Conceptual Frameworks for Developing and Comparing Approaches to Improve Adolescent Motor-Vehicle Safety

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Abstract: This paper presents practical frameworks for developing and comparing approaches to improve adolescent motor-vehicle safety by merging concepts from the fields of developmental psychology and injury prevention and combining these with elements of a policy-analysis approach. Together, these models offer conceptual foundations for identifying intervention strategies to prevent crashes, reduce injuries in crashes, and reduce the long-term consequences of crashes and crash-related injury. In addition to helping generate ideas for interventions, the model can be used for making decisions about alternative interventions through consideration of value criteria such as effectiveness, cost, freedom, equity, stigmatization, preferences, and both technologic and political feasibility.

Using these models, multidisciplinary groups concerned with youth development, engineering, law enforcement, education, and policy development can find common ground in addressing the complex issue of teen driving safety and develop, in a systematic and rational manner, approaches tailored to the circumstances and values of the settings in which they work.
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Introduction

> A police report says the adolescent lost control of the car, skidded off the road and slammed into a tree. The driver and two other teens were seriously hurt. The father of young Alex said police told him speed was a factor . . .[1]
>
> An Arlington resident died Saturday, hours after the vehicle the teens and several companions were riding in crashed into a wall barrier on Texas 360, police said.[2]
>
> The victims included the driver [name], 18, who was . . . pronounced dead on arrival at the hospital . . . . Passengers . . . were hospitalized and treated for injuries. [Name] was in critical condition Friday morning with head injuries and on a ventilator . . . . Alcohol was a contributing factor in the crash, police said.[3]

The specifics of these incidents, all reported in June 2007, demonstrate the diversity of circumstances of adolescent motor-vehicle crashes. Motor-vehicle crashes are the greatest threat to the health and well-being of U.S. adolescents, accounting for 38% of all deaths among youth aged 16 to 19 years.[4] In 2004, nearly 5000 adolescents in this age group died of injuries in motor-vehicle crashes,[4] and adolescents aged 16–19 were four times more likely than older drivers to be involved in a crash.[5] In addition, the presence of other adolescent passengers increases the crash risk of unsupervised adolescent drivers, and the risk increases significantly with the number of adolescent passengers.[6]

The magnitude and diversity of the adolescent motor-vehicle injury problem call for a comprehensive range of approaches. The recent report of the Institute of Medicine (IOM) Program Committee on Contributions from the Behavioral and Social Sciences in Reducing and Preventing Teen Motor Crashes[7] approached the issue of adolescent motor-vehicle crashes by integrating public health, engineering, and developmental perspectives. The intent of this article is to present conceptual frameworks compatible with an integration of the varied perspectives presented by the IOM report, with the aim of helping scholars and practitioners organize evidence and promote new ideas about interventions to reduce the risks associated with adolescent driving.

As with any public health problem, motor-vehicle crashes among adolescents can be conceptualized using the social–ecologic framework. This framework, originally articulated by developmental psychologist Urie Bronfenbrenner, describes levels of interacting ecologic systems influencing behavior, specifically de-

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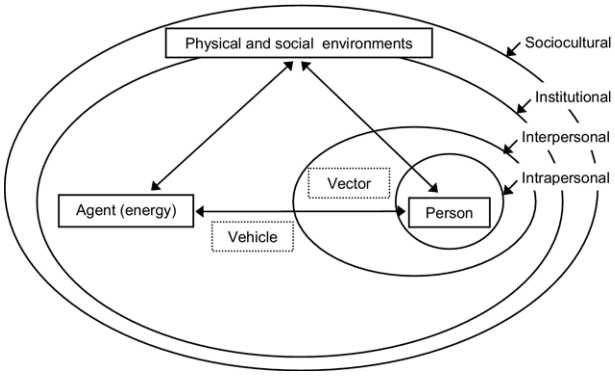

Figure 1. Integration of public health model with Bronfenbrenner's social–ecologic model (source: Runyan[11])

scribing the microsystem, mesosystem, exosystem, and macrosystem.[8] The multiple levels of the framework refer to varied and distinct social systems within the family and broader contexts, including the overall culture, in which children develop. Others have redefined the framework in terms more familiar to the public health community to encompass the individual, interpersonal relationships, organizational and institutional factors, and broader sociocultural characteristics.[9,10] The model, shown in Figure 1, incorporates the agent–host–environment model of public health, sometimes referred to as the infectious disease model.[11]

Further, injury control pioneer William Haddon developed a flexible and practical model for conceptualizing interventions specifically to address injury-related problems. Although not directly derived from the social–ecologic framework *per se,* the original Haddon model (Figure 2) is compatible with the framework and is a straightforward organizing tool for generating intervention and prevention ideas.[11,12] A third dimension (Figure 3) provides an additional perspective useful for assisting program planners and prevention specialists through the complex process of considering and deciding which intervention approaches to apply.[13]

Social–Ecologic Framework As Related to Adolescent Driving

Intrapersonal Level

At the foundation of the social–ecologic model (Figure 1) is the understanding that multiple interacting factors influence behaviors and, consequently, health. The factors are conceptualized within nested levels of influence. The innermost level of the framework, the *intrapersonal level*, involves individual characteristics, including both biological and behavioral factors. In the case of adolescent driving, individual biologic factors include, for example, visual acuity, coordination in managing the car, and impaired judgment or reflexes due to intoxication. Behavioral factors include decision processes in risky situations, distraction by peers, knowledge of driving rules and operation of the vehicle, the ability to interpret and respond appropriately to sensory information about potential hazards or roadway conditions (e.g., responding to a skid on ice), and motivations to drive safely and abide by traffic laws.

Interpersonal Level

The second level of the framework, the *interpersonal level*, incorporates factors dealing with how adolescents relate to others. These might include peers, as well as parents, teachers, pedestrians, and/or other drivers. Examples include interactions with parents about rules for using the family car. Peer relationships may become a factor with regard to pressure to engage in risky driving behaviors (e.g., speeding, drinking and driving, racing) or when an adolescent legally obtains a driver's license before being ready to drive responsibly, perhaps owing to parental desire to do less chauffeuring.

Institutional Level

The third level described in the social–ecologic framework, the *institutional level*, is associated with institutions and organizations with which a person affiliates or by which the person is influenced. In the case of adolescents, these might include schools or related activities (e.g., sports teams, social clubs), churches, and employers, as well as other community-based youth organizations (e.g., scouts, after-school programs, volunteer activities). Examples at this level related to adolescent driving might include school policies about permitting driving to school or during lunch breaks,[14] as well as policies that influence driving behavior and crash occurrence. For instance, the availability of school parking lots, participation in after-school activities, and opportunities for driver education may affect adoles-

Phases	Factors			
	Host (Driver)	Agent/vehicle/vector (Automobile)	Physical environment (Structures & facilities)	Social environment (Norms, policies & procedures)
Pre-event (Pre-crash)				
Event (Crash)				
Post-event (Post-crash)				

Figure 2. Haddon matrix template

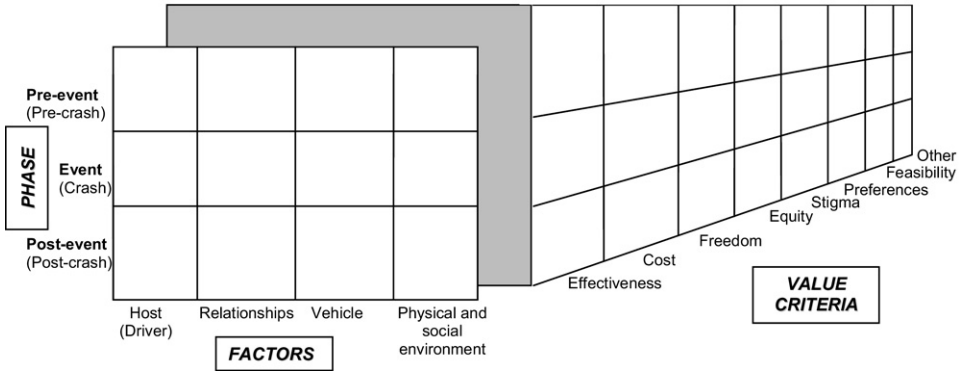

Figure 3. Three-dimensional Haddon model (adapted from Runyan[13])

cent driving behaviors, as would the availability of transportation for church, school, or other events. Similarly, work schedules and the availability of employment for adolescents in places served by public transportation may influence the need to drive.

Sociocultural Level

At the *sociocultural level* are factors such as broad social norms and expectations about driving-related behaviors, as well as local and federal policies that influence driving behaviors.

Examples of these factors include speeding laws and their enforcement, graduated driver's licensing laws (GDL), driver education incentives and requirements, drinking age limits, and specific enforcement procedures targeting adolescents (e.g., prom-night stops to check for driving under the influence of alcohol). Additional social and structural efforts at this level may include the conscious design of alternative transportation opportunities aimed at limiting adolescent driving exposure, such as making public transportation more accessible to adolescents and promoting designated-driving practices to prevent alcohol-related driving incidents. Underlying the broader social and cultural dynamics of prevention are the multilevel, multifaceted networks of local, state, and federal law enforcement protocols designed to promote adolescent motor-vehicle safety.

Haddon Model As Related to Adolescent Driving

Haddon developed his model from the perspective of public health, using the model to identify strategies for intervening to reduce the likelihood of injury events and injuries.[12,15,16] The public health model itself articulates the relationship between the vulnerable host and the agent of disease or injury within the environment, as described by Susser.[17] Developed largely within the context of infectious disease, this formulation identifies the *host* as the person at risk of experiencing a given health problem (e.g., malaria, chickenpox, measles). In the case of a motor-vehicle crash, the host is the person experiencing the injury, whether driver, passenger, or pedestrian. The *agent* of disease, in the case of infectious diseases, is the bacterium or virus responsible for the infection. With respect to injury, Haddon defined the agent as the energy transferred to the host in amounts or at rates damaging to the body.[12] He noted that different types of energy transfers are responsible for injury, including transfers of mechanical energy (e.g., momentum forcing a head into a windshield during a crash), thermal energy (e.g., burns associated with fires or scalds), chemical energy (e.g., inhalation of carbon monoxide or ingestion of poisonous substances), and radiation energy (e.g., sunburn). In either an infectious disease or injury context, the public health model addresses the various characteristics in the *physical environment* (e.g., buildings, roadways) as well as the *social environment* (e.g., norms, practices, policies, political will). Energy is delivered either by an inanimate vehicle (e.g., steering wheel) or by an animate vector (e.g., another passenger).

Haddon incorporated these factors from the public health model (host, agent, and physical and social environments) into a matrix that, except for the agent, parallels the social–ecologic framework nicely. He used the factors, which both influence injury events and can be changed, as the columns of his matrix. Also, he added rows to depict the timing of interventions and their effects on the injury process, which he conceptualized as having pre-crash, crash, and post-crash phases.[16] Haddon later employed broader terminology (pre-event, event, and post-event) in his model to address injury causes other than motor-vehicle crashes (Figure 2).[16]

Used effectively as a brainstorming and problem-solving tool, the Haddon matrix can help identify a multitude of ideas for preventive interventions. In public health terms, it is often helpful to employ a sentence-completion exercise in which one fills in the factors and phases as follows: "_____ [an idea] is an intervention designed to change _____ [factor] that will have its effect at the time of _____ [phase]."[13] For

example, airbags are an intervention that change the vehicle and have their effects at the time of the crash (even though they are installed in the car at the assembly plant). This idea would be noted in the "vehicle" column, "crash" row of the matrix (Figure 2). Likewise, efforts to reduce drunk driving by teaching individuals to select a designated driver is an individual (driver) intervention with effects at the pre-crash phase (i.e., preventing crashes) and belongs in the "host" column, "pre-crash" row.

Integrated Model

Although the Haddon matrix has been widely used by injury control professionals since it was first developed more than three decades ago, social scientists may find a model that integrates more closely with the social–ecologic framework to be more appealing. In Table 1, we propose such a model. Our integrated model is similar to the Haddon matrix but has an additional column for relationships and integrates physical and social environment features with the different levels of the framework. For our adolescent driving example, the relationships column has been split into separate columns for peers and parents. In addition, instead of separate columns for physical and social environments, the integrated model has one column for institutions and organizations (third level of the social–ecologic framework) and one for sociocultural practices and norms (fourth level of the framework). Each of these two columns is subdivided into sections for interventions in the physical and social environments. In the institutions column, for example, interventions in the physical environment include those directed at schools and adolescent employers; interventions in the social environment include the driving-related policies of schools and workplaces. Similarly, in the sociocultural column, physical environment interventions encompass efforts to modify roadways, and interventions in the social environment include strategies such as insurance incentives for safe drivers, nighttime curfews for adolescents, and promotion of norms associated with less tolerance of adolescent drinking and driving.

Value Criteria Used in the Hybrid Social–Ecologic Haddon Matrix Model

Both the Haddon model as originally conceived and the version modified to more closely integrate with the social–ecologic framework provide a mechanism to help identify and catalog a myriad of intervention possibilities for addressing any type of health problem. However, the models fall short of helping practitioners arrive at clear decisions among the varied approaches generated by using the models. To address this shortcoming, a third dimension can be added which introduces a layer of practical considerations to the Haddon model (Figure 3) to aid planners in a practical way by helping them move from a broad set of ideas to a systematic process of thinking through key values to guide decisions.[13]

This review process, which draws on a policy-analysis process,[18,19] entails considering what criteria are important to a given decision. The choice of criteria will vary, depending on the context and aspect of the problem. For example, planners might want to emphasize different values for different communities or for new adolescent drivers versus older adolescents. First, any practitioner is almost always concerned with evaluation (based on sound evidence) of *effectiveness* (i.e., Does the intervention work?). Of course, quality and type of evidence available vary, so this judgment is not always clear-cut. Sometimes judgments about effectiveness rely on theory about what should work or on experience that may not meet the standards of evidence-based planning.

Second, other criteria might be considered, including *horizontal and vertical equity*.[18] Horizontal equity refers to a universal approach. Considering whether an intervention is directed at all adolescent drivers, for example, is to assess whether it has horizontal equity. Vertical equity, in contrast, exists when an intervention seeks to treat people differently so as to equalize them in terms of risk or opportunity. In regard to risk, one might consider whether to focus on higher-risk adolescents and impose more strict regulations on them in order to equalize their risk with that of other adolescents. For example, should more stringent GDL restrictions be pursued for younger drivers or for those who have already demonstrated more dangerous driving behavior? In regard to opportunity, practitioners might consider an approach that seeks to equalize safety opportunities by ensuring that the best forms of driver education or technologies to monitor adolescent driving are free for those unable to afford them. Such an intervention would demonstrate vertical equity by helping to equalize opportunities for safer driving among youth at different economic levels.

Another value that is often considered important in intervention decisions is *freedom*. Considerations include: Whose freedom is infringed upon, and how much? Are the freedoms that are limited important? Whose freedoms are protected? For example, the issue of an adolescent's freedom may arise when introducing random traffic stops, without probable cause or suspicion, on prom nights to identify individuals driving under the influence of alcohol. Likewise, equipping cars with speed governors (to limit the maximum achievable speed) or satellite tracking systems (to monitor automobile movement and speed) could be viewed as limiting freedoms because behaviors are monitored. On the other hand, to the extent that parents use these strategies rather than restricting vehicle use, adoles-

Table 1. Haddon model integrated with the social–ecologic framework: an example applied to teen driving

	Factors					
		Relationships			Physical and social environments	
Phases	**Host**	**Peers**	**Parents**	**Vehicle**	**Institutions and organizations**	**Sociocultural practices and norms**
Pre-crash phase (Interventions to reduce likelihood of crash occurring)	■ Teach driving skills to teens ■ Reduce use of cell phones ■ Reduce drinking and use of other drugs ■ Encourage better sleep habits	■ Encourage activities that do not require driving ■ Reduce peer alcohol use ■ Foster designated driver practices	■ Support parents for limiting teen access to cars ■ Train parents in strategies for better teaching of driving skills to teens ■ Train and prepare parents to identify risk-related behaviors associated with driving (e.g., driving many friends)	■ Vehicles with ignition lock system hooked to breathalyzer ■ Monitoring devices in cars to alert teens or parents when teen is driving recklessly ■ Devices in cars to prohibit driving too fast or too close to other vehicles or specific hazards	Physical ■ Locate schools so driving is not required ■ Provide no student parking at schools to discourage driving ■ Provide more desirable public transport to school and work Social ■ Teen driver insurance penalties ■ Laws restricting teen driving for work ■ Later start times for schools	Physical ■ Accessible public transport ■ Planned communities with jobs, schools, homes in close proximity Social ■ GDL laws limiting driving hours ■ Nighttime curfews
Crash phase (Interventions to reduce risk of injury when crashes occur)	■ Encourage use of seat belts	■ Encourage peer support for seat belt use by all occupants	■ Encourage parents to let teens drive only in cars with full passive restraint systems	■ Ensure that maximum crash protection is available in all cars	Physical ■ Law enforcement practices to monitor speed and traffic density Social ■ Incentives for companies to produce more crash-worthy cars ■ Workplaces employing teens in driving tasks ensure that vehicles used by teen employees are safe	Physical ■ Roadside barriers to prevent cars from entering oncoming traffic or nearby water, or going over cliffs Social ■ Insurance and tax incentive to purchase crash-worthy/ready cars
Post-crash phase (Interventions to reduce negative health outcomes of crashes)	■ Teach first aid skills to all teens	■ Teach first aid skills to all teens	■ Teach first aid and CPR skills to all parents	■ Program GPS devices in cars to signal emergency care providers directly, after a crash	Physical ■ Locate on-call EMS substations near busy roads, highways, and main street intersections Social ■ Encourage public support for use of trauma-care triage by EMS providers	Physical ■ Ensure accessibility to emergency vehicles Social ■ Universal health insurance

CPR, cardiopulmonary resuscitation; EMS, emergency medical services; GDL, graduated driver licensing

cents may view such efforts as enhancements of their freedom.

The *cost* of interventions is often important to those involved and can be considered in various ways. Not only does this criterion relate to how much money is involved, but also to the issue of who bears the cost of a given intervention: Car manufacturers? School systems? Individual families? In addition, it is imperative to assess and appreciate the cost and implications of **not** employing the intervention (e.g., medical care, loss of lifetime earnings).

Stigmatization is often considered important in making decisions about health issues. Does a given group (e.g., adolescent drivers under a certain age, or those with traffic violations who must start the GDL process from the beginning) become stigmatized as a result of the intervention, and is such stigmatization desirable or undesirable with regard to the particular intervention? For example, is the potential stigmatization associated with returning to the bottom of the GDL ladder a successful motivator to safe driving, or is it too demoralizing?

Preferences of the affected community is another criterion often considered in determining intervention approaches. In the case of adolescent driving, this consideration might include the preferences of adolescents, as well as parents or the broader community. Among parents, the preferences of those weary of driving their adolescents to functions might be balanced by the preferences of those who want to enhance the safety of their adolescents. Likewise, the community may prefer promoting public transportation over reducing the legal driving age, whereas adolescents may prefer early access to vehicles and the resulting opportunities to transport friends. The practitioner trying to sort through such preferences will need to consider whose views carry more weight, while also trying to understand what those views are and how they relate to the various options under consideration.

Finally, *feasibility,* whether technologic or political, is important to consider. *Technologic feasibility* is concerned with the ability of proposed technologic solutions to be implemented and to work. For example, global positioning system (GPS) now makes it feasible to track automobiles almost anywhere, whereas this was not possible only a few years ago. The concepts of feasibility and effectiveness are closely related. Although something may be technologically feasible in the ideal sense, the actual deployment to scale may fall short of feasibility owing to effectiveness issues in the "real world" implementation of the measure. For instance, it may not be feasible to have GPS devices installed and used in all vehicles driven by adolescents.

Political feasibility is concerned with the ability to enact and implement an intervention. This type of feasibility might, for example, depend on the political will to enact new laws or policies (e.g., strengthening GDL policy or implementing policy to prohibit students from driving during school lunch time). Often preferences and feasibility intersect. If the community or powerful groups within the population favor an intervention, then political feasibility is more likely. In addition, the term refers to the feasibility of successfully implementing and enforcing an intervention. For instance, is law enforcement able to successfully enforce the new policies in the community with available resources? In this situation, political feasibility and cost issues may intersect.

To conclude the review process, each of the criteria discussed above needs to be carefully considered and assessed relative to the others. Then the intervention options under consideration can be assessed in the context of one another using a weighting process,[13] leading to better informed decisions about selecting a specific intervention approach.

Discussion

This article examines the use of the social–ecologic framework as a way to conceptualize adolescent driving issues and interventions and demonstrates how the framework can be employed, by building on the Haddon model, as a means of developing and considering intervention options. In addition, the article describes how to examine specific intervention options relative to key criteria for decision making.

We argue that this type of approach provides those who address adolescent driving across different disciplines (developmental, engineering, law enforcement, educational, and policy development) with a conceptual tool for considering multiple approaches to the complex issues related to adolescent driving safety and for thinking through priorities in a systematic manner. We encourage the use of these frameworks in multidisciplinary groups where multiple perspectives and different values can be incorporated into the development of effective adolescent driving interventions.

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