explicitly or implicitly addressed. One can imagine the time, cost, and accuracy concerns associated with the kind of community sampling that he intimates as appropriate.

Everett continues with the observation that our study "at best tells us what bicycle program experts think constitute the obstacles to bicycling." We would amend this to read "the most important obstacles." Then the sentence would succinctly state the objective and achievement of the study.

In response to Everett's specific numbered comments,

1. He is correct about the ranking, although a better manner in which to present Table 1 would have been to assign both objectives a ranking of 2 and list the infrastructure objective first. Since the numerical ratings are listed, the impact of such a change would have been minor. As discussed in the organization of the problem section, hierarchy terms are provided definition by subsequent terms into which they are divided. This is true for the infrastructure term.
2. Everett raised a good point, which was a subject of debate at MBA. A counterargument was that if the masses understand themselves so well, why do we have so many expert psychoanalysts? Bicycle program experts are experts because they have studied the subject. DOT did keep this source of uncertainty in mind, however, when actually using the results to develop a program. As is discussed in the last part of the section on identification of critical objectives, "given the variability among bicycle program and institutions experts' responses," specific rankings were not used in formulating the program. Rather, experts' rankings were used as indicators, and the weaknesses of the survey, as exemplified by Everett's point, were known. Thus Everett's charge that we attempted to substantiate a preconceived notion is unwarranted and inaccurate.
3. As stated above, the purpose of the paper was to profile the methodology, not to present specifics. For more information on expert participants, readers are referred to the report by Moran (1). Also in this comment, Everett inaccurately characterizes the process used. As discussed in the paper, a small group of bicycle and institutions experts formulated an assessment structure, which was then used as the basis for the workbook sent to a larger group of bicycle and institutions experts.
4. Everett's implication is that persons heavily involved in a field cannot be objective. We agree to an extent but also realize the importance of insights that are provided through experience and involvement. Thus we always recommend that panel representatives differ in background, degree of involvement, and perspective. Then results are evaluated and used and the biases of the panel and limitations of the survey are known.
5. For a discussion of the studies reviewed during the objectives identification task, please refer to the task description and the bibliography in the report by Moran (1).

In conclusion, we again thank Everett for his comment and hope that our responses cause the paper to be better understood.

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Bicycle Task Analysis: Development and Implications

MAUREEN WIRTH, ELLEN CONE, AND KATIE MORAN

Agreement as to what the critical tasks in bicycling are is essential to the development of valid bicycling educational programs. The bicycle task analysis (BTA) represents a significant first effort to describe what is involved in safe and efficient bicycle operation. In general, it follows the format of the motorcycle task analysis and the moped task analysis. A panel of 15 nationally recognized bicycling specialists reviewed the first draft of the BTA to check for inaccuracies, errors of omission, and organizational design. Following a complete revision of the first draft, the same review panel completed a criticality rating. This was a process by which specific tasks were rated in three categories: efficiency of operation, accident prevention, and accident severity. It is this criticality scoring that does the most to further one's understanding of what tasks are most important in bicycling for safe and efficient operation. The BTA provides a more reliable basis for developing a bicycling education program than that used by any existing bicycling curriculum.

A task analysis is a complete description of the behaviors, knowledge, and skills necessary for the successful completion of a particular task. Task analyses have been written for automobile, motorcycle, and moped operation, and their most common use is in the development of instructional programs. The reason for this is that a task analysis breaks a gross skill, e.g., motorcycle operation, into its component parts (such as turning left and operating alongside parked vehicles) and also sequences the behaviors into teachable segments (e.g., approaches in center of lane, observes roadway for traffic, proceeds with turn, operates at reduced speed and maintains adequate separation, and looks for indications that vehicle will enter roadway). In addition to its use in developing educational programs, a task analysis can also be used for the evaluation of educational programs, the development of educational materials, and the understanding of correct operational procedures.

The bicycle task analysis (BTA) recently completed by Mountain Bicyclists' Association (MBA) represents the first effort to systematically catalog what is involved in successful and efficient bicycle operation. The BTA is similar in format and organization to other task analyses.

The underlying philosophy used in the development of the BTA is also important, since this directly affected content. Our philosophy is based on two premises. First, we believe that the bicycle is a legitimate transportation mode that enjoys the rights and responsibilities of highway use. Second, we support the concept that competent bicyclists and motorists must share the road system and that behaviors must be developed by both groups to facilitate that sharing. We have been criticized by some for being too aggressive and by others for being too conservative. Perhaps that means we were successful in finding a middle-of-the-road approach. Also, it was decided that safety, although certainly an important element to be considered in any bicycling program, must be integrated with efficiency and comfort.

But the BTA was not done as an independent project as were previous task analyses. Instead, it was completed as the first step in the development of a comprehensive bicycling curriculum, an identification and analysis of what is involved in bicycling. Indeed, MBA is using information from the BTA in the formulation of the Comprehensive Bicyclist Education Program that was pilot-tested by using 1000 fourth, fifth, and sixth graders in several Colorado school districts (including Denver) in May 1981. An adult program had already been developed.

In our opinion, the information in the BTA provides a more reliable basis for developing a bicycling education program than that used by any existing bicycling curriculum. Rather than relying solely on common sense and intuition, we were able to obtain judgments from nationally recognized bicycling specialists as to exactly what is most critical. This judgment and the most recent accident data give a firm foundation for curriculum content.

A complete description of the methodology used in writing the BTA as well as an analysis of the results obtained from the criticality scoring and a discussion of future implications follow.

METHODOLOGY

Writing a task analysis is somewhat like writing one's personal memoirs. There are so many details in such a jumble of recollections that it is necessary first of all to establish a framework with which to organize the information.

Organizational Framework

Our organizational effort for the BTA began with a thorough review of the motorcycle task analysis (1) and the moped task analysis (2). These provided a cumulative structure that started with the most basic tasks and built to the more complex ones.

The first section of the BTA deals with basic control tasks--the fundamental bicycle-handling skills as they would be performed in an off-road environment. This section includes mounting the bicycle, balancing, pedaling, turning, stopping, and dismounting. The second section, tasks related to the roadway, describes how to negotiate the most common roadway configurations (e.g., intersections, traffic circles, curves, and downgrades) without taking surrounding traffic into account. The third section, tasks related to traffic conditions, introduces the specific tasks needed to accommodate surrounding traffic. To explain further, the basic turning maneuver is described in section 1, correct lane position for a left turn through an intersection is described in section 2, and the process of negotiating for a gap in traffic in order to make a left turn is described in section 3. The most frequently used behaviors are presented in the first three sections.

Sections 4-7 deal with the tasks related to the environment, to the operator, to passengers and packages, and to special bicycle facilities.

The key to locating a specific task is determining what situation creates the need for the behavior. For example, scanning is covered most completely in section 3 (traffic conditions), since scanning is designed to detect overtaking or cross traffic. But scanning is also referred to in sections 1 and 2 because it is an important habit to develop.

We did differ somewhat from the moped and motorcycle task analyses when we attempted to describe specific situations frequently encountered by bicyclists but not covered in one or both of the earlier works. The moped task analysis, for example, does not contain behaviors related to negotiating interchanges or traffic circles. Although there may be a general perception that bicycles do not belong in what is viewed as demanding traffic environments, it cannot be denied that the average bicyclist is very likely to encounter both traffic circles and interchanges in normal urban bicycling. We therefore modeled our treatment of these two conditions after the motorcycle task analysis. We also added a section entitled "Surveillance" to the beginning of section 3 because we believe that observing for traffic is perhaps one of the most important behaviors to be considered in a traffic context. We also added an entire section on special bicycle facilities because of their unique significance to bicycle operation and dropped a section on tasks related to the vehicle (moped or motorcycle) because of the relative simplicity of maintaining a nonmotorized vehicle as compared with a motor vehicle.

Within each of the sections we created a hierarchical structure of headings and subheadings to provide the most complete coverage of situations bicyclists encounter. Each task was assigned a number, which reflected the hierarchical level at which it occurred. For example, reducing speed is a major heading in section 1 (basic control tasks). There are three topics to be discussed under speed reduction: normal speed reduction, rapid speed reduction, and emergency speed reduction. These three subheadings were structured and numbered as follows:

16. REDUCING SPEED
16.1 Normal Speed Reduction
16.11 Prepares to Reduce Speed
16.12 Decreases Speed
16.2 Rapid Speed Reduction
16.3 Emergency Speed Reduction

The specific tasks under each subheading could then be addressed in sequence, expanding the hierarchy as appropriate.

To conserve space, information that was presented in an early section was not repeated in later sections. Instead, the appropriate task was listed and a reference provided for more-detailed information. For example, hand signals for left and right turns and speed reductions are detailed in section 1. In later sections in which a signal is required, the BTA indicates when it should be given but does not repeat how to make the signal.

Content

Once the overall structure was designed to ensure that everything could be covered under the headings and subheadings, it remained to provide the details of bicycle operation in each situation presented. Two categories of information are provided in the task analysis: behaviors and knowledge or skills. "Behaviors" refers to the actual tasks involved, for example, "insert foot into toe clips"; behaviors are listed in a column on the left-hand side of the page. The knowledge-skills section provides information needed to complete the task effectively, such as, "toe clips are used to increase pedaling efficiency," and these are written in paragraph form on the right. The knowledge-skills section also presents background information on accident data, variations in bicycle design or handling, technical specifications, and techniques for performing the behavior in question. The knowledge-skills section was also used to identify restrictions on the use of a behavior and to describe alternatives to the recommended approach; for example, novices should avoid congested traffic circles.

The content of the first draft was drawn from a variety of sources (1-8), including issues of the magazines Bicycle Forum and Bicycling. We also relied heavily on our own personal bicycling experiences and on informal observations of bicyclists. We were not able to collect formal observational data on bicycle operations because of severe time and cost limitations.

The tasks described focus on the general rules of safe operation that can be applied in most situations. Naturally, there are many differences of opinion regarding the correct way to handle a particular traffic situation. Frequently the differences of opinion reflect the various operating styles and levels of proficiency exhibited by bicyclists. Novice bicyclists will frequently opt for the course that keeps them as far removed from traffic as possible and will always yield to motorists no matter what the traffic configuration is. Very experienced bicyclists, on the other hand, will frequently operate in the midst of traffic and follow all vehicular traffic laws. Both these styles reflect the bicyclist's perception of what is safe. We were required to examine the variety of options for dealing with a specific situation and choose one that is most substantiated by the literature and corresponds most with the abilities of an average bicyclist. It also had to be consistent with the practice that the bicyclist obeys the rules of the road. For example, an in-depth analysis of data from the National Electronic Injury Surveillance System by the Consumer Product Safety Commission in 1976 revealed that loss of control is one of the leading factors in all bicycle accidents. This is supported by accident data collected by Bike-Centennial, which reveals that road-surface hazards contribute significantly to that loss of control. The rock or obstacle dodge is an effective way of avoiding a potential hazard such as a rock or a pothole without swerving into possible traffic. Although the average bicyclist may not be familiar with this maneuver, instructors for the effective-cycling course and the Missoula bicyclist training program indicate that it is not difficult for their students to learn. Therefore, it is included as a behavior for bicyclists. Not included, however, is the bicyclist behavior of jumping his or her bicycle over lateral obstructions such as expansion joints or railroad tracks. Although successfully used by experienced bicyclists, this behavior seems to be beyond the average skill level (especially since most bicyclists do not use toe clips), and there is no indication in the literature that this is the only or best approach. Therefore, we chose a more conservative method for dealing with lateral obstructions.

In those cases in which we could not determine the best way of handling a particular situation, we turned to the moped and motorcycle task analyses to determine whether there was any similarity in behaviors. In many cases we found that the tasks required for mopeds seemed to relate well to the norms for bicycle use. If anything, they reflected a more conservative approach than we were using for bicycles. (This could possibly be a result of the relative inexperience of moped users as compared with bicyclists.) The motorcycle task analysis was used infrequently because of the tremendous difference in speed capabilities between motorcycles and bicycles; however, it was used in the sections on negotiating interchanges and negotiating traffic circles because it constituted the only written documentation of how any two-wheeled vehicle should handle these situations. Adjustments were made to these references to eliminate any behaviors that were irrelevant to bicycles, such as use of acceleration lanes.

Clearly, there were many instances in which we used our best professional judgment to determine how a bicyclist should handle a particular situation. There are numerous aspects of bicycle operation that have never been considered in a formal fashion; they range from the best side of the bicycle to use for mounting to which side to use in passing a wrong-way oncoming bicyclist. It was our intent to choose a particular method, indicate the alternatives in the knowledge-skills section, and use our reviewers to identify the errors, inconsistencies, and gaps of information.

Level of Detail

A recurring problem in the preparation of the first draft was determining the appropriate level of detail. We wanted to describe behaviors in such a way that a person unfamiliar with bicycle operation would be able to understand them. Therefore, rather than say that the bicyclist "shifts gear," we stated that the bicyclist "moves gear shift lever until it clatters and then moves it further until it becomes quiet." But the problem then arises of where to limit detail. That same task could be described in several subtasks that could identify which hand should be used, how fast the lever is moved, or the sequence of shifts required to reach a particular gear. We avoided this level of detail because of two problems. First, the more detail provided, the more attention that needs to be paid to the variations in bicycle design, age of bicycle operator, and operating conditions. Not only different styles of bicycles (e.g., single speed, three speed, five speed, and ten speed), but also different manufacturers and components would have to be considered. To ignore these factors while providing highly specific detail would make the task analysis invalid. Another problem to be avoided was the differing information needs of the various audiences for the increased detail. If the detailed information needs of an engineer are met by describing the degree of lean and pounds of pressure required for a turn, the needs of educators would also have to be met through such information as the exact position for starting a turn, the frequency of a hand signal, etc. The increased volume of information would make the document unwieldy. A very pragmatic concern was also the limitations of our own information. There were many situations in which our information was sketchy at best. We tried to restrict our level of detail to that which we could firmly support with documentation or consensus of expert opinion.

We also tried to provide general rules of operation that could be applied in a variety of situations rather than describe how to handle every possible traffic condition. Therefore, we have described how to make a left turn in moderate and in fast-moving traffic, but we have not established special cases for two-lane, three-lane, and four-lane streets or for turns into driveways or alleys. Similarly, we described a recommended maintenance check, but we did not describe how to repair any of the problems that might be found. We believe that the level of detail provided is sufficient to meet the needs of our primary audience--those who want to teach and measure safe bicycling behavior--and to provide direction for those who need to conduct more-detailed analyses.

The preliminary draft was our best effort to collect all the information available and organize it into a working document. Its primary purpose was to elicit comment on the nature of information that should be included in a BTA. We then set up a two-stage review process--the first a general review and commenting procedure, the second an actual rating that used a predetermined scale of the criticality of each task to safe and efficient bicycling. Through the first stage of the review we hoped to develop a consensus concerning what should be included in each task and each section in order to produce a complete and accurate BTA. The second stage would then pinpoint which tasks were considered the most critical, so that priorities could be established for choosing the material to include in a bicycling education program. In the next section, we shall discuss reaction to the first draft.

Initial Review

The review process was a means of substantiating and refining the information collected for the first draft of the BTA. We selected 15 professionals from around the country, who have each developed expertise in at least one area of bicycling (e.g., law, accident research, planning, expert bicycling, education, traffic engineering, and technical writing) to participate on the evaluation panel. We chose each reviewer for his or her knowledge, experience, and ability to review the BTA as a technical document. A list of reviewers and their affiliations is presented below:

Bruce Burgess, executive director, Bicycle Touring Group of America;

Ken Cross, vice president, Anacapa Sciences, Santa Barbara, California;

John English, director of research, National Committee on Uniform Traffic Laws and Ordinances;

Steve Faust, planner, Urban Mass Transportation Administration, Region II;

John Fegan, research psychologist, Office of Research and Development, Federal Highway Administration (FHWA);

John Forester, cycle transportation engineer, author of Effective Cycling;

Richard Jow, contributing editor, Bicycling magazine;

Eileen Kadesh, bicycle coordinator, District of Columbia Department of Transportation;

Josh Lehman, bicycle program coordinator, Seattle, Washington, and contributing editor, Bicycling magazine;

James McKnight, president, National Public Services Research Institute, Alexandria, Virginia;

Mary Meletiou, assistant bicycle coordinator, North Carolina Department of Transportation;

Dick Rogers, chief, Office of Bicycle Facilities, California Department of Transportation;

Alex Sorton, associate director, research and development, Northwestern University Traffic Institute, Evanston, Illinois;

William C. Wilkinson, program coordinator, U.S. Department of Transportation; and

John Williams, editor, Bicycle Forum, and bicycle coordinator, Missoula, Montana.

We encountered one problem immediately in communicating to the reviewers the purpose and organization of the BTA. The idea of a comprehensive listing of tasks involved in an activity had been encountered by only a few of the reviewers; this is not surprising in that only three task analyses have ever been written for highway vehicles. The reviewers tended to think in terms of a bicycle education program. Their comments reflected the fact that they were reviewing the BTA as a curriculum or program in itself, to be used intact by teachers or students rather than as a first step in curriculum development. Their immediate reaction, therefore, was that the BTA was too long and detailed. The organization of the BTA also confused many reviewers. They could conscientiously comment that a task or series of behaviors had been omitted from a section when actually the tasks belonged, and had appeared, earlier or later.

The other major issue we dealt with was the injection of personal style and opinion into the comments. This was not a factor we wanted to avoid, since we were requesting individual perceptions of optimal bicycling behavior. The reviewers' comments merely reinforced our belief that different people have different bicycling philosophies concerning, for instance, assertiveness, bicyclists' right to the road, and types of equipment. Although there was strong agreement in such areas as helmet use, the reviewers differed widely in areas such as lane position. This also served to highlight the need for a document such as the BTA to describe the consensus.

Revision Process

We received approximately 2500 separate comments, which included a comment by several reviewers on almost every single task in the BTA. We proceeded through the analysis task by task. The tasks that received several similar comments were changed according to the consensus. We accepted the validity of the reviewers' comments and tended to go ahead and revise the tasks accordingly unless a distinct conflict appeared between reviewers or between reviewers' comments and the philosophical guidelines we had developed of viewing the bicycle as a legitimate transportation mode. In these cases, a resolution was achieved through discussion among the three authors of the BTA after having reviewed the literature available and having consulted other reviewers.

The revision process of the first draft also revealed some sections that needed reorganization. This was accomplished pursuant to specific comments generated by the reviewers. One major change in organization was made, for example, in section 22, (negotiating intersections). Whereas we had previously included an initial segment entitled "Approaching Intersections," by using the format from the motorcycle and moped task analyses, we omitted this in the revised BTA because the tasks in this and subsequent sections appeared repetitious and confusing. Instead we included them under segments on traversing an intersection, turning right, and turning left.

Another change was that in the first draft of the BTA we tended to analyze alternative behaviors and recommend one, but in the revised draft we presented the viable behavioral choices along with the knowledge relevant to each behavior; the task was then written as a choice between those behaviors. For instance, the first draft of the BTA stated in section 8, "avoids bike lanes separated by parked cars," whereas the revised edition states, "chooses whether to ride in bike lanes separated by parked cars." This change of tone was in response to the variety of our reviewers' opinions concerning the best bicycling behaviors. By stating the various problems involved in a situation and the alternatives available, we allow a bicyclist to modify his or her behavior according to a specific situation or personal consideration.

Also revealed by the review of the first draft was the need for a format that was easier to read and comprehend. We followed the format of the motorcycle task analysis by indenting, in an outline form, each subordinate task. The revised BTA constituted our final draft; the assignment of criticality scores remained as the second stage of the review process.

Criticality Procedure

The rating of bicycling tasks is essential to the development of valid priorities concerning material to be taught in a bicycling education program. Any program will be operating under time constraints from other school courses or from the busy lives of adult participants. The bicycling education programs developed to this point have selected material to teach without benefit of any specific research concerning which tasks are actually most important to bicycling. Only recently have several studies of bicycle accidents appeared (9), which give a solid background for deciding which tasks are most crucial to the prevention of commonly occurring accidents.

The criticality procedure used for the motorcycle task analysis was our main source of information. However, two issues proved unique in our situation. The first and most important was that the criticality procedure of the motorcycle task analysis was designed solely to choose the tasks that were most critical to the prevention of an accident. Although we are concerned with teaching safe bicycling, our education and bicycling philosophies dictate that safety be integrated with efficiency and comfort on a bicycle to produce optimal bicycling.

We therefore realized the need for a system with which we could ascertain the tasks that are critical to the prevention of accidents and bicycling efficiency; it will be explained in detail under the description of our criticality procedure.

Our other concern with the criticality procedure of the motorcycle task analysis was its complexity, both for the raters and for the tabulators. There were four scores to produce for each task: behavior frequency, error probability, accident likelihood, and accident severity. The four were multiplied together to form an overall indication of criticality. These factors provided the combination of the potential frequency and severity of an accident attributable to a particular behavior on a motorcycle. However, since we did not have hard observational data on behavior frequency and error probability, our reviewers would essentially have to guess the scores for these two factors. Therefore, we felt that it would be much more valid and satisfying to the raters to have them estimate one general score concerning the importance of each task to the prevention of an accident. This eased the tabulation procedure as well as eliminated the need to round off individual scores, as was done for each of the scores in the motorcycle task analysis.

In summary, the scoring procedure we developed was tailored to

1. Produce scores relevant to the information we needed in order to prioritize educational materials,
2. Fit with our philosophy that optimal bicycle riding includes safe as well as efficient riding, and
3. Be satisfying to raters who were using their experience, knowledge, and personal observational data to make judgments on scores.

The scoring procedure itself involved rating each task as to its importance to the following categories:

1. Efficiency of operation,
2. Accident prevention and avoidance, and
3. Accident severity.

The efficiency of operation category set up an ideal of efficiency, and the rater was then requested to score the correct performance of the task as to its effect in reaching or hindering that ideal. The ideal reads as follows: The efficient bicyclist should operate confidently and skillfully and be able to enjoy bicycling, which entails

1. Functioning as a normal element of the traffic flow (obeying traffic laws and rules and recognizing the bicyclists' right to the road);
2. Operating smoothly and without interruption (except by normal traffic-control devices);
3. Operating a vehicle that is a viable mode of transportation or recreation (solving problems of baggage, weather, environment, etc.);
4. Maintaining total control of the bicycle (operating the bicycle as an extension of self); and
5. Maintaining riding comfort (pedaling style, gearing skills, and riding position).

The rating scale for this category goes from -5 to +5; +5 means "very significant to reaching the ideal"; 0 means "irrelevant to reaching the ideal"; and -5 means "great hindrance to reaching the ideal."

The second category, accident prevention and avoidance, requests the raters' estimate of the chance or probability of having an accident due to the correct performance of a task. An accident is defined in the following way. A bicyclist falls off the bicycle or falls with the bicycle due to (a) collision between a bicycle and a motor vehicle, (b) collision between two bicycles, (c) collision between a bicycle and a pedestrian or an animal, (d) collision between a bicycle and a stationary object, or (e) loss of control by bicyclist.

Some tasks apply to the prevention of an accident, and some apply to the avoidance of an accident. For example, scanning is more important in accident prevention, whereas emergency stopping is more closely related to accident avoidance. However, both types of tasks were scored in this category on the same scale. The scale ranges from -5 to +5; +5 indicates that the chance of an accident is greatly reduced; 0 means that the behavior would have no effect on the chance that an accident might occur; and -5 indicates that the correct performance of the behavior greatly increases the chance of an accident.

The negative scale was included as a necessary option. Although we felt that all the behaviors in the BTA were important for both efficiency of operation and accident prevention, we wanted to allow for differences of opinion. Also, we wanted to determine what tasks, if any, might hinder efficiency but be critical in terms of accident prevention, and vice versa.

The accident severity category defines how severe an accident would be if it were to occur in conjunction with the correct performance of the task that is being scored. To increase rating consistency, the assumption was made that a helmet and bicycling gloves are worn in all cases. The scale used was that of the National Safety Council (10). The scale, approved by the American National Standards Institute (ANSI), ranges from 1 to 5:

1, no injury;

2, possible injury (injury that is reported or claimed by the victim but is not evident to observers);

3, evident injury that is not incapacitating (any injury other than one that is fatal or incapacitating and is evident to observers at the scene of the accident);

4, incapacitating injury (any injury other than a fatal one that prevents the person from walking, bicycling, driving, or normally continuing activities she or he was capable of performing before the accident;

5, fatal.

We did not request the reviewers to rate every task in the BTA; we omitted many of the basic handling skills that were described in much detail. These tasks (such as maintaining vertical balance on a bicycle, mounting, and dismounting) are so fundamental to bicycling that no other maneuvers could occur without them. We also felt that, in many cases, it was adequate to collect ratings for superordinate behavior instead of requesting ratings for each detailed subordinate task. For example, reviewers were asked to rate "prepares to change lanes," a superordinate behavior under which are included "signals intention to change lanes" and "checks roadway again before initiating lane change." But since our purpose was for the reviewers to decide which tasks were most critical, we felt that most of the tasks should be rated, both to furnish a complete data base and to avoid our biasing of the procedure.

The criticality scores were recorded on a microcomputer that calculated means and SDs for each task. A discussion of the results follows.

RESULTS

The final draft of the BTA was read by 12 of the 15 original reviewers. (Three did not participate because of personal time constraints.) Reactions were given in two forms: narrative comments from the reviewers and the actual criticality ratings.

Narrative Comments

The most obvious difference between the comments on the first and the final drafts of the BTA was quantity. The final version elicited only 200 or so comments, and almost no two comments concerned the same item. Though the primary purpose of this second review was not general response, as it had been for the first version when approximately 2500 comments were made, the reduced response seems to indicate that many of the changes made in the BTA were acceptable to the reviewers.

There were some errors pointed out. For example, we stated in the BTA that using the right arm straight out as a right-turn signal was permitted in several states, but one of our reviewers pointed out that it is a legal signal only in Minnesota. And two reviewers suggested that longitudinal (pavement) markings are considerably more complex than described in the BTA and referred us to the FHWA Manual on Uniform Traffic Control Devices.

Most opinions expressed concerned lane position. Generally, the BTA advises the bicyclist to control the lane when at an intersection, i.e., assume a center-lane position. Several reviewers took exception to this. One decried the zig-zag approach at intersections that would be required for a bicyclist riding in the right-lane position who had to move to the center and then back again to the right for making either a right turn or for traversing the intersection. One was very concerned at the prospect that right-turning vehicles would pass on the bicyclist's right, although that is exactly why we described the maneuver in this manner; i.e., if the bicyclist is going to go straight through an intersection, why should she or he be in a right-lane position that would prevent motorists and even other bicyclists from making a legal right-turn-on-red? Some took exception to the fact that we recommended that bicyclists yield the right-of-way to motorists who were obviously not cognizant of the bicyclist's rights. Several suggested that the use of diagrams might help to clarify some of these complex traffic operations.

Interestingly, one reviewer recommended a slow-and-scan approach rather than a complete stop when dealing with stop signs. Although many bicyclists, adults in particular, confess to using that approach, few have suggested teaching that method, especially to children. (Stopping at stop signs received one of the highest scores in the criticality rating for accident prevention and a fairly low score in efficiency.)

Criticality Ratings

Differing philosophies widely affected the scores given to a particular task. For example, one reviewer gave negative scores in the accident prevention category every time a bicyclist left a right-lane position, even when he or she was preparing to turn left. The same reviewer also gave negative scores to the perimeter, or two-stage, left turn. Another reviewer gave negative scores in the efficiency category every time the bicyclist was to stop. Stopping can certainly be inefficient, but the criticality instructions had indicated that the ideal of efficiency included stopping at traffic-control devices.

Throughout the following discussion on criticality scores, numbers given refer to the mean, or average score. Every behavior that received a particular score is not always discussed. This editorial judgment is exercised because we want to highlight the most worthwhile findings and because the statement "uses emergency braking technique if parked car door is opened in bicyclist's path" is so closely related to the statement "uses emergency braking technique" that the repetition seems pointless.

One of the most easily recognized groups of scores is the highest. In the efficiency category, scores of 4.5 and above were given to the tasks that describe gear selection on upgrades. Scores of 4.0-4.4 were given to tasks that detail proper pedaling and accelerating, proper body position, the importance of knowing when to shift gears, and the ability to select an appropriate lane. Other high scores (3.6-3.9) in the efficiency category were given to the following tasks:

1. Operates in a right lane in a lane-sharing position;
2. Operates in the left position of the lane when preparing to make a left turn;
3. Moves to a center-lane position when merging;
4. Does not ride facing traffic;
5. Obeys traffic-control devices on bicycle routes;
6. If oncoming vehicle is yielding, maintains speed and position;
7. Builds endurance prior to long rides; and
8. Performs regular maintenance checks.

In other words, according to our reviewers, the most critical tasks in terms of bicycling efficiency involve gearing, pedaling, maintenance, and lane positioning.

Next are the tasks that received the highest scores in the accident prevention category. (Remember, it was assumed here that all bicyclists are wearing a helmet and gloves.) Scores of 4.5 and above were given to the following:

1. Scans left, right, and left again;
2. Responds to red lights and stop signs;
3. Does not ride facing traffic;
4. Crosses intersection only when safe; and
5. Maintains an adequate stopping distance between the bicycle and a preceding vehicle on a downgrade.

Scores of 4.1-4.4 were given to the following:

1. Reduces speed in emergency;
2. Scans to rear and side before changing lane position;
3. Scans surroundings on and off the roadway continuously, shifting gaze frequently;
4. Continuously scans roadway ahead and to the sides;
5. Scans behind prior to any lane changes;
6. Signals left turns;
7. Maintains safe speed on downgrades;
8. Observes road surface more closely on downgrades;
9. If a passing vehicle attempts to return to the lane prematurely, slows quickly, moves to the right, and leaves the roadway if necessary;
10. Yields the right-of-way to cross traffic when required;
11. Even if cross traffic should yield, yields if necessary;
12. Reduces speed if necessary to avoid conflict with a left-turning vehicle;
13. Makes independent judgments when riding with a group;
14. Determines whether gap between oncoming vehicles is sufficient for a left turn; and
15. Uses a headlight and taillight if riding at night or on dark roads.

In summary, our experts are telling us that the most critical tasks in terms of accident prevention are scanning, stopping at stop signs and red lights, riding with the traffic, being able to stop quickly without losing control of the bicycle, knowing which lane to be in, using lights at night, and yielding when necessary to avoid conflicts (defensive driving strategies).

The reviewers have clearly indicated the most critical tasks in terms of both efficiency of operation and accident prevention. Of interest is an examination of the differences between the two and of whether there were times when accident prevention scores were higher than those for efficiency. This was found to be so. Tasks that received a score of 2.5-2.9 higher in accident prevention than in efficiency include "responds to red light," "responds to flashing red light or stop sign," and, "leaves roadway if necessary if vehicle pulls in front of bicyclist." Other tasks that were rated 1.5-2.4 higher in accident prevention than in efficiency are "uses hand signal for normal speed reduction," "reduces speed rapidly," "reduces speed normally," "responds to yellow light, flashing yellow light, and yield sign," "signals left turn," "makes a perimeter (two-stage) left turn," and "selects an alternate route or avoids riding in conditions of limited visibility."

The accident severity category proved difficult because accident severity is a function not only of bicyclist behavior but also of environmental conditions, motor vehicle speed, etc. But in general, the highest accident severity scores tend to parallel the highest accident prevention scores. Also, there were several unique factors in this category that affected the average score. First, several reviewers gave a range for a score; i.e., 3-5 rather than one particular score. And second, if a reviewer recorded a zero for accident prevention, accident severity was automatically recorded as a blank; this meant that often the accident severity score was an average of fewer than 12 scores.

The SD revealed some interesting findings. Remember that the efficiency of operation and accident prevention categories could be rated from +5 to -5 (although very few minus scores were recorded), whereas the accident severity category was scored from +1 to +5. This difference in the range of scores would create the appearance of more reviewer agreement on accident severity. Despite this bias, consider the following variations of the SD. In the efficiency of operation category, the SD ranged from 0.7 to 4.8; in accident prevention, from 0.4 to 3.8; and in accident severity, from 0.5 to 1.7. An SD of 0.9 or less was scored for only five of the tasks (out of 627 rated) in the efficiency of operation category, 102 of the tasks in accident prevention, and 303 of the tasks in accident severity. Conversely, an SD of 3.0 or higher was recorded for 15 of the tasks in efficiency of operation, four of the tasks in accident prevention, and none of the tasks in accident severity. This seems to indicate that there is more agreement as to what is important in terms of accident prevention and accident severity than in efficiency of operation. This may be because of the amount of accident research that has been completed during the past 10 years, whereas bicycling efficiency has not been so well documented.

Not surprisingly, the greatest agreement (SD of 0.9 or less) for tasks in efficiency of operation parallels that for the most critical tasks: uses gears to maintain cadence and performs a regular maintenance check. There was also widespread agreement that using eye protection is not particularly important. There was less agreement (SD of 3.0 or higher) about dismounting and backtracking to alternate routes if signing prohibits bicycles and if necessary walking the bicycle on sidewalk bicycle paths.

In terms of accident prevention, the greatest agreement (SD of 0.5 or less) concerned scanning, riding with traffic, and maintaining lane position while proceeding through a curve. There was less agreement (SD of 2.5 or higher) about using a leg or belt light if one is infrequently caught in the dark for a short time and well-lighted routes are available and about operating in a center-lane position. The most disagreement (SD of 3.8) concerned the following task: "when traversing an intersection, moves to left position of lane if there is heavy right-turning traffic."

Summary of Results

An array of numbers and list after list of tasks can be disconcerting. In an effort to place our findings in a simpler format, we prepared the following summary:

1. Some tasks limit efficiency but are important in terms of accident prevention.
2. There is greater agreement as to what is critical in terms of accident prevention than as to what is critical in terms of efficiency of operation.
3. The most critical tasks in terms of efficiency of operation include (a) uses gears properly; (b) pedals with pressure on ball of foot, uses toe clips, and maintains a steady cadence; (c) performs regular maintenance checks; (d) selects appropriate lane; and (e) builds endurance prior to long rides.
4. The most critical tasks in terms of accident prevention include (a) scans continuously, (b) responds to stop signs and red lights, (c) rides with traffic, (d) uses emergency speed reduction when required, (e) signals left turns, (f) selects appropriate lanes, (g) yields when necessary to avoid a conflict or collision, (h) makes independent judgments when riding with a group, and (i) uses a headlight and taillight when riding at night or on dark roads.

The results also indicate that, although there is agreement that lane position is important to both efficient operation and accident prevention, there is no consensus as to what the best lane position actually is. For example, the task "operates in the right of the lane (right lane or lane-sharing position) on roads that have wide lanes, and when there is a safe (defined as maintaining an adequate lateral separation from hazards that occur on the right side of the road, such as sewer grates and doors of parked cars, as well as from hazards to the left, such as overtaking vehicles) or right-lane position" received a 3.9 for efficiency and a 3.8 for accident prevention. But a lower rating (2.9 for efficiency and 2.0 for accident prevention) was given to the task "operates in the center of the lane (center lane or lane-occupation position) on roads that have narrow lanes when no safe right-lane position exists, when operating at the speed of traffic, when traveling through an intersection, when crossing narrow bridges, when preparing to change lanes to the left, and when in a center or left lane." There was, however, more agreement about "operates in left position of lane when preparing to turn left," which also received higher scores (3.6 for efficient operation and 2.5 for accident prevention).

Lane position is, of course, especially important when the rider negotiates intersections. The BTA recommends moving to the center position of the lane when it is clear in order to go straight through or traverse an intersection. This received a higher score for efficiency (2.5) than for accident prevention, with an SD of 2.1 and 2.7, respectively. However, moving to the left lane or left-lane position to prepare for a vehicular left turn in moderate traffic received a 2.3 for efficient operation and a 3.1 for accident prevention.

CONCLUSIONS

The BTA has significance in several areas. First, it clearly highlights the most critical tasks (such as scanning), which obviously should be included in the development of any educational program. It also points to the fact that on-bicycle training, especially to teach skills such as emergency stopping, is essential. Second, it provides a basis by which existing programs may be evaluated. This is important because, in our opinion, many bicycling curricula available today do not include adequate instruction on scanning, emergency stopping, proper gearing and pedaling techniques, etc. (11). Third, the detailed description of bicycle operation may also be used to evaluate bicycle facilities.

What are the successes of the BTA? For the first time, an effort has been made to describe the consensus of leading bicycle specialists. Also, it is an attempt to focus on bicycling as a whole and to integrate safety aspects with considerations of efficiency. In addition, the BTA provides an overall structure for reviewing the field of bicycling; it can easily be used as a general resource or reference document, perhaps as an introduction for new people in the growing field of bicycling. But most important, it begins the major task of identifying what is truly critical in bicycle operation.

In spite of the successes of the BTA, there are also some limitations, which suggest future research needs. First, there is an obvious need for more formal observational data. In particular, more work needs to be done to determine the optimal lane position for bicyclists in different situations. In addition to an analysis of accident data to determine the bicyclists's lane position in a variety of situations, field observations could be conducted to describe the lane position assumed by most bicyclists negotiating intersections; bicyclists trained in the procedure detailed in the BTA could also be observed. Another need is to collect data concerning what lane positions to recommend to bicyclists based on both their age and skill level. The question of judgment must also be addressed--i.e., the bicyclist asks not simply "Is this maneuver safe?" but "What maneuver is safest at my skill level in this particular traffic situation?" And more empirical data are needed to back up the criticality ratings in both the accident prevention and accident severity categories. It must be pointed out that any educational program based on the BTA, which does a thorough job of describing what is involved in bicycle operation, must also include information on basic traffic concepts. In general, it seems vital that those involved in bicycling come to some sort of agreement on the "how to's" of bicycling. If there is discord among those in the field and more and more people are deriving both a career and a livelihood from bicycling, how can our needs be adequately presented to decision makers in government and education?

There is increasing concern for energy conservation and continuing interest in the importance of physical exercise, both of which are well served by bicycling. A document such as the BTA represents a significant and timely first step in consolidating information about bicycling that can be used in developing educational programs for bicyclists. But in many respects, the BTA raises as many questions as it answers. It is our sincere hope that the BTA will serve as an impetus for further research, for we view the BTA not as an end, but as a beginning.

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Abridgment

Engine Tune-Ups and Passenger Car Fuel Consumption

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The effect of engine tune-up on passenger car fuel consumption, including criteria for determining when tune-ups are needed for achieving good fuel economy, was investigated as part of a 1975 Federal Highway Administration study. A sample of 22 recent-model family cars was selected for the study. Each car was operated at a series of uniform speeds on a level straight test road, both immediately before and immediately after a major engine tune-up. Road, weather, and speed conditions were identical for the test runs before and after engine tune-up. Fuel consumption data were recorded for all test runs. A table was prepared that shows the percentage of change in fuel consumption that resulted from the tune-up for each of the 22 test cars. This table also lists for each car the age at the time of the study, the accumulated mileage, and the distance traveled since the last tune-up. The principal conclusion of the study is that passenger car tune-ups for cars less than six years old are unlikely to improve on-the-road fuel economy unless there is some evidence of actual fuel loss or waste. Out of the sample of 22 cars, only a third operated with better fuel economy in the normal range of running speeds after tune-up than before. Fourteen percent consumed more fuel per mile of travel after tune-up than they did before.

The improvement in passenger car fuel economy that can be expected from a major engine tune-up for cars in use less than six years was investigated for the Federal Highway Administration in 1974 and 1975. The purpose of the study was to develop on-the-road data on the fuel economy benefits of engine tune-ups for family cars during their first five years of service. Study details on which this paper is based were given in a report by Claffey (1).

Reports of two recent investigations to determine the effect tune-ups have on passenger car fuel economy are available. However, neither study involves the direct measurement of on-the-road passenger car fuel economy before and after full engine tune-ups. Walker and others (2) report that in diagnosing a random selection of 5666 cars in service they found that only about a third needed engine maintenance to improve fuel economy. These researchers also arranged for tune-ups for a small sample of the cars that were found by inspection to need engine maintenance to save fuel. Laboratory fuel economy measurements that used a dynamometer before and after the tune-up of each of these cars indicated that the tune-ups improved fuel economy by about 10 percent. A study by Bayler and Eder (3) found from an extensive review of the records of engine tune-ups to correct emissions deficiencies for 322 cars and of the corresponding fuel economy data that such tune-ups resulted in an average improvement in fuel economy of 4.7 percent. They also arranged for engine tune-ups for a random sample of 26 compact cars and for a random sample of 31 intermediates. In each case fuel economy was determined both before and after the tune-up by using laboratory measurements with the dynamometer. They found that tune-ups improve the average fuel economy of the compacts by 2.7 percent and that of the intermediates by 1.6 percent for a pattern of highway speeds.

The study reported on here involved measuring the fuel consumption rates of a selection of 22 cars from the population of family cars in normal use both before any change was made in the vehicle and again after a complete tune-up. Before and after fuel consumption rates were determined for each car while it was idling and for uniform on-the-road running speeds of 16.1 km/h (10 mph), 32.2 km/h (20 mph), 48.3 km/h (30 mph), 64.4 km/h (40 mph), 80.5 km/h (50 mph), and 96.4 km/h (60 mph) on a section of paved level straight road. All test runs were made when air temperature was between 23.3°C (80°F) and 26.0°C (90°F), humidity was between 60 and 70 percent, there was no wind, and the pavement was dry. All before-and-after test runs for each car were made by the same test-car driver and always in the same manner. Tire-inflation pressures were noted when each car was received from the owner. These were not changed.

SELECTION OF TEST VEHICLES

Each of the 22 vehicles used in the study was a family car less than six years old at the time of the study. Fifteen were standard or luxury-type cars and seven were small cars or compacts. Twelve were customarily operated in a rural area (the vicinity of Potsdam, New York) and 10 in an urban area (Utica, New York). No attempt was made to select one car model rather than another.

A 22-car sample is, of course, too small to represent adequately the millions of cars registered in this and other countries if each car in the population is unique. However, each car is not unique. Only a few manufacturers produce all the cars and car parts in use. The test sample includes vehicles