Estimating Cost Effectiveness of Wearing Motorcycle Helmets

Presented by Gwendolyn L. Gill
PhD Student in Public Policy (Economics)
University of North Carolina at Charlotte
Contact me at: glgill@uncc.edu

Introduction: In 2010, 14% of all traffic fatalities (4,502) and 4% of all traffic injuries (82,000) were motorcyclists. In 2014, nineteen states and D.C. have universal helmet laws (helmets required for all riders); twenty-eight states have age-conditional helmet laws (helmets required only for those under a certain age); and three states have no helmet laws. Even in states with a universal helmet law, only 89% of the motorcyclists, on average, wear a helmet. For states with age-conditional or no helmet law, only 49% of motorcyclists wear helmets. The trend is to repeal or relax universal helmet laws (since 2010, one state repealed its law and eight others have considered repeal or relaxation since 2010). Instead of treating the use of a motorcycle helmet as a transportation issue, this study looks at helmet use as a public health issue.

Research Question: What is the cost effectiveness of wearing a motorcycle helmet as a "treatment" against death, head injuries, and traumatic brain injuries (TBIs)?

Study Objectives:

1. Estimate the probabilities of selected health outcomes (death, head injuries and TBIs) for helmeted and non-helmeted motorcyclists who are involved in crashes.
2. Using these probabilities, determine the expected costs of selected health outcomes for helmeted and non-helmeted motorcyclists.
3. Estimate the incremental cost effectiveness between not wearing a helmet (treatment 1) and wearing a helmet (treatment 2) for selected health outcomes.

Terminology and Injury Definitions:

Effectiveness – ratio of incidences of particular health outcomes

MAIS – Maximum Abbreviated Injury Score, the standard used to determine costs of selected treatments and severity of TBIs

MAIS Levels and Example of Injuries

MAIS	Injury Level	Type of Injury	Head Injury Example
1	Minor	Superficial	Minor laceration of scalp
2	Moderate	Reversible injuries; medical attention required	Major laceration of scalp, blood loss < 20%
3	Serious	Reversible injuries; hospitalization required	Skull fracture, penetration < 2 cm
4	Severe	Non-reversible injuries; not fully recoverable without care	Depressed skull fracture, penetration >2 cm
5	Critical	Non-reversible injuries; not fully recoverable even with care	Depressed skull fracture, laceration of spinal artery
6	Maximal	Nearly un-survivable	Massive brain stem crush

TBI Measurements:

TBI Level	Example
Potential	Unspecified head injury with no loss of consciousness (MAIS=1)
Mild/Moderate	Concussion, non-depressed skull fracture (MAIS 2-3)
Severe	Depressed skull fracture with penetration greater than 2 cm (MAIS>4)

Objective 1 - Estimate probabilities for selected health outcomes: I used the effectiveness values of helmets to prevent selected health outcomes found by Cook et al. (2009) and NHTSA (2011) along with total number of study observations in Cook et al., to estimate the probabilities of certain health outcomes (death, all head injuries, minor head injuries, all TBIs and severe TBIs) for motorcyclists wearing helmets and not wearing helmets at the time of a crash. An example calculation is below.

Estimating the probabilities of death, use the definition of effectiveness:

$$Ef = Incidence\ (helmet)/Incidence\ (no\ helmet)$$

where

$$Incidence\ (helmet) = {}^{\#Death(helmet)}/_{\#\ Helmeted\ Riders}$$

and

$$Incidence\ (no\ helmet) = {}^{\#Death(no\ helmet)}/_{\#\ Non\text{-}helmeted\ Riders}$$

From NHTSA (2011), Ef(death) = 0.37
From Cook et al. (2009):

Number of helmeted riders in study = 59,299
Number of non-helmeted riders in study = 45,173
The number of deaths reported in study = 3,736
The fatality rate of death = 4% of all motorcyclists involved in a crash

So,

$$0.37 = \frac{3736 - \#Death(no\ helmet)}{59299} \Big/ \frac{\#Death(no\ helmet)}{45173}$$

which results in

$$\#Death(no\ helmet) = 2{,}515 \quad and \quad \#Death(helmet) = 1{,}221$$

Finding the probabilities of death given helmet usage involves

$$\frac{\#Death(helmet)}{\#Total\ Deaths} = 0.3268$$

and

$$\frac{\#Death(no\ helmet)}{\#Total\ Deaths} = 0.6732$$

Finally, combining the helmet use probabilities with the overall probability of dying in a motorcycle crash yields,

$$Probability\ of\ death\ if\ wearing\ helmet\ at\ time\ of\ crash = 0.04 * 0.3268 = 0.013$$

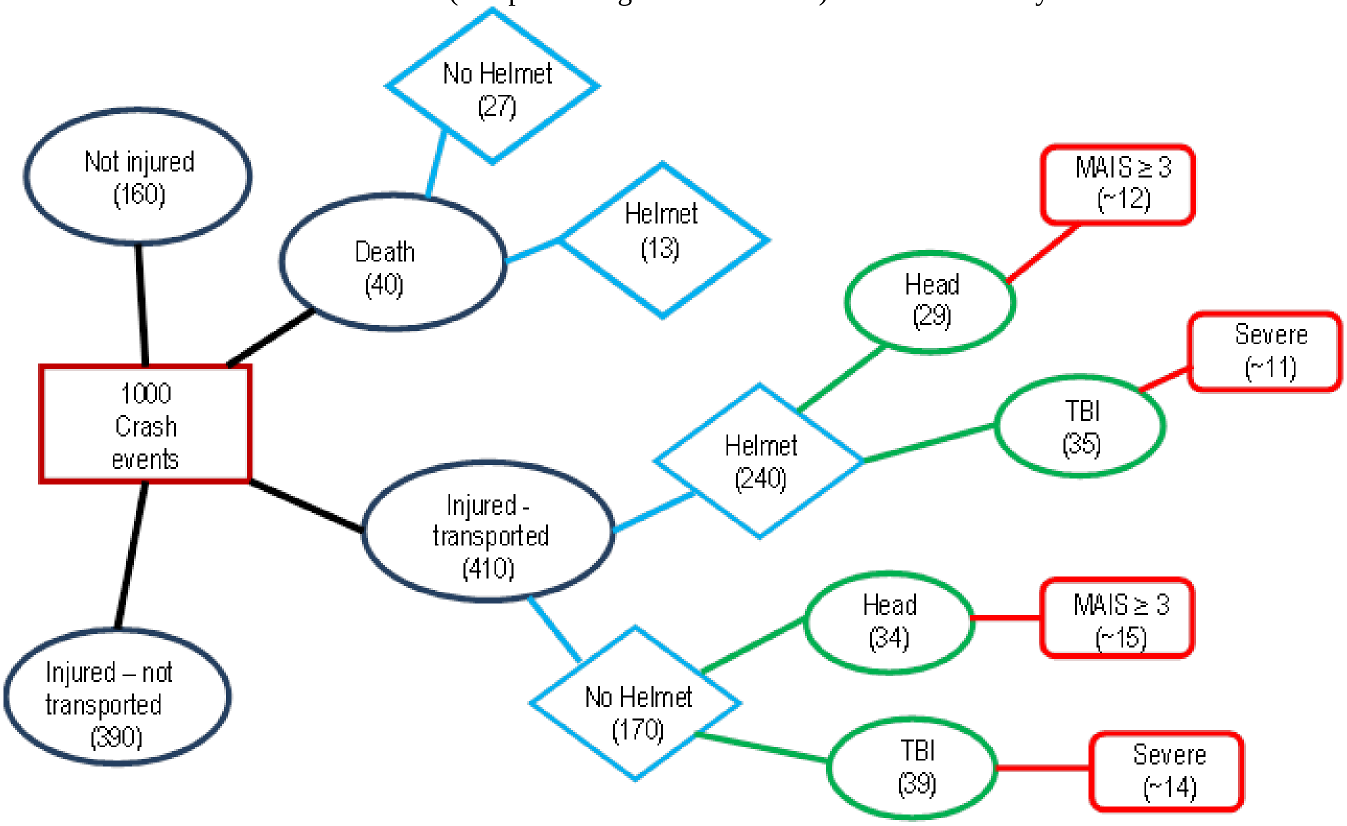
and

$$Probability\ of\ death\ if\ not\ wearing\ helmet\ at\ time\ of\ crash = 0.04 * 0.6732 = 0.027$$

The remaining probabilities are estimated using the same method.

The chart on the next page shows the number of injuries and deaths expected out of 1000 crashes of helmeted and non-helmeted motorcyclists.

Predicted Health Outcomes (# experiencing health outcome) Per 1000 Motorcycle Crashes



Objective 2 – Determine the expected costs for helmeted and non-helmeted motorcyclists: Using the probabilities found in Objective 1 (divide the values in the chart above by 1000 to get the probabilities) and costs for select health outcomes from NHTSA (2009), indexed to 2010 dollars, I calculated the costs incurred by helmeted and non-helmeted riders and the savings enjoyed by the helmeted motorcyclists.

The expected cost equation is:

$$EC_{X,Out} = C_X + (Pr_{Out} * C_{Out}) + (1 - Pr_{Out}) * C_{Out}$$

Where

$EC_{X,\ Out}$ – Expected cost of health outcome (Out) based on helmet usage (X), reported in 2010 $US.
C_X – Cost of treatment ($0 – no helmet and $140 – wearing helmet)
X – Treatment/helmet use (N – no helmet and H – wearing helmet)
$Pr_{X,\ Outt}$ – Probability of health outcome based on helmet usage
C_{Out} = Cost of health outcome

Expected Costs and Cost Savings

Outcome	**$EC_{N,\ Out}$**	**$EC_{H,\ Out}$**	**ΔEC_{Out}**
Death	$173,352	$83,606	$89,746
Severe	$57,920	$47,594	$10,324
Minor-Head	$364	$442	- $78 (no savings)

While there is no obvious cost savings for a minor injury between wearing a helmet and not wearing a helmet, the remaining values show a significant cost savings resulting from wearing a motorcycle helmet.

Objective 3 – Estimate the incremental cost effectiveness: The expected savings are one side of the public health perspective regarding the use of motorcycle helmets. The other side involves estimating how much the suggested "treatment" – wearing a motorcycle helmet – costs. In this section I only consider the cost of the helmet (an average of $140 US in 2014) as the cost of treatment.

$$ICER_{N-H} = {(C_N - C_H)}\Big/{(QALY_N - QALY_H)}$$

where

$ICER_{N-H}$ – Incremental cost of treatment ($/QALY gained by wearing a helmet over remaining life)
C_N – Present value of the cost of treatment (not wearing a helmet)
C_H – Present value of the cost of treatment (wearing a helmet)
$QALY_N$ – Quality Adjusted Life Year when not wearing a helmet
$QALY_H$ – Quality Adjusted Life Year when wearing a helmet

In this section,

C_N − $0, because there is no associated helmet cost.

$QALY_H$ − 31.7 years, which is the remaining life of a motorcyclist who is the mean age (47) of the age group with the largest number of motorcycle crashes (40-54 years old) and an average life expectancy (78.7 years). For simplicity, the $QALY_H$ assumes perfect health for the entire 31.7 years.

$QALY_N$ − the total life years adjusted for the loss of quality due to a select health outcome. These values are derived from Spicer, et al. (2011).

C_H − the present value of the aggregate costs of wearing a helmet for 31.7 years. Motorcyclists are encouraged to replace their helmet at least every five years (or sooner if there is any possibility of damage). Over the remaining 31.7 years, an average motorcyclist should purchase seven helmets. Using the average cost of a helmet ($140), an inflation rate of 2%, and a discount rate of 5%, the present value is found by

$$C_H = \sum_{t=0}^{6} {(140 * 1.02^{(t*5)})}\Big/{1.05^{(t*5)}} = \$851$$

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Outcome	**$QALY_N$**	**$QALY_H$**	**$ICER_{N-H}$**
Death	0	31.7	$26.84/QALY gained
Severe TBI (MAIS= 5)	17.8	31.7	$61.22/QALY gained
Minor Head Injury (MAIS=1)	30.4	31.7	$654.62/QALY gained

As the table shows, the cost of the "treatment" – wearing a motorcycle helmet, is small for the more costly health outcomes (death and a severe TBI) while relatively expensive for the minor health outcome. These treatment costs could be used to devise a type of financial incentive for encouraging motorcyclists to wear helmets.

A limitation of this section is that the QALY for wearing a helmet only considers the state of health. Another element that needs to be included in this analysis is the quality of life that some motorcyclists claim is lost by wearing a motorcycle helmet. These losses include an alleged diminishing of sensory experiences (hearing, feeling, seeing) as well as a experiencing a loss of autonomy and self-determination. While these negative adjustments to life quality may seem irrelevant, these elements fuel the (successful) arguments for repealing or relaxing universal helmet laws. Thus, these losses must be measured and included in the next phase of this study.

Conclusions and Policy Implications for Study Results: As other studies have shown, wearing a motorcycle helmet when involved in a crash can save a motorcyclist from death, head injuries, and TBIs. This study also shows the economic advantage of wearing a motorcycle helmet. The expected monetary savings increase as the severity of injury increases. One surprising result is that the cost of treatment (wearing a helmet) exceeds the expected costs of a minor (MAIS = 1) head injury.

Regarding policy implications, past and current events inform us that using any form of coercion (i.e., universal helmet law) is ineffective. The aggregate average compliance for states with universal helmet law is only 89% and universal helmet laws are constantly under attack by certain groups within the larger motorcycling community. A new perspective is needed. This study suggests viewing helmet as a public health concern rather than a legal compliance matter. Providing the information from this study to motorcyclists when they are most receptive – at the moment of decision about purchasing and wearing a motorcycle helmet – seems to be a reasonable first step.

Areas of Future Research: Several weaknesses in the amount and type of data available for analysis limit our understanding of the benefits of helmet use. For example, most studies have divided the data into two groups – those wearing helmets and those not wearing helmet. However, this gross stratification ignores the advantages and disadvantages of the different *types* of helmets available to motorcyclists. Furthermore, we need additional information regarding the level of injury and TBI suffered along with the status (and type) of helmet use. There is a significant difference, in cost and life quality, between a mild and a severe TBI, yet we can only estimate which level of injury is actually suffered, and we have even less information concerning helmet use and the type of helmet worn (if one was worn). A large-scale, coordinated data acquisition project, involving emergency departments (severity of injury) and first responders (helmet use status and helmet type) is needed to obtain the information for a more finely tuned analysis. Finally, qualitative analysis is needed to integrate diminished experiences and loss of personal autonomy (due to mandated helmet use) into the calculations of quality adjusted life years.

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