRoute, which is a database engine that they use for in-vehicle route guidance. They also developed routing services for the World Wide Web and other online commercial services. Their focus is on accessing and managing their GIS database system, not logistical planning.

SHOULD Weight: 1 = Low, 2 = Medium, 3 = High importance

Item	Description	Must/ Should	Weight	gdsICE	GeoRoute Municipal	TransCAD
	GENERAL					
1.1	Run on IBM compatible personal computers	MUST		No	Yes	Yes
1.2	Output for high resolution (SVGA) color monitors	MUST		Yes	Yes	Yes
1.3	Run under MicroSoft Windows (3.1 or later)	MUST		No	No	Yes
1.4	Work within at least one of the following networking environments: (a) Novell, (b) IBM LAN, (c) Windows NT	MUST		No	Yes	Yes
1.5	Be compatible with non-proprietary database (ANSI SQL, ODBC, and OLE 2.0 compliant)	MUST		Yes	Yes	Yes
	MAJOR FUNCTIONALITIES					
2.1	Plan snow plow routes that minimize the time required to obtain the level of service desired	MUST		Yes	Yes	Yes
2.2	Plan snow plow routes that optimize use of equipment, material, and stock piles	MUST		No	Yes	Yes
2.3	Assist in identifying duplication of traveled routes among agencies	MUST		Yes	Yes	Yes
2.4	Assist in locating and sizing new truck stations	MUST		Yes	Yes	Yes
	PROGRAM OUTPUTS					
3.1	Sequential plan of roads to be plowed, in tabular form with accurate descriptions of map nodes	MUST		Yes	Yes	Yes
3.2	Route timing, categorized as productive and non-productive times	MUST		Yes	Yes	Yes
3.3	Length of plow route (pass miles/lane miles/centerline miles/time)	MUST		Yes	Yes	Yes
3.4	Inventory of equipment used and their assignments to each plow route	MUST		No	Yes	Yes
3.5	Inventory of spare equipment	MUST		No	Yes	Yes
3.6	Maps showing just the routes, and complete maps	MUST		Yes	Yes	Yes
3.7	Location of stock piles	MUST		No	Yes	Yes
3.8	Truck station assignments for equipment	MUST		No	Yes	Yes
3.9	Points at which re-supply is necessary and supply depot to go to	MUST		No	Yes	No
3.10	Lists of equipment sorted by criteria such as station, route etc	SHOULD	3	Yes	Yes	Yes
3.11	Equipment operator information (driver, phone number etc)	SHOULD	3	Yes	Yes	Yes
3.12	Catalog of routes that require special attention	SHOULD	1	No	No	No

Table 2, Part I: Specifications for software and analysis of software packages

SHOULD Weight: 1 = Low, 2 = Medium, 3 = High importance

Item	Description	Must/ Should	Weight	gdsICE	GeoRoute Municipal	TransCAD
PROGRAM INPUTS						
ROAD INFORMATION						
4.1.1	Road maps (connections, lengths)	MUST		Yes	Yes	Yes
4.1.2	Number of passes/segment	MUST		No	Yes	Yes
4.1.3	Targeted time to complete all passes	MUST		Yes	Yes	Yes
4.1.4	Materials and application rate needed (salt/sand/chem)	MUST		Yes	Yes	Yes
4.1.5	Priority of road	MUST		Yes	Yes	Yes
4.1.6	Time to service	MUST		Yes	Yes	Yes
4.1.7	Truck speed (difficulty)	MUST		Yes	Yes	Yes
4.1.8	Bridge locations	MUST		Yes	Yes	Yes
4.1.9	Signalized intersections	MUST		Yes	Yes	Yes
4.1.10	Interchanges (including design type)	MUST		Yes	Yes	Yes
4.1.11	Average daily traffic	MUST		Yes	Yes	Yes
4.1.12	Average rush hour traffic	SHOULD	2	No	No	No
4.1.13	Peak traffic and times of occurrence.	SHOULD	2	No	No	No
4.1.14	Traffic magnets (those small areas that have high ADT counts).	SHOULD	2	No	No	No
4.1.15	Default equipment to be used per segment	MUST		Yes	Yes	Yes
EQUIPMENT INFORMATION						
4.2.1	Unit type, including truck, plow, and sander type, effective plowing width, sander calibration, brine tank (pre-wetting) equipped, etc.	MUST		Yes	Yes	No
4.2.2	Location of originating shops.	MUST		Yes	Yes	Yes
MATERIALS INFORMATION						
4.3.1	Inventory of commodities.	MUST		No	Yes	Yes
4.3.2	Location of supply stock piles.	MUST		Yes	Yes	Yes
TRAINING AND SUPPORT						
5.1	Create data bases importing data from Mn/DOT's base map in ARC/INFO	MUST		Yes	Yes	Yes
5.2	Supply the same basic package to both agencies	MUST		Yes	Yes	Yes
5.3	Customize and update the software	MUST		Yes	Yes	Yes
5.4	Provide on site training	MUST		Yes	Yes	Yes
5.5	Provide a training schedule indicating duration, scope, and expected computer proficiency level	MUST		Yes	Yes	Yes
5.6	Provide training and support for customizations and updates	MUST		Yes	Yes	Yes
5.7	Provide on site support during installation	MUST		Yes	Yes	Yes
5.8	Provide telephone support at all other times	MUST		Yes	Yes	Yes
5.9	Allow for multiple licensing agreements (including individual and site licenses)	MUST		Yes	Yes	Yes

Table 2, Part II: Specifications for software and analysis of software packages

Item	Description	gdsICE	GeoRoute Municipal	TransCAD
COST COMPARISON				
6.1	Cost of a single user license	$300,000 (turnkey package for one county)	$60,000	$9,995
6.2	Cost of additional licenses	To be determined	$60,000 each	$8,995 (copies 2-5), $7,995 (6-15), $6,995(16 and up)
6.3	Data conversion from Mn/DOT's base map	Included	$2,000	To be determined
6.4	On site training	Included	$10,000	$1000/day + expenses
6.5	Additional on site support during installation	$8,000 for 4 days on site	$15,000	To be determined
6.6	Customization	To be determined	$10,000	To be determined
6.7	Annual support and maintenance	To be determined	15%	$995/copy

Table 2, Part III: Specifications for software and analysis of software packages

5 Recommendations for how to Proceed for the Next Phase of the Project

The goal of this part of the research is to provide detailed recommendations on how to proceed with the project, using the specification requirements obtained in the first phase of the project, and the results of our analysis of existing simulation software systems obtained in the second phase of the project.

We analyze here a number of options, indicate for each of them advantages and shortcomings, and make our recommendations accordingly.

Before examining the alternatives we have analyzed, we have to keep in mind that none of the existing packages satisfies in full the specification requirements, as shown in Table 2. However, the three software simulation packages we have examined in detail (gdsICE from GDS, GeoRoute Municipal from PSR, and TransCAD from Caliper) satisfy most of the requirements, and so are all considered in our recommendations.

The software package that satisfies almost all the requirements is TransCAD. The major missing requirement is that it does not allow for multiple types of trucks (requirement 4.2.1). However, as explained in detail later, the company is willing and interested in providing customization to satisfy the missing requirements. GeoRoute Municipal also satisfies most of the requirements. The major missing requirement is that is runs under OS/2 instead of Windows (requirement 1.3). gdsICE does not satisfy some very important requirements, such as running on a personal computer (requirement 1.1). Other major missing requirements are the fact it does not allow to specify the number of passes/segment (requirement 4.1.2), assumes a signle stock-pile (requirement 3.7) and a single truck station (requirement 3.8).

Both GeoRoute Municipal and gdsICE are substantially more expensive than TransCAD, as shown in Part III of the Table 2, but do not offer significant additional functionalities.

The options analyzed and our recommendations are:

1. Option Recommended: buy TransCAD;
2. Options Not Recommended:
   (a) buy GeoRoute Municipal;
   (b) buy gdsICE;

(c) use consultants to analyze snow plow routes instead of buying a simulation software package;

(d) discontinue the project.

These options cover the whole spectrum of choices available, and this provides a strong basis for our recommendations. Considering advantages and shortcoming of all the options examined, we recommend to buy TransCAD, as explained in detail later, and we reject all the others options.

5.1 Option Recommended: buy TransCAD

The software package that maximizes the number of requirements satisfied while minimizing the cost is TransCAD from Caliper. Even though TransCAD does not satisfy all the requirements, a conversation with a company representative has indicated that it is possible to customize the package to achieve the missing requirements. The company is willing to do the customization.

The general requirements and major functionalities are all satisfied. Optimizing the use of equipment, material and stock piles (requirement 2.2) is not specifically addressed, but can be achieved iteratively by running multiple scenarios with different conditions.

Output requirements are either already met (requirements 3.1 to 3.3 and 3.6 to 3.8) or should be trivially customized (requirements 3.4, 3.5 and 3.10 to 3.11). No explicit way is given on how to handle resupply of sand or chemicals (requirement 3.9), but discussion with a company representative has indicated that adding this requirement should be relatively simple.

All the input requirements are met for road and material information. The major unsatisfied requirement is the fact that TransCAD does not allow to use multiple types of trucks from the same depot. Discussion with a company representative has indicated that this requirement could be satisfied with additional customization of the software package. The traffic information requirements (these are only SHOULD and not MUST) are not met by any of the packages examined.

The training and support requirements are all met.

Major Advantages:

- TransCAD has been designed from the beginning for personal computers,
- it is an open system that can be easily integrated with other software (either by passing data through files and databases, or by writing customized software) and expanded,

- it supports a large variety of data formats and so can be used with available data,
- it handles almost all the requirements from the specifications (as explained earlier in more detail),
- it includes methods for finding optimal location of facilities (could be used to locate truck depots),
- it has an intuitive and easy to use user interface,
- it provides an impressive collection of basic tools and facilities that can be used for many other applications that require GIS,
- the product has been used by other municipalities for applications that require arc routing (even though not for snow plow routing). For instance, the city of Austin, Texas has completed a pilot project for routing solid waste collection vehicles,
- the cost of the software package is limited, compared to any other package with similar functionalities. Two licenses will cost $18,990 and cost of additional copies is decreasing. Caliper offers a turnkey software license (that includes one copy of TransCAD, data base preparation and conversion, on-site installation, and one day of training) for $19,995,
- the time needed for installing TransCAD and using it effectively is short, considering its easy to use interface, comprehensive documentation, and ease of importing data files,
- external devices, such as GPS units, can be connected and integrated with the routing software.

Major Shortcomings:

- it allows for only one type of truck from each depot,
- the optimization is limited to optimize the time needed to deliver the desired level of service. No direct method is given to optimize factors such as use of equipment, material, and stock piles (even though this could be obtained indirectly by running multiple simulations with different conditions),
- it does not allow for automatic reallocation of routes among different depots (when routing from multiple depots, the roads have to be assigned to each depot in advance of running the optimization)

Considering that the advantages greatly outweigh the shortcomings, and that the company that produces the software is willing to negotiate customization of the product to satisfy the missing requirements, this is the only option we recommend.

The TransCAD package is flexible, powerful, easy to use, reasonably priced, and we expect multiple additional uses of it by the two agencies for other applications. There is also a great potential for use of TransCAD from other agencies and municipalities in the state of Minnesota.

5.2 Options Not Recommended

(a) Buy GeoRoute Municipal

GeoRoute Municipal is perhaps the most complete product available for snow plow routing, but lacks some of the general capabilities available in TransCAD, it is not as flexible and open, and has a much higher price.

GeoRoute Municipal meets most of the general requirements, except that it doesn't run under Windows (requirement 1.2). It runs currently under OS/2, and Windows '95 is planned for future development, but no firm date is given. Oracle is supported but there is no mention of OLE compliance in any of the literature provided (requirement 1.5).

The software satisfies the requirement of minimizing the time for completing the service required (requirement 2.1). Optimizing the use of equipment, material and stock piles (requirement 2.2) is not specifically addressed, but can be achieved iteratively by running multiple simulation scenarios.

All program input and output requirements are satisfied, and so are the training and support requirements.

Major Advantages:

- the amount of customization needed is limited,
- the software could be operational in a short period of time,
- the product has already been used by other municipalities for applications that include snow plow routing, for instance, in the city of Ottawa (Ontario), the Regional municipality of Ottawa Carleton, and the city of LaSalle (Quebec),

- PSR is willing to discuss forms of lease, forms of payments prorated on the expected savings, etc.

Major Shortcomings:

- the price to be paid for the software is steep, and it remains to see if the cost of the software is justified by the expected savings produced by an improved use of the equipment and the facilities. The estimated cost of this option (provided by PSR) is approximatively $175,000 for the two agencies.

All things considered we do not recommend this option. There is no clear technical advantage in GeoRoute Municipal over TransCAD, and its cost is significantly higher.

(b) Buy gdsICE

gdsICE has been developed as an improvement of the original CASPER system developed for the Indiana DoT by Purdue University. At this point, it is not completely clear who owns the rights to this software product.

The major general requirement that gdsICE does not meet is that it runs on a VAX system, not an IBM compatible PC (requirements 1.1 and 1.3). gdsICE also does not run under any of the networking environments specified (requirement 1.4).

All the major functionalities are met except that requirement 2.2 (to optimize the use of equipment, material and stock piles) is not specifically addressed. In the version used by Indiana DoT, there is only one stockpile per zone, and each route is planned assuming that re-loading is not necessary.

The program output requirements that are not met can be added, according to a company representative, through the use of the database engine. All the input requirements that are not met in the current version of gdsICE could also be added, because the GIS engine used can take any number of attributes, and can import data from many commercial systems (including ARC/INFO). However, it is not clear if the optimization software will be capable of handling a different number of passes per segment (requirement 4.1.2).

Major Advantages:

- the product is derived from the CASPER system, a system developed by the Indiana DoT and in regular use there.

Major Shortcomings:

- gdsICE does not meet many of the requirements, as detailed earlier,
- the system is less flexible in the support of databases (the database supported is Oracle) and data formats,
- the price to be paid for the software is steep, and it remains to see if the cost of the software is justified by the expected savings produced by an improved use of the equipment and the facilities. The estimated cost of this option (provided by GDS) is approximatively $300,000 for each agency,
- who owns the legal rights to the software is not completely clear right now, and apparently, some negotiations are still under way with the Indiana DoT.

Considering the numerous and serious shortcomings, we do not recommend this option.

(c) Use consultants to analyze snow plow routes

This option calls for asking a consultant to perform a manual analysis of the snow plow routing for the two agencies, for instance as proposed by OSM.

Major Advantages:

- the estimated cost is approximatively $20,000 for the two agencies,
- there is no long term commitment to any specific software package.

Major Shortcomings:

- this is a one shot solution, and the agencies will not have the ability to run the same analysis at different times, with different scenarios, under different conditions, etc.,
- any other agency (Mn/DoT district, Minnesota county, or municipality) interested in optimizing snow plow routes will have to go through the same process at the same expected cost, Sharing of results and transfer of technology across the different agencies will be minimal,

- the cost appears high for a one shot solution, considering that it is not clear that the savings in operational costs that would be obtained from this analysis will be sufficient to offset its cost.

Considering that the shortcomings are substantially greater than the advantages, this is an option we do not recommend.

(d) Discontinue the project

The last option we examine is to discontinue the project.

Major Advantages:

- this choice will not create any commitment to a specific product and technology. Considering that technology advances rapidly, this will allow to consider in the future more advanced and less expensive solutions, that would likely become available as technology develops,
- this is the least expensive option, no money is spent.

Major Shortcomings:

- it ignores the current advances in the computer and GIS technology that make automated snow plowing an objective within reach,
- it ignores future benefits of increased automation, future savings of equipment, opportunity to provide a better service using the same amount of resources,
- it ignores the fact that technology is expected to continue improving at a rapid pace for many years to come, and that waiting for a perfect time to adopt it would unnecessarily delay benefits that are currently within reach and affordable.

This is an option that we do not recommend. The time appears ripe for using the technology that is available today at an affordable cost. Terminating this project now that a viable simulation software package has been found will result in wasted effort.

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