Chapter XVI

Isobard's Geographic Information System Solution

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Abstract

This chapter presents a case study of Isobord[1], a Canadian manufacturer of high quality particleboard that uses straw instead of wood as the main raw material input. Isobord is facing critical operational problems that threaten its future. Gary Schmeichel, a biotechnology consultant hired by Isobord, must recommend how much straw collection equipment to purchase and what kind of information technology to acquire to help manage equipment dispatch operations. Schmeichel is exploring how geographic information systems (GIS) and relational database management systems (RDBMS) might help manage operations, but budget and time constraints and organizational inexperience seriously threaten these efforts. Decisions must be made immediately if there is to be any hope of implementing a system to manage the first year's straw harvest. Readers are challenged to put themselves in Schmeichel's shoes and prepare recommendations for Isobord.

Background

"… Like Rumplestiltskin, Isobord is spinning straw into a wealth of new opportunity!" The room erupted with applause as Gary Filmon, Premier of the Province of Manitoba, Canada, dramatically concluded his speech welcoming Isobord Enterprises Incorporated to the small town of Elie, Manitoba. The ceremonial ribbon cutting officially certified Elie as Manitoba's latest boomtown and home to the world's first large-scale strawboard production plant.

The new 215,000 square foot Isobord plant is designed to produce more than 130 million square feet of premium-quality strawboard per year. What makes the Isobord operation unique is its reliance on an annually renewable agricultural by-product, straw, as the primary raw material input. Most particleboard plants rely on wood as the primary input.

When it is completed, the Isobord facility is scheduled to process 200,000 tons of wheat straw per year to produce its high quality strawboard product. Initial runs of the product quickly earned great praise in consumer markets, due to the superior physical and mechanical properties of the straw-based board. Specifically, because Isobord uses straw fibers and non-toxic, environmentally-friendly isocyanurate resins in the manufacturing process, the final product performs better than standard wood-based particleboard in terms of water resistance, moisture swell, elasticity, internal bond, weight, density, strength, moldability, and screw retention. U.S. consumers of particleboard were so excited about Isobord's product that they agreed to purchase 75 percent of the output before the plant was even constructed!

According to Gary Gall, Isobord's president, "The beauty of the Isobord product is that it utilizes an annually renewable natural resource that was previously considered to be an agricultural by-product. By utilizing the straw we can simultaneously help to combat the negative effects of straw burning, and create a sustainable business in Manitoba." Until Isobord came along, Manitoba farmers were forced to burn straw after the harvest each fall. With the Isobord option, farmers can now sell the straw, reduce their workload, and cut down on air pollution in one fell swoop.

Setting the Stage

Isobord, a startup company headquartered in Toronto, Ontario, is in the process of developing a strawboard processing plant in the fertile Red River valley of Manitoba, a location some 2,000 kilometers away from the head office. Isobord's ability to create a sustainable operation in Manitoba is largely dependent upon the abilities of its management team. Unfortunately, while fund-raising, production and promotion have all received consistent attention by senior Isobord executives, the problem of harvesting straw has been essentially ignored. These executives seemed to believe that the straw would deliver itself to the new Isobord plant.

Feasibility studies were subsequently conducted by consultants to quantify the costs associated with collecting straw. Unfortunately, Isobord lacked an internal figure who understood both agriculture and the technical aspects required to coordinate the logistics of a massive straw harvest. Furthermore, Isobord had not yet retained any in-house information systems expertise. This lack of resources was paired with a technology-averse attitude of senior managers within Isobord, brought on by prior bad experiences with IT projects.

Case Description

Isobord's success hinges on the availability of straw. Without straw there can be no board. At full-scale production Isobord will consume 400,000 wheat straw bales per year. The quantity of straw demanded by Isobord far exceeds any previous efforts at straw collection. As such, Isobord must carefully devise strategies to undertake the collection of straw resources. If straw resources become depleted, Isobord will lose revenues of approximately $200,000 for every day that the plant is shut down.

The initial business plan was based on the assumption that if Isobord offered to buy the straw, farmers would be willing to collect and deliver it to the plant. After all, farmers typically had problems getting rid of straw after the harvest each year (with heavy crops, straw was particularly difficult to reincorporate into the rich soils of the Red River Valley). As a result, farmers often resorted to burning as the only viable straw removal alternative.

Isobord saw this as a golden opportunity: instead of burning, farmers could sell their straw. This would reduce the negative environmental/air quality effects of burning (smoke created by burning straw is particularly stressful to children and people with respiratory ailments such as emphysema or asthma). The plan was simple and logical. Isobord would help alleviate burning problems by purchasing the wheat straw from farmers.

Isobord offered farmers $30 per metric ton of straw delivered to the plant. By doing so, they placed an economic value on a material that previously enjoyed no real market. Wheat straw, which had been used in small quantities for animal bedding, could now be sold in large quantities for a guaranteed price. Isobord was certain they would receive a warm welcome from the local community: they were providing a vehicle for farmers to simultaneously dispose of their straw and to make money.

What Isobord officials failed to consider was the effort required to collect and deliver the straw. As they quickly learned from the farmers, it is far easier to put a match to straw than it is to bale, stack, and haul large loads of low value goods to a distant plant. Compared with a typical $160/acre wheat crop (assuming average yield of 40 bushels per acre and average price of $4 per bushel), Isobord's offer of $30/metric ton (effectively $30 per acre, assuming an average yield of one metric ton per acre) did not provide sufficient economic incentive to persuade farmers to collect and deliver straw bales. Farmers would need baling equipment, stacking equipment, loaders, and trucks — all different from the equipment required for harvesting and transporting grain. By the time all the work was completed, farmers claimed they would be losing money by selling straw to Isobord. The farming community quickly became disinterested in Isobord's proposals. They were not willing to act as the manpower, equipment suppliers and logistical controllers for Toronto's high rollers. Isobord's simple dream of "build it and they will come" had crumbled.

Plan A had failed: straw would not be baled and delivered directly by farmers. But the first endeavor was not a total failure. Isobord management had learned a great deal about straw collection through its interactions with the farming community. Clearly, obtaining straw would require more focused efforts.

Current Challenges/Problems Facing the Organization

If the project were to continue, Isobord would have to get very serious about straw collection. To make its business case to investors, Isobord had to demonstrate the availability, affordability and annual sustainability of the required 200,000 ton straw supply. The banks insisted that Isobord provide contracts stating that farmers would supply straw, at a stated price, for a five-year period. If Isobord could not produce proof of a guaranteed straw supply at a known price for a minimum time period, the banks would not continue to contribute money to the project. Once the straw supply was committed to Isobord by the farmer, it would have to be baled, stacked and transported to the plant. Management insisted that regardless of the chosen straw collection method, it must fit within the established budget of $30 per metric ton.

The firm encouraged a group of farmers to set up the Straw Producers Cooperative of Manitoba to help develop the straw supply base. The Co-op was made up of a board of ten directors, each of who was responsible for promoting the Isobord project to a district in southern Manitoba. The Co-op's chief objective was to convince farmers to sign straw supply contracts with Isobord.

Soon after the Co-op was formed, Isobord President Gary Gall decided that additional efforts should be focused on organizing the straw collection operations. Gary contacted Rudy Schmeichel, a motivated independent startup consultant from Toronto who had just completed a contract with Lifetech, a new biotechnology company. Rudy accepted the Isobord challenge and moved to Manitoba. He was met at the Winnipeg airport by Scott Griffith, Isobord's only Manitoba staff member. Scott drove Rudy to the Elie office, located on the main floor of an old three-story house that had previously been a convent. From the convent, Rudy and Scott began their crusade to organize the Straw Division.

Rudy quickly made contacts in the community. He spent considerable time in the coffee shops listening to the locals talk about the Isobord project. He began to get his bearings and soon established a place for himself in the community. From his "field research" Rudy began to devise a plan to bring straw from the field to the plant. Major operations included: (1) baling the swaths of wheat with a baling unit (i.e., a tractor pulling a baling machine that gathers loose straw into standard-sized 4'x4'x8' bales); (2) stacking the bales with a bale forwarder (i.e., a tractor that collects bales and stacks them at the edge of the field); and (3) dispatching a loader and multiple trucks to the field to pick up the bales and haul them to the plant.

Baling and Stacking Logistics

Each baling unit can process up to 36 bales per baling hour, travel (between fields) at a maximum speed of 30 kph, and will cost approximately $250,000. Each bale forwarder can process up to 90 bales per hour, travel (between fields) at a maximum speed of 90 kph, and will cost approximately $220,000. Since the capabilities of bale forwarders exceed those of baling units, it made sense to organize equipment into "baling crews" consisting of one bale forwarder and two or more baling units. Baling crews communicate with the central dispatch office using two-way VHF radios.

While the straw collection process may appear fairly simple initially, Isobord faces a number of serious constraints. First, the maximum time available for baling is estimated to be only 600 hours per season, based on expectations regarding typical planting and harvesting schedules (e.g., straw harvesting must fall within the August-October window), climatic conditions (e.g., rain or snow can make fields inaccessible, and straw cannot be collected if its moisture content exceeds 16 percent), available daylight hours, and anticipated equipment breakdowns. Rudy estimated that approximately 75 percent of the 600 available hours will be spent baling, although this could range anywhere from 90 percent to 60 percent, depending on how efficiently dispatch is able to route the baling crews.

A second constraint is that straw must be collected from a wide geographical area: approximately 6,000 targeted fields are randomly distributed over a 50-mile radius of the plant. Operators will be required to navigate an expansive network of unmarked municipal mile roads; finding an unknown field might be compared to finding a house in a city where the streets have no names — or perhaps to finding "a needle in a haystack." Furthermore, very few landmarks exist on the Manitoba prairies to help vehicle operators find their way. If operators get lost, they could waste hours of valuable baling time. Stephen Tkachyk, an Isobord baling crew chief, had experience navigating country roads at night. He stated that if you get lost at night, your best bet is to go to sleep in the truck and find your way in the morning!

Hauling Logistics

Several trucking companies were asked to provide quotes for hauling services. Because of the unique nature of this hauling job, all of them requested additional information. To provide quotations the trucking firms wanted to know the following:

- The number of loads that would be hauled from each location
- The distance to be hauled
- The location of the pick-ups
- The routes to be traveled

To accumulate the necessary information, Rudy suggested that "trip ticks," such as those offered by automobile associations, be created that defined the route from each field to the plant. Rudy needed the distance numbers as soon as possible so that the trucking companies could provide quotations, so Scott began developing handwritten trip ticks. However, with over 300 Co-op members, many of whom farmed multiple wheat fields, this process quickly became tedious. Furthermore, given the shifting nature of wheat field locations due to crop rotation, it was apparent that these "one-off" trip ticks would become outdated very quickly.

An Initial Solution

To organize routing of baling crews it was first necessary to determine where Co-op members were located. Scott purchased maps of Southern Manitoba and began marking the Co-op member locations using colored pins. Unfortunately, initial information provided by Co-op members only indicated locations of farmhouses, not wheat fields. Isobord would need to know specific wheat field locations in order to provide baling service (legal field descriptions are designated by section-township-range coordinates, e.g., field SW-12-07-02-W is on the South West quarter of section 12-07-02, West of the central meridian).

Over the next few weeks, Scott developed a system that would be easier to change as Isobord's needs changed. Using an Apple Macintosh computer and drawing software, he divided Isobord's straw collection area into a number of grid sections. Each grid section had a designated exit point, and the single best route between the grid exit point and the plant's straw storage site was identified. The best route between each particular field and the grid exit point was then determined on a field-by-field basis. The result of this exercise was a series of grid maps that included relevant roads, a section grid (i.e., one square mile sections each identified by a legal land description including section, township and range), towns, hydrography, and the locations of Co-op members' farmhouses.

A grid section reference identifier and distance-to-plant data were then added to each Co-op member's database record. The grid mapping process sped up the calculation of trucking distances, and provided a graphical reference base for all Co-op member locations. When the grid maps were complete Scott produced reports using Microsoft Access that summarized distance to be traveled, routes to be taken, and number of loads to come from each location (number of loads was determined as a function of acres under contract from each Co-op member).

When a field is ready to be baled, a Co-op member will now call Isobord's dispatch office to schedule baling. The farmer will provide his name, the number of acres to be baled, and the legal description of the field. Dispatch operators will then prioritize the calls and assign them to a specific baling crew. The baling crew will navigate to the new field using detailed grid maps. The goal of the dispatch operators will be to minimize each crew's travel time, in order to maximize productive baling time.

Isobord had minimal technology available to coordinate baling efforts. Isobord was currently only about ten employees strong, and Scott, a management student who was just starting to learn how to program, was the only employee with any knowledge of software development. Isobord's information technology architecture consisted of a PC running Microsoft Access database software, which Scott used to create prototype databases, as well as Scott's personal Macintosh computer that he used to create the digital maps. During the prototyping stage no formal systems methodology was used to guide development. Systems were developed based on theoretical concepts as to how a baling operation of Isobord's magnitude could be organized. During development the software was continually revised as new ideas surfaced. Based on the lack of in-house expertise and resources, Scott began to seek out a third party solution.

Information Technology Options

Scott saw the value of using computers to help solve Isobord's straw collection problems, and so he did further research to learn what information technologies were available to help administer dispatch operations. He learned that systems used for computerized dispatch typically utilize two technologies. The first, relational database management systems (RDBMS), are used to create the custom interface required for entering, manipulating and storing data. The other dispatch technology commonly used, geographic information systems (GIS), are used to store and manipulate digitized map data. GIS map data consist of real-world latitude and longitude coordinates, which may be input to the system using available paper map data, or via global positioning systems (GPS) receivers. When combined with RDBMS technologies, GIS can be used to attach meaningful attributes to map elements (e.g., a user could display a particular city on a map as circle, and then attach population, land area, and tax base data to the circle). The appendix contains a technical note describing GIS technology in more detail.

A RDBMS and GIS combination would allow Isobord to administer and control all information relevant to straw collection, such as:

- information pertaining to all Co-op members, including wheat field locations and summaries of accounts payable for harvested straw
- a record of all calls received requesting baling service
- activity records for all field operations
- inventory of all machinery, parts and supplies
- payroll for employees who provide baling services

The GIS component of Isobord's system would consist of two main parts: map data and analytical capabilities. To map out Co-op members' field locations and coordinate machinery, Isobord requires "quarter-section grid" data (which defines all sections of land in Manitoba by their legal description), and "road network" data (which details all provincial and municipal roads throughout Isobord's dispatch area). Other map datasets (e.g., provincial hydrography, rail lines, towns and cities) would be useful for navigation purposes. The ideal GIS would display incoming calls, color-coded to indicate priority, on a digital map of Isobord's straw collection area. Thus, dispatch operators would have a constant visual representation of current operations, and would be able to assign baling crews in such a way as to minimize travel time.

By using a true GIS, Isobord could track important information about baling operations on each farm field visually. The field would be displayed on a digital map and each field point could be tied to all the data pertaining to the field. Dispatch operators viewing a field location on a map could access data pertaining to that field, including when the farmer called to have the field baled, field size (number of acres), type of wheat straw planted on the field (spring, winter, durum), and type of combine (farm equipment) used to harvest the straw. This information would allow Isobord's dispatch operators to make decisions quickly based on current information. The power of easily accessible spatial and operational data through a GIS/RDBMS system would provide dispatch operators with the means to optimize the effectiveness of the baling fleet.

Isobord's GIS should also be capable of analyzing the shortest and/or fastest path between any two points on a map. During calculation, the GIS should take into account variables, such as the number of turns required to travel from one place to the next, the speed limit, and the road conditions for each segment of road. The user should also have options to classify roads (paved, gravel, or clay), define speed limits, or even remove a road from any route calculations (e.g., if it is unfit for travel due to flooding).

GIS Prototype

Scott believed GIS software would be perfect for managing Isobord's straw resources and maximizing baling crew efficiency. He began to develop an experimental prototype GIS application using Microsoft Access. The grid maps previously created on the Macintosh were imported into the Access database and attached to Co-op member records. For each Co-op member, the dispatcher could now click an icon to load up a map of the relevant grid section.

While the prototype system admirably demonstrated the benefits of using a GIS, its functionality was limited. The map "data" were actually static and discrete graphical images, rather than dynamic GIS datasets. As a result, any change in a Co-op member's field locations required a change to the underlying graphical image. In a true GIS, digital maps would be derived from data contained in an underlying GIS dataset; any changes to the data in a true GIS dataset would automatically be reflected in the map displayed. Furthermore, the prototype did not contain analytical functionality (thus, shortest route calculations could not be performed).

By this point Scott had developed a solid understanding of how straw collection logistics could be organized in order to maximize the utilization of equipment. However, he suspected that, as a new company, Isobord's ideas about how to manage operations would evolve significantly over the first few years of operations. As a result, Scott thought that retaining in-house control over software design would enable Isobord to implement a flexible solution that could be modified as the business of straw collection evolved. Scott therefore intended to internally develop database components in Microsoft Access, and then link that data to a commercial GIS tool. This solution would allow for flexibility in database design, while providing the analytical capabilities such as route optimization and thematic mapping offered by a full-scale GIS package. By performing some of the work in-house, Isobord would be able to control costs during the prototyping stage, and easily implement changes to software and processes as the art of a massive straw harvest became a science. At this point, Isobord approached three GIS consulting firms to discuss the possibility of creating a dispatch information system.

Firm #1: International Operating Systems (IOS)

With only three employees, International Operating Systems (IOS) was a small but innovative information systems consulting firm. IOS offered to sell Isobord a package called Bentley MicroStation (www.bentley.com), a geoengineering software application with GIS capabilities. MicroStation provided basic database and mapping capabilities, and IOS was willing to further develop the analytical capabilities required by Isobord.

While Scott was impressed with IOS, he had concerns about the complexity of the MicroStation proprietary programming language and the package's limited database functionality. To create a robust and user-friendly application, the MicroStation GIS would have to be linked to an Access database. The link was theoretically possible through ODBC (Open Database Connectivity — a standard database communications protocol), but IOS had never actually linked a MicroStation application to an Access database.

IOS developed a proposal for Isobord that included development of base map data in MicroStation, and a basic link to the Access database. IOS asserted that it would need to develop the road network dataset and portions of the quarter section grid dataset. IOS would also need to create and identify river lot locations. The total development cost would be $20,000, including the MicroStation application, dataset development, an initial MicroStation-Access link, and a two-day training session on MicroStation for one Isobord staff member.

Firm #2: DataLink Mapping Technologies

Further research revealed a second small GIS consultant, DataLink Mapping Technologies (www.granite.mb.ca/datalink/). DataLink specialized in developing GIS applications using MapInfo (www.mapinfo.com), a Microsoft-endorsed application. As with the MicroStation application, MapInfo could be linked to an external database via ODBC. MapInfo's documentation explicitly indicated that it could be integrated with Microsoft Access. It was also compatible with other database products through ODBC.

As with IOS, the DataLink proposal indicated that the road network data were not yet available from the Province of Manitoba. Thus, MapInfo could provide a solid base for displaying Isobord's geographic data, but could not perform shortest route calculations. Also, while integration of MapInfo with an external Access database was theoretically possible through ODBC, DataLink had not experimented with this MapInfo feature. DataLink produced an informal quotation to supply MapInfo, complete with the quarter section data, river lots, and hydrography, for under $10,000.

Firm #3: Linnet Systems

An official at the Manitoba Land-Related Information Systems department recommended that Scott contact Linnet Systems (www.linnet.ca), a data warehousing, surveying and systems development firm. After discussing the situation with Isobord, Linnet put together a detailed proposal that included acquisition of hardware, software, datasets, and all required development and training to provide a "complete business solution." Scott was surprised to learn that both DataLink and IOS would be purchasing all or part of their GIS datasets from Linnet.

Linnet wanted to aid in the development of an administration system to help Isobord monitor and control their operations. Linnet had already developed an extensive production management system for Louisiana Pacific, an oriented strand board (OSB) plan in northern Manitoba, to help monitor all aspects of its operations (e.g., resource planning, plant scheduling, hauling, paying invoices, tracking materials usage), and was eager to apply this knowledge to Isobord.

Linnet's proposal to Isobord was presented in standard systems development life cycle format. It included requirements and design, prototyping, application development, implementation, training, testing, and troubleshooting. The total price tag before taxes was $295,000. Throughout the quoting process, Linnet representatives repeatedly stressed that they only build systems that provide benefits to the client.

Scott further questioned Linnet about the possibility of using global positioning system (GPS) technology to monitor the movements of Isobord's baling fleet in real time. With GPS, Isobord could continuously monitor all of the equipment in the field; equipment operators would never get lost because the dispatch operators would always know their exact location. The GPS system would require a base receiving station equipped with a base-station monitoring device to relay all incoming GPS coordinates to a computer terminal. GPS units would cost approximately $2,200 per unit, plus $40,000 for a base station at the plant.

Linnet planned to develop the entire application using Power Builder to create the user interface and Oracle as the back end database. The GIS functionality would be developed within ArcView. All of Isobord's data would be stored in the Oracle database and accessed by both the Power Builder App and the ArcView App through ODBC. Linnet touted the benefits of Oracle and PowerBuilder as scaleable platforms capable of running systems throughout an enterprise. Their staff consisted of over 65 employees including several professional developers who consistently used Oracle/PowerBuilder and ArcView to provide solutions for clients.

Overall Evaluation of Technical Alternatives

Regardless of the solution chosen, Isobord would have to create a formal plan for the information system. The process of designing the structure of the database would be controlled largely by Isobord employees — and its success would hinge on their ability to communicate the system requirements to the chosen vendor. Through prototyping Isobord had created a working entity-relationship diagram for the project and had also documented the overall process flow for operations. At this point Scott and Rudy were the only individuals within Isobord who understood the intricacies of baling, stacking and hauling logistics. Unfortunately their knowledge was based on theory rather than experience. At this point they would have to invent the process and the supporting technology in parallel to complete an information system in time for the first straw harvest.

Time was required following initial development to test the system by simulating the conditions during a straw harvest. By populating the system with farm location data, and then running a series of test queries, Scott and Rudy hoped to verify that the functionality of the software met operational requirements. Typically farmers could provide a legal description of their land. The description would adequately identify field locations for about 75 percent of the Co-op members. For the other 25 percent of field locations, Isobord's dispatch office would require a paper map to ensure that the fields could be properly digitized and added to the GIS.

As a final provision, users would need to be trained in the operation of the dispatch information system. The software would have to be intuitive and user friendly if it was to be successful. This demanded that the software and hardware solutions had to be both stable, and not overly complex. Scott had heard mixed reviews about Microsoft Access. Professional developers he spoke with frequently said "it's a great place to start, but it has its limitations. It's not good for multi user systems beyond 10 clients or so, and it has a slow database engine so you need to watch your table size…" Beyond Access, the other technologies suggested by technical consulting firms were foreign to Scott. It was clear that new IT skills would have to be developed rapidly regardless of the solution chosen.

The Decision

Certain Isobord executives had become so enthused about the prototype system that they wanted to go ahead and use it for the first year. Other key players believed that it would be preferable to do things manually first, before investing in any information technology. Scott recommended implementing a real GIS system on a smaller scale during the pilot testing phase, when straw harvested would be used mainly as buffer inventory (i.e., a "backup" supply of straw that would help to prevent a stock out situation), so that the bugs could be identified and fixed before straw collection became mission-critical.

Budget constraints made the acquisition of expensive software problematic. The original budget had been prepared with the understanding that farmers would bale and deliver straw themselves. With Isobord undertaking straw collection operations, the realities had changed considerably. It was difficult to finance a software project that was not even anticipated during initial budgeting.

As Rudy paced back and forth through the upstairs chapel in the convent, he needed answers. He knew that equipment purchases were dependent on his ability to coordinate the logistics of straw collection, but how could he quantify this decision? How many baling and forwarding units should be purchased? How should dispatch operations be managed? What information technology solution should he recommend? What was the long-term, strategic value of a GIS to Isobord? He needed to come up with an action plan now to be ready for straw collection in five short months …

References and Further Reading

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Reed, D. (1998). Mapping up customers. *Marketing Week, 21* (10), 47-50.

Pack, T. (1997). Mapping a path to success. *Database*, *20* (4), 31-35.

Web Sites:

Internet Guide to GIS. http://www.gis.com. Managed by ESRI, http://www.esri.com.

Interactive GIS demos, including JAVA and Shockwave applets, are available on the Web (e.g., http://www01.giscafe.com/technical/Demos.php; http://www.mapinfo.com/free/index.cfm)

Company Web Sites:

Isobord (www.dow.com/isobord), MapInfo (www.mapinfo.com), Linnet Systems (www.linnet.ca).

Trimble Navigation Limited. Trimble Global Positioning System (GPS) Tutorial, http://www.trimble.com/index.html.

Endnotes

[1] Isobord was acquired by Dow Bioproducts Ltd. in June 2001 (www.dow.com/bioprod). The information in this case relates to Isobord's operations prior to the acquisition by Dow.

Appendix

A Technical Note on Geographic Information Systems

Geographic information systems (GIS) allow users to integrate databases with computerized maps. By integrating maps with traditional databases, GIS software can produce visual representations of complex data. The visual aspect of GIS is its key strength. Virtually any data can be mapped to create a picture that captures the nature and extent of the relationship between the data and its geography. For example, GIS is often used by marketing organizations to plot demographic data for regions within a given city or postal code. This form of analysis allows users to create maps that display regions that fall within required demographic parameters.

GIS have been embraced by many organizations as a tool for generating competitive advantage. It is most commonly used for strategic planning, natural resource management, infrastructure management, routing and scheduling, and marketing. Telecommunications companies in particular have embraced GIS solutions. For example, Ameritech Cellular and Germany's Deutsche Telekom have exploited the power of GIS software in comparing potential site locations for new communications towers. Factors such as physical characteristics of the land, interference from other communications devices, height restrictions, weather patterns, consumer demand, and even the probability of floods, tornadoes, and other natural disasters are all analyzed by the GIS model to help define optimal locations for new towers. John Smetanka, director of R&D for On Target Mapping, knows the importance of GIS in telecommunications planning. He commented that, "When you map out all the variables, sometimes there are only one or two places a tower can be built. Maps are critical to having plans approved."

GIS are also used for information management. Deutsche Telekom is converting all paper-based drawings of their telecommunications networks into digital data. The geography of their networks is currently shown on over 5 million paper drawings and schematics. The digital versions of these documents will be integrated into a GIS data warehouse that will eventually hold three terabytes (i.e., three trillion bytes) of information. By using a GIS rather than a conventional database, Deutsche Telekom is able to record precise spatial locations for every component within their communications infrastructure. This capability makes the maintenance of drawings and physical components much easier.

The potential applications of GIS may be limited only by the imagination of its users. Proponents believe GIS will become a universal business tool. GIS applications require powerful computers that until recently were not readily available. With cheaper, faster computing power infiltrating businesses, GIS is now accessible to mainstream users.

GIS Data

Map data are stored in two different formats. Raster data are used to store images such as aerial photographs, and are extremely demanding on computer systems in terms of storage and processing requirements. Vector data are used to represent spatial lines and points, such as the highways, roads and rivers found on common paper maps, and require less much storage space and processing power.

A major challenge currently facing GIS users is the acquisition of data. GIS software provides users with the power to perform complex data analysis, but map data (raster or vector) are unfortunately not always readily available, and developing new datasets is time-consuming and expensive. Data to build a GIS dataset usually come from three sources: paper-based maps, aerial or satellite photographs, and/or global positioning system (GPS) receivers.

- **Paper Maps.** Data from maps can be input using a digitizing tablet. Digitizing a map is a painstaking process of tracing each line with a digitizing tablet, clicking to create individual points, and then joining the points to create vectors that represent the lines on the map. The quality of a GIS dataset developed from paper maps is directly dependent on the quality of the original map, the number of points used to define each line, and the skill of the digitizer operator. It is also possible to scan the original map to create a raster image, and then use computer software to automatically generate a vector image. This approach is becoming more popular, but requires significant computer processing power.
- **Photographic and Satellite Images.** In addition to simple aerial photographs, satellites can take pictures of the earth using a wide array of imaging techniques. Data collected from satellites include pictures taken within the visible light spectrum, ultraviolet light (UV), and near infrared (NIR) light. Electromagnetic energy can also be measured using satellites. GIS software can use these different forms of spatial data to generate images.
- **Global Positioning Systems.** GPS receivers use satellite positioning to derive precise coordinates for a point on the earth. GPS receivers convert signals from orbiting satellites into latitudinal/longitudinal position, velocity, and time estimates. Data from a minimum of four satellites are required for these estimates. Coordinates for any type of landmark can thus be derived and then stored for translation into map data. Data can also be transmitted in real time from the GPS receiver to a base station. By joining these point coordinate data to create vectors or lines, a map can be created that displays the precise path traveled by the GPS receiver. This technique is often used to define roads. Collecting GPS data can be time-consuming because it requires collection of information at the physical location on the ground. However, the data collected using GPS is considered better than data collected by other means, since it relies on actual coordinate data rather than data interpolated from a paper map.

The Power of GIS

Once raw map data have been acquired, attributes are attached to map points and stored in an integrated database package for later reference. As many attributes as necessary can be attached to each line or point on the map. This allows users to create complex graphical structures such as road networks, and then keep track of details such as road names, speed limits, surface types, highway classifications, street signs, and number of accidents per segment.

Once detailed data have been attached to the GIS, the user can begin to unleash its analytical capabilities. For example, one add-on GIS application called Network Analyst allows users to determine the best possible route between any two points on the road network with two simple mouse clicks (taking into account variables such as speed limit, traffic patterns, number of turns required on route — and even assigning different times for left and right turns). The capability of GIS as a routing tool has been embraced by organizations such as emergency services, taxi companies, bus companies, package delivery companies, and trucking companies. FedEx now uses a GIS to plot carrier stops to optimize carrier efficiency, and save time and money. Routing is only one example of the analytical capabilities available through GIS.

Challenges

One of the greatest challenges facing users of GIS is the lack of data standardization. Different software vendors use different file formats, and problems arise when users try to integrate datasets with varying scales to create a digital map. For example, the dataset that defines all roads within a certain area may be of 1:50,000 scale, while the bridges on these roads may be at 1:20,000. When the two datasets are layered, the bridges may not appear on the roads. In this case, many users choose to adjust the bridge data so that the bridges appear over the roads. Unfortunately, this practice degrades the quality of the bridge data, resulting in a picture that is more visually appealing, but less precise than the original. Errors are introduced each time a dataset layer is added and altered, and the reliability of the data is increasingly degraded. Scale matching is one of the most challenging aspects for GIS data developers.

GIS critics have warned of possible abuses of this technology. In the marketing arena, for example, GIS have been criticized as counter-productive. When marketers use GIS to uncover specific target or niche groups, they can introduce greater costs by trying to reach small segregated populations. Direct marketing relies largely on economies of scale to achieve penetration. Chris Greenwood, Director of a GIS consulting firm, noted that when you drill down into a market, you may end up spending the same money as a mass mailer, yet you will reach a smaller population. Greenwood believes that "The trick is to get the geographical scale to match the potential business benefit … In my experience, people try to buy better geography than the underlying business issues require."