Intelligent Bicycle Routing in the United States

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As bicycling continues to gain popularity as an alternative transportation mode, questions arise as to how transportation departments are going to promote and support bicycle use effectively within the existing infrastructure. Maps are limited; the print medium precludes them from conveying up-to-date information. What is needed is a sophisticated information system that serves a number of main functions: (a) giving bicyclists accurate information on available routes, facilities, bicycling opportunities, safety issues, and registration; (b) providing commuters with more bicycling options, such as linking bicycle use with public transit or carpools; (c) furnishing cyclists with easy-to-use information that is widely accessible and meets cyclists' unique and specific needs; (d) serving as an efficient administrative tool for inventory tracking and demand measurement to help make cost-effective bikeway improvements; (e) promoting efficient and effective bicycle transportation practices and maximizing use of the existing public transportation infrastructure; and (f) becoming an overall support tool for enhancing the quality and quantity of bicycling in the United States. Ways in which an intelligent bicycle routing expert system can play an integral support role in all of these areas are examined.

As environmental concerns and energy conservation take a front seat on many agendas across the United States, bicycling is increasingly viewed as the efficient, practical transportation alternative. Ever-expanding bikeways projects reveal a shift in attention toward the cyclist, and in some U.S. cities, bicycle mode share has reached 23 percent (*1*). In fact, bicycle use is growing at an estimated 4 percent per year. The bicycle causes no pollution, is good exercise, is inexpensive, allows riders to avoid traffic congestion, and requires little parking space—just a few reasons that the bicycle is an attractive alternative to the automobile.

Yet significant factors impede bicycle use from reaching its full potential. The lack of a legible and effective bike route system forces most bike transportation trips, nearly half of all bicycle miles traveled, to take place only on the street system that is legible: urban arterials and collectors, many of which are rated unacceptable for bicycling. Shifting these bike trips to other routes, of which the vast system of residential side streets is a primary component, is mainly a problem of increasing their legibility through effective information systems. Departments of transportation may address this problem with maps, both as a means of conveying bikeway information to consumers and as an administrative tool to priority rank roadway improvements for bicycling. But three fundamental limitations inherent in print communication seriously limit its effectiveness for bicycle transportation purposes:

1. The limitations of paper size and print size preclude maps from conveying the detailed information bicyclists need to make adequate, even safe, route decisions;
2. Roadway characteristics and motor traffic volumes change at a pace that cannot be matched by the medium; and
3. Only one set of assumptions can be reflected on a map, thus limiting its utility to one class in the broad spectrum of bicyclists.

Moreover, the high level of demand for more user-specific route information cannot be accommodated because of the intensive amount of staff time required to convey this "expert knowledge." Referring cyclists to multiple surrogate sources of this information, such as bike clubs, stores, associations, and other cyclists, is not efficient and may not provide an appropriate focus specific to that individual.

What is needed is an information system that can quickly and effectively convey route information while working as an overall support mechanism for the bike community within the existing infrastructure. It is often much easier for people to jump in their cars and drive, even short distances, rather than ride, simply because current road and highway systems are designed specifically to accommodate the automobile. Until effective support mechanisms for the bicycle are in place, bicycle use will not be able to reach its full potential.

A proposed solution is to develop an intelligent bike routing expert system. Such a system would compare specific and accurate information about available road- and bikeways and traffic volumes with the individual bicyclists' travel needs, skill levels, and preferences in order to generate and communicate on demand the most suitable route for each individual's specific needs. Because of the unique ability of this advanced technology system to reflect the intricacies of dual realities, the route generated will have high attractive power and therefore a high probability of being used.

This paper explores the potential of an intelligent bicycle routing expert system, a sophisticated information system that can serve many functions:

- Provide bicyclists accurate, up-to-date information on available routes, facilities, bicycling opportunities, safety issues, and registration;
- Offer commuters more bicycling options, such as linking bicycle use with that of public transport or carpools;

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- Give cyclists easy-to-use information that is widely accessible and meets their unique and specific needs;
- Serve as an efficient administrative tool for inventory tracking and demand measurement to help make cost-effective bikeway improvements;
- Promote efficient and effective bicycle transportation practices and maximize use of the existing public transportation infrastructure; and
- Become an overall support tool for the enhancement of the quality and quantity of bicycling in the United States.

MINNESOTA EXAMPLE

It is hard to overlook the eagerness to ride of residents of Minneapolis/St. Paul, Minnesota. An informal study revealed that on a weekday summer evening at Lake Calhoun in Minneapolis, 360 cyclists pass through a 1-mi stretch of trail per hour. During the day, 2,000 people may bike into downtown Minneapolis, and at least 10 percent of all adults bike to work at least once during the year. Aside from walking, cycling is the most popular form of outdoor recreation in the state. In fact, Minnesota adults are cyclists at nearly twice the national average; there are more people cycling the streets of Minneapolis/St. Paul in winter than in Los Angeles at any time of the year (*1*).

Significant barriers, however, limit the use of bicycles for recreational and transportation purposes throughout Minnesota. An overall lack of awareness of bicycling possibilities and support for cyclists from several fronts impedes maximum usage. For example, Minnesota has approximately 750 mi of trails and 4,600 mi of paved shoulders (*1*), yet many cyclists are unaware of the existing trails and routes available to them. Though many recreational trails are represented in maps, very little information is given to the user, other than the length of the route in miles, the surface of the route, and, in some cases, a vague degree of difficulty. This information is seldom geared to the individual cyclist, which may make him or her somewhat apprehensive about traveling out of the way to use new trails.

For example, one cyclist chooses a 31-mi ride from a 1989 Minnesota trail guide (the last issue of the publication), only to discover while cycling that more than half of the route is on a two-lane highway where 55-mph traffic is at a steady flow. This is not a pleasurable experience for the cyclist; though he is experienced and can ride comfortably with traffic, riding along with constant traffic for a considerable length of time is not what he had in mind. And for a beginner, this route could pose significant hazards.

Bicycle use for commuting is also limited. Those who wish to ride to work face a number of challenges. Everyday city routes—those that get a cyclist from home to work—are seldom represented in current maps. What is reasonably usable [76 percent of urban arterials and corridors have been rated substandard for bicycling in the Twin Cities (*1*)] is not legible, and the cyclist is forced to undergo a trial-and-error method of finding the best path to take. In addition, there is little guarantee that once the cyclist arrives at work, appropriate facilities, such as showers, lockers, even secure bicycle parking, are available. There is simply a lack of corporate awareness as to the priority required for needed improvements. For those who live too far away, bicycling to work, or even part way to work (Bike and Ride), is virtually a nonoption. The result is that even though rush-hour traffic continues to increase, a less-than-desired number of commuters turn to bicycles as the preferred transportation mode.

The bicycle also remains in direct competition with the car. The Twin Cities metro area is neatly designed for the automobile, its elaborate highway system allowing commuters "back door" travel to and from the suburbs, while at the same time creating more far-flung, car-dependent suburban land developers. With few transportation alternatives, people rely on what they know—their cars. This trickles down to other levels as well. Very few cyclists are ever ticketed for breaking bicycle laws; such laws are seldom enforced in the Twin Cities (*1*). And drivers education is just that, *drivers* education; rarely is the bicycle even mentioned in class. The result is that fewer people, motorists and cyclists alike, are aware of the laws and safety issues that directly affect cyclists.

The overall lack of support for and awareness of the widespread bicycling possibilities in Minnesota has made it a less-than-adequate environment for cyclists. In *Plan B, The Comprehensive State Bicycle Plan,* the Minnesota Department of Transportation (Mn/DOT) cites the results of an international study comparing cycling and noncycling cities worldwide. The study found that cities with higher ratios of bicycle mode share are "not notably different, in terms of weather, geography, or standards of living, from their neighboring cities in which bicycles are used much less frequently. . . . The primary factor differentiating the two sets of cities: differences in public policy and levels of government support." In its commitment to maximize the growth potential of bicycle use in the state of Minnesota, Mn/DOT has adopted this perspective: "If you build it, they will come" (*1*).

SUMMARY OF SUPPORT NEEDS

Providing more accurate and up-to-date maps for cyclists and adding facilities to the workplace is only a small portion of what is needed to solve the problems of cyclists in today's urban and rural environments. A number of factors that directly affect cyclists are unique to cyclists and demand the development of full support systems.

First, the bicycle as a vehicle mode is extremely sensitive to the most minute details, details that do not have the same impact on automobiles or pedestrians. For example, a cyclist is intuitively aware of such things as the horizontal distance in fractions of inches between the sections of a bridge deck, the "bump" created where a curb ramp meets the road (sometimes 2 in. high), drain gates, manhole covers, railroad tracks, and expansion and contracting joints. Such small details may go unnoticed by a motorist or pedestrian, but they affect a cyclist's safety and riding experience as well as the condition of the bicycle itself.

Details affecting cyclists also occur over an extremely broad spectrum of parameters, from the smoothness of the road or trail surface to factors that define the attractiveness of a route such as sun, shade, noise, visual scenery, traffic, maintenance, and personal security. Again, the details are tiny. For example, potholes, broken glass and other debris in the street, snow and ice cover in winter, and the safety of the neighborhood itself can influence maintenance and personal security. Although many of these factors are of concern to motorists and pedestrians, they determine whether or not a cyclist can even use a route.

Finally, it is essential for the success of any support system designed for cyclists that it be able to acknowledge the unique needs, capabilities, and desires of each cyclist. This means addressing different levels of skill, strength, assertiveness, and comfort—all of which make the suitability of routes highly variable. In balancing the inextricably tied factors of safety and convenience, a route that will work for one class of cyclists will not work for all cyclists. In effect, the routes must be as unique as the individuals themselves.

Effectively and efficiently serving this set of customers demands sophisticated but easy-to-use communications systems that meet the individual needs of each cyclist as well as administrative tools to inventory, manage, improve, and maintain the bikeway infrastructure. Implementing these information tools means providing cyclists with useful, highly accessible, up-to-date bicycling information on recreational trails and city routes while providing a support mechanism for adequate trail maintenance. By aggressively mining the potential of the infrastructure, creating this support for cyclists can be accomplished with existing information before major investments are required. An intelligent bicycle routing expert system can play an integral role in that "mining" process.

INTELLIGENT BICYCLE ROUTING

Many of the support functions needed to increase bicycle use can be incorporated into an intelligent bicycle routing expert system that helps cyclists find the best route to a given destination on the basis of rider profiles, road conditions, and route availability. The following sections examine the origination of the system concept, the workings of the system, the system capabilities, the ways in which these capabilities address the related factors affecting cyclists and the cycling environment, and the manner in which such a system would integrate bicycling into the rest of the transportation community.

Background

In 1990 PEAKSolutions installed an expert system for Mn/DOT called RouteBuilder. The system supports the entire process of permitting oversize and overweight vehicles, including permit and route generation, the purpose of which is to alleviate the otherwise heavy workload of permitting officials while providing an efficient, consistent approach to the permitting process. The system accounts for all varying vehicle specifications and at the same time strictly complies with state laws and regulations. It has reduced the time that it takes to issue permits from hours to minutes, and it now generates complex routes in less than 45 sec. A significant feature of the system is its built-in "maintenance tools," which provide the ability to update and change data regularly as road conditions are altered by weather, construction, and the like. The use of such tools ensures that only correct, up-to-date information is provided to the system user, thus guaranteeing accuracy in the overall permitting process.

RouteBuilder gave people at Mn/DOT and PEAKSolutions the insight to build a similar expert system geared to cyclists. The system would generate the best route for each individual cyclist on the basis of his or her capabilities, needs, and desires as well as route conditions and availability. Safety issues would be highlighted. Maintenance capabilities would be incorporated into the system to ensure that all information about bicycle routes was accurate and up to date, while providing a forum through which maintenance crews could priority rank those bicycle trails most in need of improvements. This multipurpose tool would serve cyclists and Mn/DOT officials alike. In 1991 PEAKSolutions and Mn/DOT created a "mirage," or design-level prototype, for such a system, which has become the Bike RouteBuilder System Mirage. In the form of a computer program, the mirage demonstrates proposed functionality of an intelligent bicycle routing expert system.

Structure of Program

As a personal computer-based expert system, the intelligent bicycle routing system would proactively lead the user through the program, requiring zero to little training time for the system's operation. The program would work by first helping the user define the rider's profile and preferences and then asking the user to identify the rider's planned destinations and type of route he or she is seeking. For example, the rider may be looking for a specific point-to-point route or for a recreational route within an area. Further still, the rider may prefer the fastest over the most scenic point-to-point route, as is likely the case in a commuter trip. The route would be generated on the basis of information provided by the user and available route information.

To be able to match rider profiles with adequate routes, the intelligent bicycle routing system would require (a) a knowledge base that contains the necessary information associated with those specifications and (b) the ability to maintain the context of the dialogue such that the system can draw appropriate conclusions (i.e., the most suitable route for the user).

Knowledge Base

The knowledge base for this system would contain both profile standards and routing information.

Profile Standards The profile standards could be based on the American Youth Hostel (AYH) guidelines for rating experience levels. It is a simple rating system in which A is advanced, B is intermediate, and C is novice, each level defined by the answers to a set of questions asked of the rider, such as

- Do you ride with children?
- Do you prefer shorter, more relaxed trips?
- Select the category in which most of your rides fall:
  –0 to 35 mi with frequent stops,

–20 to 75 mi/day with stops every 15 to 30 mi,
–35 to 100 mi/day at 15 to 20 mph with stops every 20 to 30 mi, or
–50 to 200 mi/day at more than 18 mph.

An intelligent bicycle routing system would ask the same questions asked in AYH guidelines to determine the rider's skill level, the first step in recognizing the uniqueness of each individual rider.

Going one step further, the system would also ask the rider his or her preferences. Some examples are as follows:

- How far and where does the rider wish to travel?
- Does the rider want to ride off-road trails only?
- Is heavy traffic a concern?
- Is the steepness of the terrain a concern?
- Does the rider prefer to ride in the sun or the shade?
- Does the rider want to use any facilities en route?

This information, along with AYH experience levels, would define each rider's profile.

One note: the rider's AYH classification could be stored in the system, thus eliminating the need to reevaluate his or her skill level with each use of the system. However, this classification could be reevaluated as desired. For example, if children were to be present for one ride and not for another, the rider's skill level could go from a C to an A, depending on all other related factors. The rider's preferences, on the other hand, would always be reviewed before the generation of each new route. This would ensure that the ever-changing needs and desires of the rider are always considered, since the purpose of each ride varies significantly.

Route Information To match rider profiles with the best routes, the system would be able to store and access descriptive details of the bicycling environment, such as traffic volumes, speed limits, pavement width, grade, and aesthetics. This elaborate routing information could be embedded in the program. Because the collection of data is a highly complex process, existing data would most likely be used in the system, to include any pertinent information related to bicycle routes that is available. For example, most bicycle route maps currently differentiate the degree of suitability associated with the routes by color coding each route and providing a key as a guide. These routes could be represented in the system and identified on the basis of their level of suitability or relative safety. Additional information could come from other maps, reports, charts, maintenance schedules, and the like.

The data used would depend on what is available in each participating state; if plans are to accommodate preferences with regard to steepness of terrain, data associated with steepness of terrain must be available. This issue is of great importance where the minute details affecting cyclists are concerned. It is not likely that applicable data exist for every curb ramp, manhole cover, drain gate, and pothole. Nor is it likely that many data address how sunny or shady a road is. One way to cope with a lack of data would be to allow for related text to be added by anyone using the system. Information could be keyed in by the user, reviewed by an authority, and, if valid, kept on line. For example, next to one portion of a route generated the text may read, "2-in. lip on curb ramp on Washington Avenue over Oak Street." This text would appear every time that portion of a route was generated, informing other users of the potential hazard or inconvenience.

Such built-in maintenance would apply to the changing road conditions due to weather and construction as well. An intelligent bicycle routing system would be most effective if its data were updated regularly, via system maintenance tools, as is done with the RouteBuilder system. A possible function of the data processing or other designated official ongoing maintenance would ensure system accuracy and dependability.

Matching Routes

As an expert system, an intelligent bicycle routing system would be able to maintain the context of each dialogue, allowing it to give the user the most appropriate route on the basis of the rider's profile and available routes best suited to meet the rider's needs. The route could be generated in either list or map form in which its start and finish points would be identified, as would be the direction to follow and the number of miles that make up each stretch of road. The user would be allowed print the route for his or her perusal.

Additional Capabilities

Safety

The vulnerability of cyclists as roadway users is reflected in startling accident rates. In Minnesota fatality rates are more than 3 times the rates for automobiles, and injury rates are more than 41 times those for automobiles; these rates grow per 100 million mi traveled (*1*). Safety information, from hand signals to helmet use, could be provided, possibly as text that offers specific safety tips or rules of the road. The information could be a note as to where a cyclist can pick up a bicycle safety handbook in that area. It could focus on actual bicycle accidents, perhaps those occurring on routes represented in that particular system, exploring possible causes and ways to avoid such incidents. Or it could be provided in some combination of these ideas. Incorporating safety issues into the system promises to increase awareness of potential hazards and safe practices with every use of the system.

Registration

Bicycle registration information could be provided either as text for the system user or as a complete function that enables the user to register the bicycle automatically, similar to the way in which permits are administered in the RouteBuilder system. Facilitating the registration process offers a potential increase in the total number of bicycles registered annually, which would improve cyclist identification, especially in the case of an accident. This would also pose an increase in revenue.

Biker's Bulletin Board

An intelligent bicycle routing system could become a central forum for cyclists, who would be able to glance at the "biker's bulletin board" for equipment for sale, upcoming bicycle tours, day trips, cycling companions, and other notes. An available keyboard would let users input information any time, giving them a new way to find people with similar interests. Social benefits aside, this bulletin board could also serve as a forum through which cyclists offer their feedback, both on the routes and the system itself—an important consideration to those looking to monitor the effectiveness of the tool and provide ongoing maintenance support for its use.

Watchdog

An underlying problem in the bicycle community is the inadequate amount of attention paid to trail and route rehabilitation. This is largely due to limited resources, but also hampering such activity is a lack of knowledge as to which trails are most in need of repair. To be able to maintain bikeways properly, the infrastructure needs certain "watchdog" capabilities that help transportation agency officials determine the order of priority of bikeways targeted for repair. When resources are limited, officials need to expend those resources first on the trails that are used the most.

Feedback on the bulletin board, in combination with data on frequency of routes used, could alert officials to specific areas in need of repair; the expert system could serve as a tracking device, keeping count of the most requested bikeways. Officials could then evaluate route conditions on the basis of whether the route in question is one of the more desirable corridors. Priority ranking to accommodate the most heavily used routes would ensure that funds are allocated to the most appropriate trails and that the most heavily used trails are kept in good condition. Furthermore, identifying these major routes could better position officials to effectively signpost bicycle "highways"—easily recognizable routes with assigned names or numbers that differentiate them from one another, the first step toward truly integrating bikeways into the overall transportation infrastructure.

Linking Intelligent Bicycle Routing and Public Transportation

An intelligent bicycle routing system is an effective means for integrating the bicycle with other modes of transportation. It is envisioned that these bicycle routing capabilities be linked to similar routing tools for public transportation and carpooling programs. Minnesota's Regional Transit Board has already taken the initiative to affix bike racks to the back of University of Minnesota buses in an effort to give students, especially commuters, the opportunity to ride in from longer distances and then turn to their bicycles for better mobility around campus.

The next phase would be to add bus routing software to bicycle routing, providing students with better information on bus services and available bikeways. This link could then occur with all Twin Cities public transport, focusing first on linking express transit stops and then on experimenting with expanded limited-stop routes, which would improve the speed performance enabled by the need for less frequent stops due to increased bicycle use.

A third transportation mode could be added to the routing tool as well: carpools. The same routing needs exist for carpooling as they do in public transit and bicycling, and incorporating all three ensures that the user is given accurate information on multiple transportation modes as well as the flexibility to choose the most suitable transportation mode to fit specific needs. This shifts attention toward the individual and his or her unique desires and capabilities, while shifting attention away from the single-passenger automobile.

Certainly a Bike Share program can be envisioned. Cyclists could create a pool through which one person whose automobile is equipped with a bike rack drives while the others in the group ride, rotating drivers as the group sees fit. This ensures cyclists who bike to work that, should the weather become less than desirable, they will not have to bicycle home. They can ride in the car. The more opportunities that exist, the more bicycle use can be encouraged.

System Access

To generate maximum use, an intelligent bicycle routing system must be usable at the novice level. Developing a system operational from a personal computer is the first step to making it as user-friendly as possible. Touch screens can be explored also, to waive any threat that a keyboard poses to the computer novice. The next step is to design the system so that it leads the user through each step in simple, nontechnical language, generating results quickly and accurately; as an expert system, it operates proactively to guide the user through the task at hand, requiring no knowledge of programming by the user. Finally, the system must be widely accessible.

There are many possibilities for locating an intelligent bicycle routing system: bike shops, tourist information and travel centers, campus unions, libraries, Chambers of Commerce, hotels and motels, shopping centers, state office buildings, and kiosks placed in key areas outdoors, such as at a park or in central downtown. The system may be available for use directly by the cyclist or by an official in charge of entering data and giving the resulting information to the caller or visitor. Outdoor kiosks are prime candidates for touch screen capabilities. Another possibility is to provide a 900 number that people could call for a small fee that puts them in touch with someone operating the system. Home computers could also be used.

PROJECT DEVELOPMENT

Initial implementation of an intelligent bicycle routing system demands that considerable attention be given to selecting target areas with the most impact and designating development phases accordingly, validating the system within a short period of time, and exploring financial opportunities. This section examines each of these areas.

Development Phases

Since the most heavily used bikeways are on or near college and university campuses, and since many students are enthusiastic about the program, initial attention ought to be focused there. (This is based on the overall student response to the Bike RouteBuilder system mirage presented at the Environmental Fairs held at the University of Minnesota–Minneapolis/St. Paul campuses April 21–22, 1992.) In Minnesota, initial target areas include University of Minnesota campuses and central areas of Minneapolis/St. Paul. The program could start with connections to and within the University of Minnesota, then expand to include other Minneapolis/St. Paul colleges and bicycle "hot spots." After that, the system could be made to include downtown Minneapolis and St. Paul, the greater Twin Cities metro area, other urban and popular tourist areas, and eventually the entire state.

PEAKSolutions, the Regional Transit Board, and RideShare (the Twin Cities carpooling organization) have been examining a slightly different approach: one that involves designing a system that integrates bike routes with University of Minnesota bus routes and carpools. This initial prototype system would use a number of preselected routes that would be embedded in the system. The purpose of this approach is (a) to allow involved parties to evaluate the potential use of the system and (b) to test the feasibility of combining mode share in everyday travel. Positive criteria would present a case for expanding the system's capabilities and area.

System Validation

A large university campus, such as the University of Minnesota, could prove to be the most effective test bed for an intelligent bicycle routing system. With so many users concentrated in one area, the potential for more feedback is greatly increased. One method of validating the system would be to select a period of time, such as 3 months, during which the system would be tested. Users would be informed of the system and asked to use it. They would then be asked to evaluate the system, perhaps on a before-and-after basis, providing feedback via the keyboard. The system would also monitor its own use, that is, the number of routes requested daily; the most requested route; the total number of users, both new and repeat; the demographics of the users; and the like. Further performance would be measured by analysis of historical and ongoing accident data, number of bicycle registrations, and other statistics that reveal any significant changes taking place. The overall effectiveness of the system, then, could be evaluated in a relatively short period.

Potential Funding Sources

The Governor's Special Commission on Bikeways stated in 1983,

> The designation of specific funding for bicycling projects and programs has been periodic, temporal, and insufficient, with a net result that planning for bicycling development is exceedingly difficult, if not impossible. Without financial commitment, such development is relegated to a low-priority status and all efforts to improve the situation are severely hampered. (*1*)

Clearly recognizable is the need for adequate funding if any kind of comprehensive overhaul of bike routes is to get under way. Grants (the Intermodal Surface Transportation Efficiency Act of 1991 has a significant amount of federal funds set aside for intelligent vehicle-highway systems and other traffic management systems) and bicycle-related taxes pose opportunities for some states, but an intelligent bicycle routing system poses funding opportunities of its own. First, making bicycle registration more accessible and easier promises to increase the number of people who actually register their bicycles, adding to total registration revenue. Next, the various location options present fee and licensing opportunities that could help pay for the system and generate further revenue from its use. Bicycle shops and hotels and motels could install the system for an initial fee and smaller future licensing payments, the value of which lies in the added service that they could provide their customers.

The system could be operational from a home computer on a low-cost, pay-per-use basis. (It is feasible that an organization that wishes to promote bicycle use and is licensed to use the system may consider allowing users to call in to its system, via modem, at no charge. This could be provided as a service for customers, posing unique financial opportunities for the licensee, i.e., drawing consumers by offering discounts for services or products to those using the system.) Additionally, kiosks could require a small user fee. Each phone call to the 900 number would be charged accordingly. So while installation of an intelligent bicycle routing system demands an initial investment, that investment promises to pay for itself through new revenue sources. Any profits can be channeled into system maintenance and route rehabilitation programs, adding further support to the bicycle community.

SUMMARY OF BENEFITS OF INTELLIGENT BICYCLE ROUTING

Effectively promoting and supporting bicycle use in urban and rural environments entails shifting from the use of current maps to a more sophisticated information and communications system; limitations of the print medium preclude maps from matching the unique and changing needs affecting the bike community. Unless these very specific needs of bicyclists are made the focal point for raising bicycling standards, improvement will be less than desired. The number of those turning to the bicycle as a practical transportation mode will not reach its potential.

An intelligent bicycle routing expert system can address these as well as other significant factors. As an expert system, this computerized program would take into account both sensitivity of detail and the diversity of bicyclists while providing a means for adequately surveying bikeways and priority ranking them for maintenance. It could also serve as a chief integration tool, tying together multiple modes of transportation. In effect, it would equip officials to promote more effective bicycle transportation practices while maximizing efficient use of the existing public transportation infrastructure. This holds the promise of economic advantage and an enhanced quality of life—the optimum result.

If you build it, they will come.

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