ISAHP 1996, Vancouver, Canada, July 12-15, 1996

ROAD SAFETY AND ACCIDENT PREVENTION IN BRAZIL

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Abstract: In this research we used the AHP to find the short term priority of the courses of action to be taken to improve road safety in Brazil. Four areas of action were considered: those on the driver, on regulations, on roads and on the vehicle. Nearly 25% of the emphasis is placed on having an adequate and effective police. The priority of police action together with road construction and maintenance is 50%.

Introduction

In this paper we present an application of the AHP to the road safety problem. This example is based on an in-progress research project. Brazil ranks fifth in the world in both population, approximately 160 million inhabitants and area, 8.5 million square kilometers. It has 1.4 million kilometers of highway roads but Brazil's roads are unsafe and lead to numerous fatalities. Statistics reveal that almost 700,000 accidents occur per year, resulting in 350,000 injuries and 27,000 deaths. However, the death toll is highly suspect due to under-reporting of accidents and the fact that accident related deaths are defined only as those occurring at the site of the accident and not those individuals who die subsequently at the hospital. As a result, the true death toll is likely to be closer to 50,000 people, as compared with about 50,000 deaths for the U.S. with a population of nearly 1.7 times that of Brazil. One of the leading causes of death, especially of young males, is automobile accidents. Of the deaths mentioned above, almost 30% are pedestrians (Table 1). The total cost of all the reported accidents is estimated at US $1.5 billion a year (GEIPOT, 1987). This dollar figure obviously fails to include the intangible costs such as pain and suffering.

The growth of cities and an increase in the number of cars per capita, accompanied by improperly utilized land and limited urban transportation planning, is leading the country to an unsustainable transportation position. If the current situation is projected into the future, we can expect severely deteriorated roads, significant congestion, and conflicts between different classes of transportation users. In this work we analyse the relevant factors which contribute most to the prevenction of accidents.

Table 1. Fatal and non-fatal motor vehicle accidents, by sex-1989*

Sex and Type of Victim	Fatal	Non-fatal
Sex		
Male	20,702	222,927
Female	6,311	97,447
Type of Victim		
Pedestrian	10,703	83,438
Passenger	7.059	109,887
Driver	9,251	127,049
Total	27,013	320,374

* Source - Ministry of Justice, Department of National Transportation, Brazil

The following sections of this paper will describe the Analytic Hierarchy Process as it applies to this road safety problem, defining the elements included in the model and detailing the application and output.

Problems Identification

Accidents are not accidents at all in the literal sense of the word. They do not simply "befall". They have very definite causes and these causes can be determined. Accidents are possibly even more important when viewed as an indicator of a fundamental flaw in the system. Undoubtedly, if this problem is examined and acted upon critically many accidents can be prevented. Increased efficiency in moving people and merchandise should mean a reduction in accidents and delays.

According to some experts in traffic engineering there are grounds for the assertion that the basic causes of accidents, inefficiencies and congestion are identical. If the cause is present under high-speed, light-volume conditions, it will frequently produce accidents. If it is present under low-speed, heavy-volume conditions it will frequently cause congestion. The outcome that is produced will be determined primarily by traffic velocity and volume. The basic causes of both accidents and congestion are incompetence or malice on the part of the driver, lack of education and enforcement, failure of the roadway to make adequate provision for certain functions of movement, and lack of effective vehicle maintenance and safety mechanisms.

Structuring The Hierarchy

Formulating the problem hierarchy facilitates the decomposition of the problem into its rudimentary components. By dissecting the problem, the essential causes and related alternative solutions can be measured. The goal, improving road safety in Brazil, is dependent on four criteria. These criteria, social, economic, political and environmental represent interests and perspectives which will be utilized in the analysis of the problem and its potential solutions.

In the next level, below the criteria, are the actors and in the level below that the actors' sets of objectives. These objectives are related to solving the problem outlined in the goal, but each actor has his own preferences. The individual objectives represent strategic directions for solving the problem which are congruent with that actor's interests (Figure 1).

SOCIETAL FACTORS:

Traffic problems are not entirely a technical problem. They are rooted in an environment consisting of multiple interests and multiple causes stretching across the salient components of society's infra-structure. Therefore, to understand and subsequently improve traffic problems in Brazil, problem analysts must examine this dilemma in relation to the main perspectives of society. The four core criteria in society are social, economic, political and environmental. Each relevant actor ranks these criteria according to his own perceptions and self-interests.

Social—Theresults of traffic problems, such as deaths and injuries, damage to property, and pain and suffering, affect individuals as well as the broader society. Quality of life and family structures are temporarily and sometimes permanently altered. Furthermore, road safety decisions also affect social elements. Policy selections invariably have trade-offs. There are social costs and benefits that must be evaluated in order to derive a net benefit (or cost) to society.

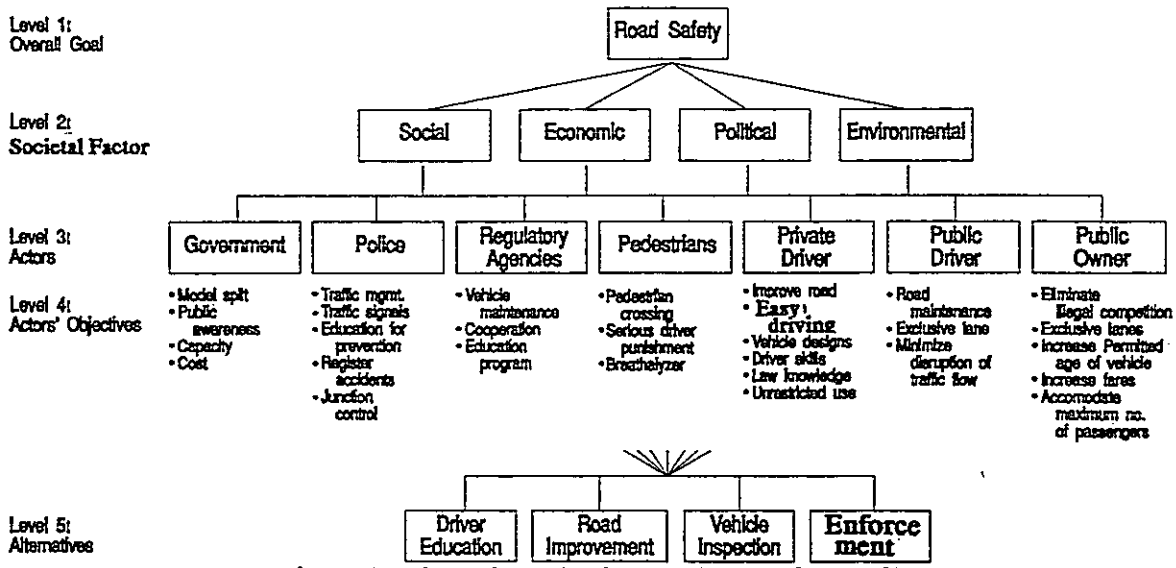

Figure 1. First Hierarchy for Road Safety in Brazil

Economic—Economicconsequences influence every policy decision. The economic cost of a selected alternative will affect the relevant actors (to varying degrees). As in the analysis of social criteria, economic evaluations involve an analysis of costs. However, the economic perspective takes a much narrower approach. While the social component considers overall utility to society, the economic element is solely interested in monetary costs.

Political—Policydecisions, including traffic safety decisions, are not made in a vacuum. Actors possess strategies which are based on self-interest and utilized to gain favorable decisions and government resources. It is necessary to reiterate that the decision makers provide relative importance to the set of environmental factors. Each actor's reliance on political factors is often dependent on his relative influence or power over other actors.

Environment—Fothe purposes of this decision structure, the term environment is restricted to the "elements of nature". Environment—plants, animals, soil, air—areinfluenced by traffic problems. For instance, chemical spills caused by transport truck accidents often penetrate the soil, contaminating nutrients as they move into ground water flows. From there these contaminates are flushed into streams, lakes and rivers, affecting plant and animal life. Another example is the road-side debris that disturbs the natural environment.

Actors and Objectives

Although a complete list of actors would be comprehensive, a more parsimonious categorization will be useful. Several groups of actors can be identified according to their objectives. Objectives, which will be discussed below, describe the set of safety improvement alternatives each actor desires. The essential actors

are government, police, regulatory agencies, pedestrians, private drivers, public owners, and public drivers. As mentioned above, each criteria is ranked from the perspective of each actor. A brief account of their objectives is provided below.

Government—Inthis case, government refers to local, state and federal levels. Government possesses a prominent position in the policy-making process and is significantly affected by every traffic problem decision. Government, however, is able to influence traffic problems using the following policies.

Modal Mix: Regulate the types of vehicles moving on Brazilian roads - buses, private, public, and business vehicles, bicycles, as well as pedestrians. The government has the ability to adjust the proportion of each type permitted on the roads. Increasing the ratio of the number of public vehicles to private ones may decrease traffic congestion because public vehicles carry more passengers.

Public Awareness: Influence behavior through public awareness campaigns. Influence drivers' attitudes by providing the public with information outlining the potential consequences, injuries *and* penalties, of undesirable behavior, such as drinking and driving or speeding.

Capacity: Regulate the proportion of each mode permitted on the roads and the overall number of vehicles. This objective is closely related to mode mix. Reducing the number of vehicles on the road may decrease traffic congestion and, as a result, improve road safety.

Cost: Establish user fees for road access and other taxation devices. The government can offset road safety costs while manipulating the number and types of drivers on the roads.

Police—Ashe law enforcement branch of the government, the police monitor and control compliance with the law as it relates to activity on the roads and streets. Police enforce the regulatory policies. The ability of the police to effectively implement the wishes of the regulatory and legislative branches of government is a critical for the safety of a transportation system. The objectives through which this particular actor can influence the process are detailed below.

Traffic Management: the physical act of directing and controlling traffic.

Traffic Signals: the existence of automated and static signals indicating right-of-way and direction.

Education for Prevention: the creation of an educational program which provides policemen with the knowledge necessary to help prevent accidents.

Register Accidents: a program which requires the public to register and report all accidents to the authorities.

Junction Control: technology and machinery which improves the flow of traffic at intersections.

Regulatory Agencies—Regulatoryagencies are those entities that are responsible for the creation and

implementation of specific rules relating to transportation. A regulatory agency sets standards regarding modes of transportation and structural elements of the roadways. The objectives through which regulatory agencies can influence the process are detailed below.

Vehicle Maintenance: establish and maintain standards regarding the quality and frequency of inspections of the physical condition of automobiles, buses and trucks.

Cooperation: create a forum in which public transportation drivers have an opportunity to discuss and relate to the regulatory environment.

Education Program: establish a driver education curriculum.

Pedestrians—Pedestrians are another important and influential element of the safety problem. This category of actors is comprised of individuals who walk or ride bicycles as a means of transportation. The objectives through which pedestrians can influence the process are detailed below.

Pedestrian Crossings: areas in the roadway which are designated as appropriate points to cross from one side to the other. These areas can either be designated as a permanent right-of-way for pedestrians, or the right-of-way can be indicated by means of signals.

Severe Driver Punishment: the establishment and enforcement of severe fines.

Alcohol Control: mechanisms to control the amount of alcohol consumed by vehicle drivers.

PrivateDrivers—Private drivers are those individuals piloting vehicles which are owned by individuals or businesses. This category of actors, with the exception of pedestrians, is possibly the largest, and therefore a very significant group. The objectives of private drivers which can influence the process are detailed below.

Improve Road: steps to improve the conditions of the road which include median strips, retaining walls or barriers, and road resurfacing.

Easy Driving: promoting a driving environment which is free of delays, congestion and danger.

Vehicle Design: the creation and improvement of automobile designs that enhance usefulness and safety of the vehicles.

Driver Skills: the improvement of other drivers' skills. The assumption of this objective is that drivers will enjoy greater safety if the skills of other drivers are improved.

Law Knowledge: making drivers aware of the relevant laws and their penalties.

Unrestricted Use: preventing restrictions which might limit the access of privately owned vehicles based upon location or date.

Public Drivers—Public drivers represent the operators of public transportation vehicles, such as taxi cabs and buses. They are interested in minimizing traffic flow, acquiring exclusive lanes and improving road conditions.

Road Maintenance: manage the quality of roads through regular re-surfacing, establishing safe shoulder widths and using lane barriers.

Exclusive Lanes: provide lanes exclusively for public mass transit which may improve public transit service and the number of people using public transit and decrease traffic congestion in the process.

Minimize Disruptions: maintaining a constant traffic flow may diminish safety problems resulting from over-congested roads. Computerized traffic lights and one way street signs are potential tools for managing traffic flow.

Public Owner—This category of government was differentiated because for the most part private companies own and manage the bus systems used for public transportation. This process is facilitated through the use of exclusive licenses. The objectives of the public owners which can influence the process are detailed below.

Exclusive Lanes: the creation and maintenance of lanes reserved only for buses. These lanes will allow buses to run more efficiently and safety, thus improving earnings for the owners.

Eliminate Illegal Competition: eliminate those buses and vehicles that operate without the proper licensing. Eliminating these vehicles will require greater use of new and existing, properly licensed carriers.

Maximize Bus Use: eliminate restrictions which limit the number of years in which a bus can be used. Currently there are restrictions which force owners to take buses out of service after a certain number of years.

Increase Fares: increase or improve fares for individual passengers. This step will allow owners to make fleet improvements which will enhance safety.

Maximize Passengers: eliminate restrictions on the number of passengers allowed on a single bus. Owners of the transportation licenses could then accommodate those passengers currently riding unlicensed vehicles and using modes of transportations that are less safe.

Alternatives—This level of the hierarchy consists of different courses of action related to roads, drivers, vehicles and regulations. These alternatives describe the possible solution sets which are impacted by the objectives outlined above.

Road: The road is an alternative which is of critical importance because of its role in providing long term solutions. Also, there is a significant likelihood that, of the four alternatives, roads are the most in need

of improvement.

Driver: The driver, while not being as important as the road, is important to the process. With the exception of enforcement, it is the only alternative which is behaviorally oriented.

Vehicle: The vehicle is another critical alternative in the model. It is through this alternative that technology would be most likely to impact the problem.

Enforcement: The final alternative is important to the problem domain because of its implications. Without proper enforcement, the previously discussed alternatives will provide marginal benefit.
Within each alternative several actions may be taken to rectify safety problems. The nature of these actions is determined by judgments pertaining to criteria rankings and character group relevance.

PRIORITIZATION:

Based on the AHP model, relative priorities of decision elements such as social factors, actors, and objectives are estimated under each node of the hierarchy using the pairwise comparison method. It is worth to mention that these priorities were generated by the authors themselves. These weights represent judgments on the relative importance or preference of the decision elements in the hierarchy. With this in mind, we derived local weights for both the criteria and actors in terms of their relative importance with respect to the goal. Figures 2 and 3 show partial results from the social standpoint, emphasizing government as the actor.

Preliminary Analysis of The Results

The results obtained by using the Expert Choice software reveal that attention must be diffused equally across each alternative. The range of relative importance was only 2.8%, extending from vehicle at 23.8% to driver at 26.6%. Therefore, each alternative similarly impacts the road safety problem. See Figure 4.

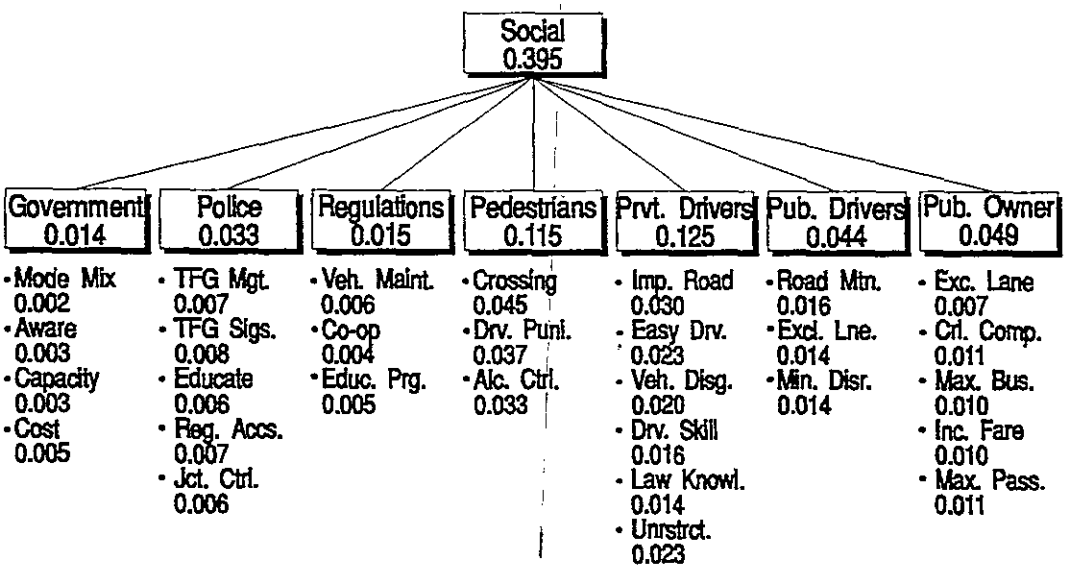

Figure 2. Partial Results from the Social Standpoint

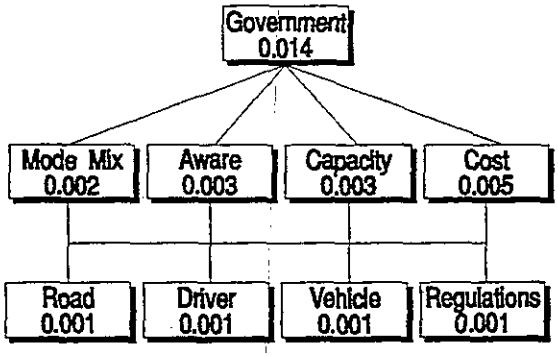

Figure 3. The Government Objectives of the Road Safety Problem

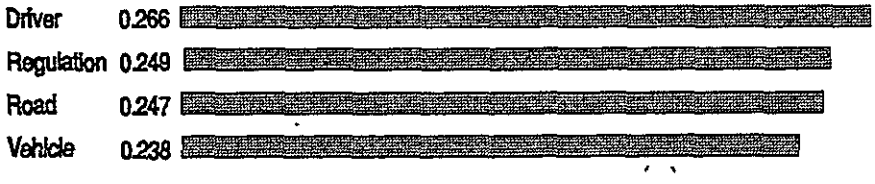

Figure 4. Synthesis of Results of Different Courses of Action Related to Road Safety

The results indicate that the most effective element for increasing road safety is the driver, with an overall priority of 26.6% followed by regulation with overall priority of 24.9%, road with 24.7% and vehicle with 23.8%. The overall inconsistency index of this model is 0.05.

However, for practical decision-making the conclusions are inadequate since stating that all alternatives

should be implemented equally would not provide much help when difficult choices need to be made about improving road safety. Although providing a systematic approach to assessing the main elements of the problem, this model does not describe how to prioritize the specific strategies available. In other words, given limited resources, more detail is required to rank the alternative actions to effectively and efficiently impact the traffic safety problem. Therefore, a second hierarchy was developed, which broke the alternative actions related to safety into another level of detail. The alternatives in this subsequent model appear in the second level of the hierarchy followed by specific actions related to each alternative.

Based on the above analysis, the following hierarchy was structured. In this model, the irrelevant factors yielding insignificant priorities were eliminated from the model (see Figure 5).

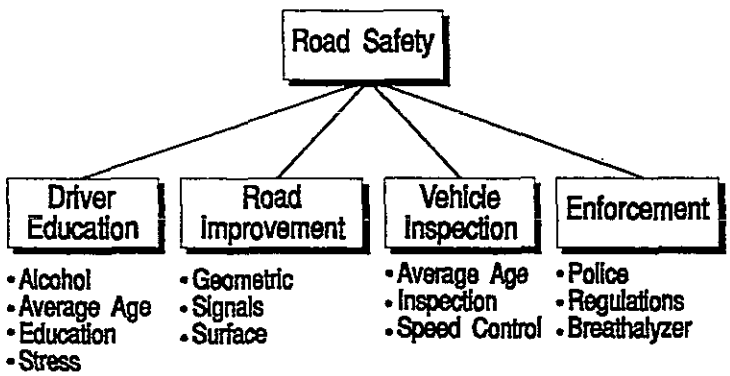

Figure 5. Second Hierarchy for Road Safety in Brazil

Representation And Analysis of The Results

By a considerable margin, police ranks highest amongst the alternatives impacting the road safety problem, with inspections second followed closely by geometric design of the roads and alcohol consumption control (Figure 6). Policing and enforcement are the keys to reducing the road safety problem. The importance of policing and enforcement may be due to its effect on the other elements in the model. Enforcement acts as a deterrent which may change behavior. This inference is supported by other data in the conclusion. Although there is some kind of interdependence between elements, alcohol was determined to be relatively important while breathalyzer rated low on the list of alternatives. The reason for this difference in ranking is due to the relationship between enforcement and alcohol. The problem of individuals driving while intoxicated can only be corrected by establishing an adequate enforcement scheme which deters behavior outside the zone of acceptability. Therefore, better policing procedures will increase safety by presenting a visible deterrent that encourages drivers to conform to the appropriate safety standards.

Figure 6. Relative Priority of Courses of Action Relative to Road Safety Problem

Apart from establishing proper policing procedures which enforce safety and traffic laws, the Brazilian government should focus on the construction and maintenance of roads. The geometric design is an important area for improving road safety. Additionally, regular re-surfacing of the roads and providing adequate roadside signs would contribute significantly to traffic safety.

The results obtained for the subsequent model shown in Figure 6 reveal that the police occupy an important position with a priority of 14%. With inspections at 10.5% and the use of breathalyzers at 5%, in total, police involvement in solving the road safety problem represents 25%. It is important to note that alcohol consumption, average age of vehicles, and education and skill of drivers, are also significant elements to be considered in road safety problems under investigation. However, without effective police enforcement solutions cannot be implemented. Therefore, the government should focus their priorities on police enforcement issues. The next priority level for government, after police enforcement, focuses on road improvements. Structural road elements like geometric design, surface conditions, and adequate signs illustrate the importance of properly engineered and maintained road facilities. Together, police enforcement and road structure command 49.3% of the priority given to traffic safety improvements.

Discussion

The Analytic Hierarchy Process provided a powerful mechanism for managing a multicriteria transportation planning problem. Using multiple pairwise comparisons it was possible to rank order alternative solutions.

The results of this application were a clear understanding of the elements involved in this problem and a priority ranking of the potential solutions.

The priorities and results of the model in this paper were primarily based on short term effects.

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